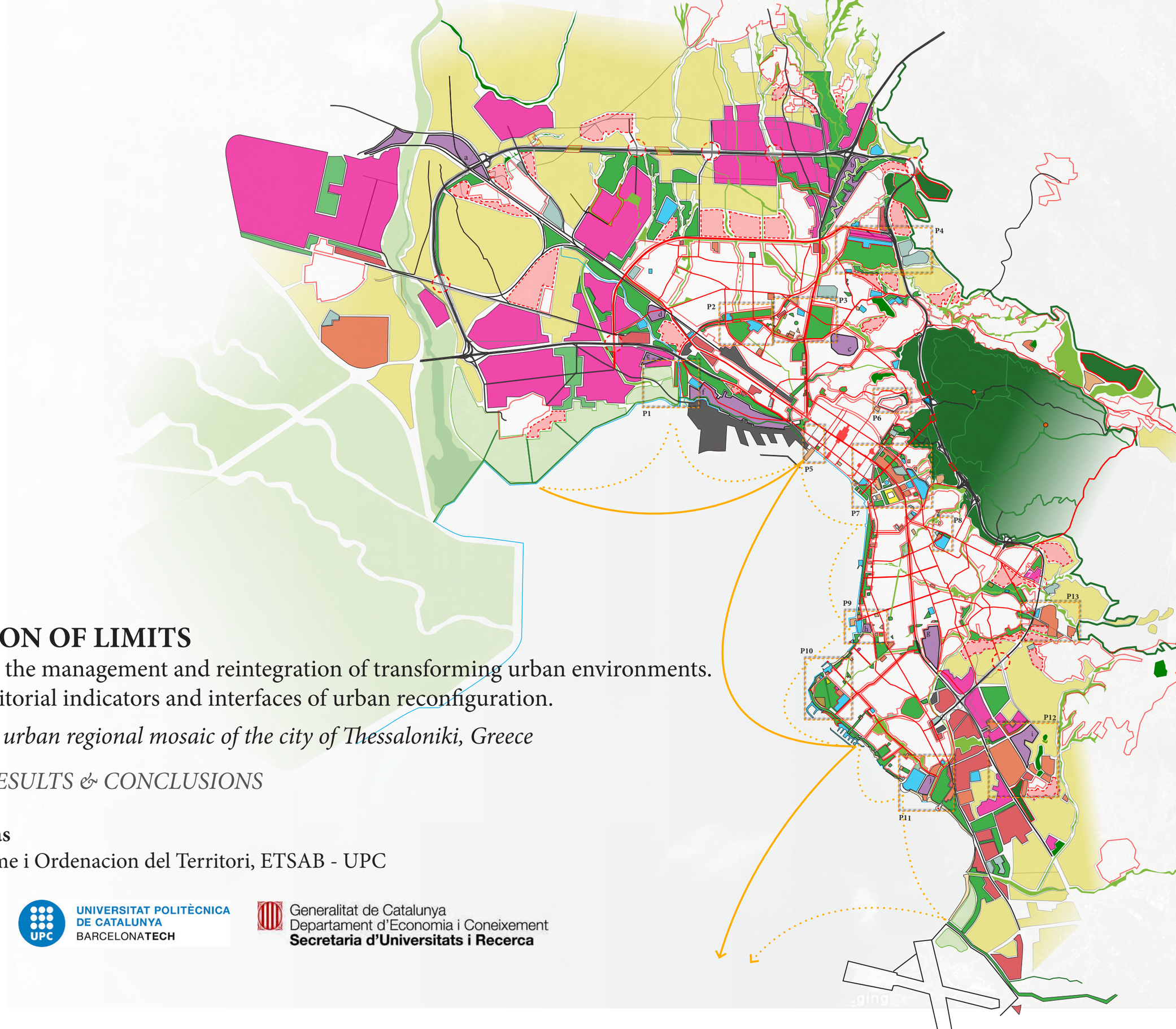

ON THE QUESTION OF LIMITS

The role of ecotones in the management and reintegration of transforming urban environments.
Urban ecotones as territorial indicators and interfaces of urban reconfiguration.

An applied study of the urban regional mosaic of the city of Thessaloniki, Greece

BOOK I - THEORY, RESULTS & CONCLUSIONS

Konstantinos Kourkoutas
Departament d´Urbanisme i Ordenacion del Territori, ETSAB - UPC

DUOT Departament d'Urbanisme i Ordenació del Territori
UPC UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH
Generalitat de Catalunya
Departament d'Economia i Coneixement
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author **Konstantinos Kourkoutas**

director **Carles Llop Torné**

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Publication structure

Book I - *Theoretical body*

I *CONTEXT / METHODOLOGY*

II *THEORY*

III *RESULTS*

CONCLUSIONS

IV. *SOURCES CITED*

Book II - *Regional & ecotonal Analysis*

0 *REGIONAL ANALYSIS / CONTEXTUALIZATION*

I *THE CENTRAL AXIS*

II *THE WESTERN WALLS*

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IV *THE EASTERN PERI_URBAN CANAL*

V *THE CITY´S RING-ROAD*

VI *SEAFRONT*

VII *SOURCES CITED*

Contents (book I)

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The path that one takes in life and respectively his / hers philosophical endeavours are laid with important waymarks manifested in situations, personal realizations and key people that appear in the way; other times pronounced and others passing unperceived, but not without leaving a mark. Such waymarks in one´s life can appear is the presence of teacher figures, whether thought out in their traditional form or in a more open definition. Teachers that take the philosophical thread and refine it, knit it to give it strength, create knots to branch off the perspective, untie others to let it wave free.

In this respect I am more than grateful to professor Carles Llop for the inspiration and passion he instilled in me to work attentively with the territory, the much needed encouragement and advice he offered throughout the realization of this work and especially during lag moments and temporary dead-ends; his high expectations for this work and the confidence he demonstrated on its positive outcome. His proactive attitude in transmitting knowledge and excitement for a critical and investigative viewpoint, have enriched and rendered the didactical, methodological and theoretical path a well travelled one.

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The land of Catalunya, the city of Barcelona, the barrio of Barceloneta, I have come to call home.

And closing, I have to dedicate this work to my brother, my parents and foremost my Mother, my first and constant teacher, her works, her preoccupation for her fellowman, her striving for critical thinking, and her ever present love in all my steps have served as an inspirational example to follow.

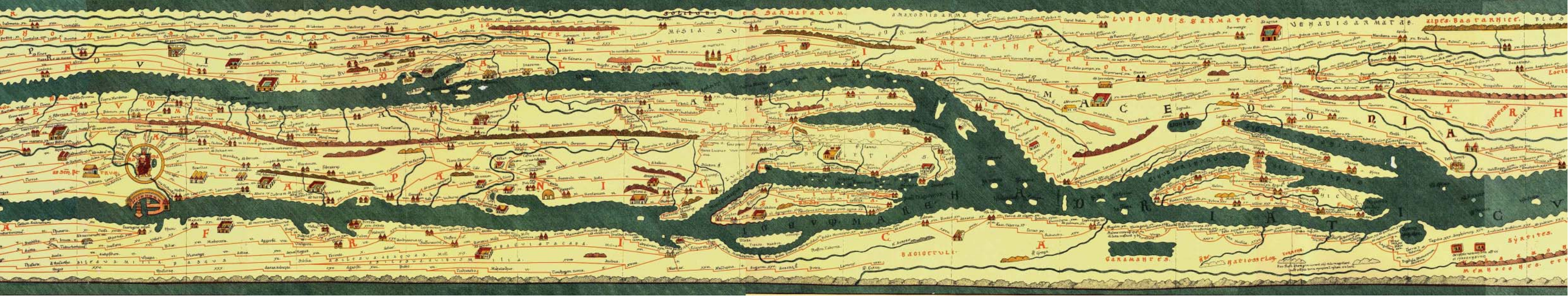
To all those whose dedication and enthusiasm move the human spirit forward.

R O
Philippopolis
M A C E D O N I A
THASOS
GULF OF CONTESSA
STRYMONICUS SINUS
GULF OF ISTILLAR
GULF OF MONTE SANTO
GULF OF CASSANDRA
Mount Athos
C. Kassandra
C. Drepano
THERMAICUS
GULF OF SALONIKI
ISTIP
L. OCHRIDA
CHARAMOUTATES
SERVITZA

Spread: Composite Map, *Outlines of Greece, 1819, by Aaron Arrowsmith*. (source: David Rumsey Historical Map Collection)

PROLOGUE

Chapter contents



I. A renovated regionalist vision

The concept of the region *per se* is malleable. Any version or definition can be defined and re-defined to suit any respective, use and circumstance; Regions in relation with and to the territory are equally malleable and manipulable; from political regions to natural / ecological there are diverse perspectives and intentions for delimiting a region. In an epistemological concept of the notion of an ecosystem, it is important to establish which view is holding sway in any given discussion or analysis,that is to decide what is encompassed by the system and what stays out. Respectively the term *region* ought to refer to any geographical unit that suits the question in-hand seeking unity and homogeneity in its general aspects. Regions may thus be defined in many ways, none of which are mutually exclusive; a region may contain, overlap, or be contained by one or more other regions; and display distinct regional characteristics at different levels and intensities both in space and in time.

Regions are not simply spatial entities. They may and usually do have fuzzy edges or boundaries which can change mitigate in response to diverse factors (internal or external). Regions cannot be perceived as a natural phenomenon. They are the consequence of human action in and on the environment, and of the human perception of that same environment, which is the primordial realm of its existence. Past and ongoing research always point to the fact that humans have a certain degree of hard wiring as far as directional sense is concerned[1]. The degree of sensory stimulation and deprivation and their proportional impacts on each person, define accordingly its entire experience of the world. Our sensing of our place in the environment informs our language and expression, and respectively influences our perception of the surroundings. Two broad characteristics are commonly considered as central to the concept of a region: i) macro-climatic and cultural-social patterns and ii) the local geomorphological features that define the (natural) limits of the region. Culturally determined human activities on the territory determine the subset regions and landscapes.

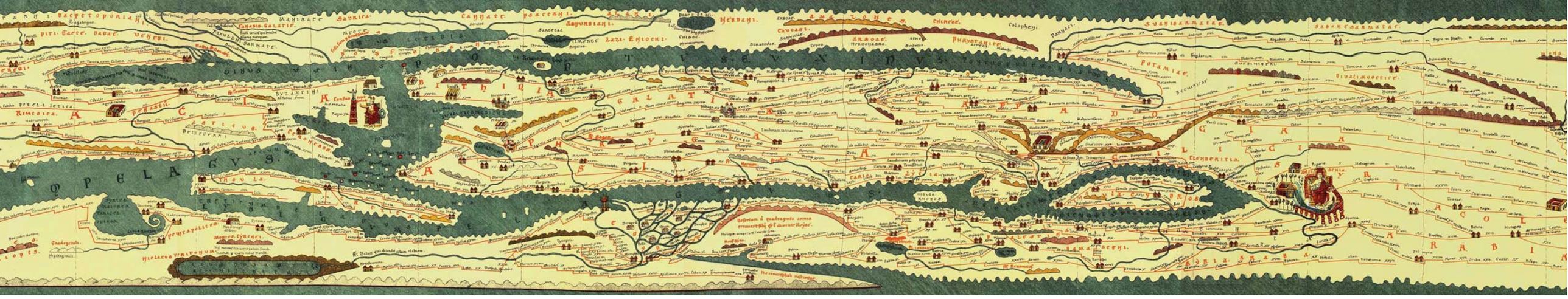
Regionalism as a school of thought and practice as conceived by the likes of Mumford and the RPAA, celebrated the capacity to provide a range of approaches towards the solution of similarly perceived problems, suggesting alternative approaches to design, different from traditional models of development, that had already started presenting deficiencies. At its core, regionalism served as an implied critique of the products and processes of mass-production society and the modernist world view. But at the same time there has always been an apparent internal tension, a contradiction within the proper concept of architectural regionalism for it sought responses creating specific, place-sensitive solutions to problems which are after all universally expressed in all regions[2]. It is a noticeable characteristic of regionalism , its preoccupation with the vernacular, and the fact that proper vernacular expressions such as architecture are suited to the place and purpose, and thus are, *regional*. Alexander Tzonis and Liane Lefaivre first coined the term *critical regionalism,* stressing *identity* as a potential counterweight to globalization forces[3], to be picked up posteriorly by Kenneth Frampton in attempt to differentiate regionalism from vernacularism, and to emphasise the notion of regionalism as a critique of modernism rather than a simplistic rejection of what is modern. In the words of Framton,

> "*Critical regionalism ...while it is critical of modernization, nonetheless still refuses to abandon the emancipatory and progressive aspects of the modern architectural legacy*"[4].

Although Regionalism did not confine itself in an anti-modernism rhetoric, at the same time it occupied an uncomfortable space between modernist and post-modernist rhetoric, aiming to develop a critical discourse on a wide spectre of topics, often with ambiguous postures[5]. Early modern planners had sought to create an ideal healthy city based on the model of a healthy body[6]. Today, instead, we are contemplating the creation of healthy cities modeled on the concept of healthy and resilient ecosystems, but contemporary planners & researchers are often encountered in the same position as their earlier peers, finding that the present understanding and application of building technologies is still insufficient to tackle the task in question integrally. The challenge today is to able to systemically conceive the city, in all its aspects and scales, from the buildings to whole districts, in the context of a wider (eco)-system; to structure the regional mosaic utilizing homogeneous groupings, differentiated from each other, and connected through diverse networks, systems and processes. As the technological advances of early industrialism permitted an increasing separation of human beings from natural processes, via mechanical and technological means, similarly cities got detached and superimposed on the territory through similar denaturalization processes on a larger and systematic scale. The modernist notion of 'connecting' the outside and the inside, surpassing the limit, apparently has not yet been fully integrated in functional terms although architectural theorists like David Leatherbarrow would argue that the boundary between inside and outside has been radically *redefined*, challenging the notions of architectural autonomy and regional coherence as an abstract reference. By suggesting that modern architectural topography, is in reality an interplay of buildings, landscapes, and cities, as well as humans, he additionally argues that the act of building is not a matter of restoring regional identity by and for solely re-creating familiar signs / elements, but of incorporating construction (energy & material) into the process of topography's perpetual becoming[7].

In ecological research, however, the preoccupation/focus on limits has shifted towards the functional connection of the *outside* and *inside* rather than the separation and confrontation aspects. This differential between *in* and *out* defines the dynamic state and the operators by which spatial conditions are sustained. The envelope, whether a building or a city, assumes the role of a flexible / dynamic mediator, an interface, between the exterior and interior realms rather than solely a rigid limit, a mere separator. This paradigm shift, in the perspective as well as the approach to its solution, towards a synergetic model, one of cooperation, demands a mental reconfiguration on a fist level: The designer's mental context cannot surpass the existing anthropogenic and environmental context. On a second level, the natural expressions of life as experienced by past generations are integrated and manifested phys-

1. Forman R.T.T. (2008)
2. Downton (2008)
3. Lefaivre, L. & Tzonis, A. (2003)
4. Frampton, K. (1987)
5. Jameson, F. (1994)
6. Williams (2007)
7. Leatherbarrow, D. (2000)



Above - Current & next page: *Tabula Peutingeriana* showing the *cursus publicus*, the road network in the Roman Empire. (source: wikipedia)

ically in the architecture of the cities and the physical molding of the territory. If city-regions are to serve as the basis of an ecological planning design then adequate regional definitions / vocabulary are essential for expressing and formulating the proposed theory and vision as proper experiences of the territory. Among the many advancements that have been made in this respect, the concept of *ecotones* as expressed initially and principally by the landscape ecology field, is an example of a notion that has aided in the advancement of the contemporary perception of the territory. The ecotones, the transitional zones / interfaces and points of inflection between two or more ecosystems, is a notion that has given a significant spin to the existing perspective on the territory, shifting the analysis / focus from an analysis preoccupied with the homogeneous, to a more precise view of the interstice areas between the patches, the complex diversity that they entail and the richness of processes that they host within.

In the case of urban ecotones, the element that comes into play is the anthropogenic factor, whether referring to a urban fabric or a human impacted landscape. An urban ecotone could be considered the interface area between urban and natural or semi-natural areas, but at the same time an urban ecotone could form between two urban patches of distinct characteristics. In either case, current research concerning urban ecotones is still in a formulative state, assimilating new concepts, integrating diverse disciplines and expanding considerations related to planning and management of the territory. The theoretical enrichment in the perspective, expressed in the added complexity detected in contemporary urban landscapes and processes within the territorial context, are serving as indicators of the formentioned paradigm shift.

The study of the mediterranean city as a concrete sociocultural context, developed within a specific geo-ecological backdrop, will serve as a test ground for studying the function and correlation of ecotones with urban form and dynamics. The mediterranean city with its long historical development, and distinct phases of succession and colonization of the territory , has passed from an efficient and balanced stewardship / management model of the territory to the high intensity, highly dissipating contemporary state, of the urabn explosion. The respective city limits have expanded to unpreceded levels often bringing in confrontation urban and natural systems and subsequently often leading to the deterioration of ecological services of the territory let alone landscape wealth loss. Similar internal limits of confrontation can also be detected within the urban fabric. A detailed study of the urban fabric of the city, including consolidated and unconsolidated patches, highlights the presence of differentiated fabrics within apparently homogeneous patches. This differentiation is a result of the effect of urban dynamics, the simultaneous superposition of historical layers over the territory and time, creating local heterotopias and anisotropies throughout the territorial fabric. Our capacity to understand these phenomena as expressions of urbanity determines to a great extend our capacity to provide adequate solutions to the problems that will arise. The necessity for such a preparation is made urgent in the contemporary context with the vast sociopolitical changes taking place on different levels and unavoidably affecting modern mediterranean cities in diverse ways and extensions.

Lefebvre talked of the *blind fields* present in our contemporary understanding of the *urban* element in cities. He insisted that we still treat the urban *with concepts that were shaped by the practices and theories of industrialization*, and fragmentary analytic tools designed / conceived during that era and therefore reductive of the contemporary *emerging reality*[8]. The problematic in our perception was not a question of *education* but of *occlusion*, breath of scope in our consideration and processing capacity.

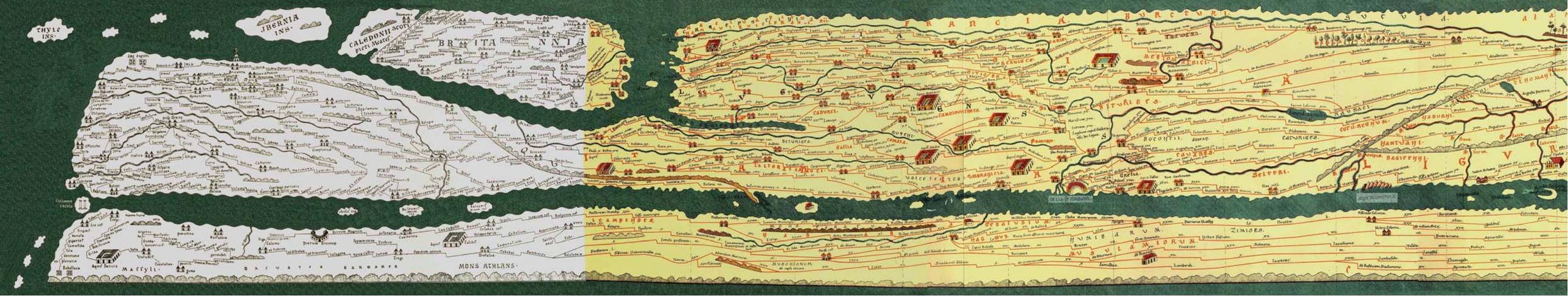
Emerging research topics & questions

Studying the mediterranean city as a specific and pronounced geo-cultural context and utilizing the recent transformations in the urban region of Thessaloniki as a practical and real case-study, permits to identify and posteriorly demonstrate the correlation between urban ecotones and urban dynamics and the distinct phases of succession experienced by anthropogenic territories and landscapes. These processes of transformation, both on a specific and a more general level, have enacted a debate on the future form of urban regions, its relation with the territory and its capacity to adapt and manage potential future challenges. The research proposal set forth by this paper was guided a serious of sets of questions that helped to eventually formulate the thesis and the respective research objectives.

RQ1. One primordial question that comes up when initiating the research is the type and degree of analogies that can be made between natural and anthropogenic (eco)systems. Accordingly, with respect to the issue of ecotones what similes exist in the respective area of urban ecotones? What are the common points as well as principal differences (phenomenological or functional) between naturally formed ecotones and artificial / antrhopogenic ecotones ? And methodologically speaking to what extend can urban ecotones be functionally classified so as to facilitate comparisons with respect to origin, structure and ecological /social processes?

RQ2. Ecotone research has indicated that ecotones provide stability for the resource patches they separate; if this is true it is useful to know at what spatial and temporal hierarchical operating scales they are effective? What has been the importance of ecotones in maintaining local, regional and global (bio)-diversity and what potential do they hold for the future management of territories? In answering this question it is vital to identify the key attributes (processes and components) of ecotones that impart resistance and resilience to the adjacent patches. That is to comprehend the ways that ecological system boundaries influence biotic diversity and flows of energy, materials (and information) and the distinctive functions that they can have (filter / barrier /corridor etc.) and intensities they can exert.

8. Lefebvre H. (1991a)



RQ3. Considering the autopoetic qualities of the territory and especially those specific to the urban /antrhopogenic regions (ekistic patterns, succession phases ...), what are the correlations that can be made between urban ecotones and the development / evolution of the urban fabric. That is to sat, in what ways can ecotones serves as indicators of past and present activity and as descriptors of the distinct urban phases characteristic of the historic evolution of each city.

RQ4. Thinking / imagining in ways that urban ecotones can function as territorial interfaces, one needs to consider in which ways they can facilitate integration of urban biomes /systems within the wider territorial ecological matrix and also the functional / operation links that connect urban ecotones with the wider urban metabolism scheme and the overall territorial efficiency? It is interesting to consider ways that humans have affected, taken advantage and / or have maintained and restored ecotonal areas in the past consciously or unconsciously . What has been and what can be the role of the ecotones in the management and restoration of a changing environments, and more precisely what potential do they hold with respect to urban fabrics? How can the diversity of flows associated with urban ecotones respond to environmental, socioeconomic and development changes, in terms of climate, land use and atmospheric processes ?

RQ5. At what spatial and temporal scales are research results most useful for decision-making and management? Is there a predictable pattern to dynamic change / shift in ecotones? Under natural / anthropogenic conditions ? What are the characteristics and processes of ecotones that are sensitive to changes in the global environment? Can we make reference to a mediterranean type of ecotone (linked to mediterranean cities & processes)

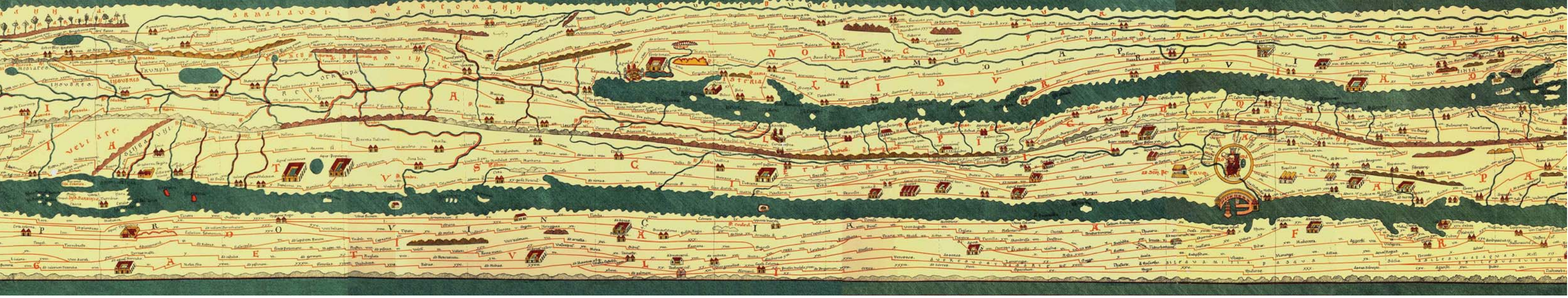
The formentioned grouped questions will guide the research perspective and analysis throughout the process. Their phenomenally wide spectre of coverage can be focused when considered in correlation with the question of urban ecotones and the case-study of Thessaloniki. At the same time they are also indicators of the intention to provide an integral analysis approach for the understanding management of urban ecotones. Their formulation is an integral part of the hypothesis its testing and verification.

II. Hypothesis

An ***urban ecotone*** is the transition area between at least two distinct urban biomes / biotopes of differentiated characteristics (morphological, socio-economic, typological etc), where this ecotonal space is characterized by a pronounced edge effect, in terms of **intensity** and **diversity** of activity, a set of defined spatial (*length, shape*) and time (*rhythm, history*) characteristics restricted to the ecotonal area but ultimately linked to the adjacent patches´ internal dynamics. The ecotone thus lies on a *critical / inflection point of* intersection between different fields or levels of ecological / social organization, and along which the discontinuities based upon discrepancies in values, interests, knowledge and power, are most likely to be located and manifested.

Due to these intrinsic characteristics most ecotones, it can be sustained that, if managed properly, urban ecotones can play a key role in maintaining territorial integrity (*ecological, functional*) and a socio-economically vibrant diversity along their course, thus resilience and consequence of long term sustainable yields. Similarly when thought out as (***re)-programmable urban/ territorial interfaces***, a direct simile to the membrane function encountered in nature in organisms and ecosystems, urban ecotones can provide the base for a paradigm shift in our contemporary perspective on cities and their functioning. A shift from a confrontational and fragmented discourse towards a synergetic and cooperational model, necessary when considering the problematic state of most contemporary cities and vital in the intend to mend and integrate the fragmented mosaics and human activity of modern urban regions. This convergence and compatibilization of antrhopogenic and natural activity can only be achieved if the necessary conceptual and design tools are developed for this purpose.

While the research focuses on the specific urban region of Thessaloniki, it also reflects on the latent potential of urban ecotonal areas, internal and external, in integrally restructuring urban functions and in improving the overall territorial efficiency of the patches / biomes involved. The study of the historic spatial evolution of the city (morphogenesis) permits to monitor the growth patterns and phenomena associated with the ecotonal areas in given critical phases of the urban development, and at the same time consider urban growth and dynamics from a renovated perspective, using ecotones as point of departure for redefining and reevaluating territorial projects and strategies.



III. Methodology

The research methodology for this paper intended to respond to an updated scientific vision of the territory and contribute constructively towards the formulation of a more coherent theory guiding contemporary practices of regional and territorial analysis and planning. First, the object of study is defined, followed by an explanation of the research structure, objectives as well as considerations taken during the analysis. Before entering in more detail on the state of the art regarding ecotones and urban region a brief outline of the diverse tools utilized in the process is also offered. The methodology as a general principle has sought to create a broad and coherent research/ knowledge base, that could be utilized specifically for the research needs of this paper, but also serving broadly as a methodology for analysing urban ecotones, thus advancing the scientific discourse and perspective of urban studies.

Object of study

The urban region of Thessaloniki as a mediterranean city paradigm / case study

The mediterranean cities have historically developed a close and interdependent relation with their respective territories and adjacent natural ecosystems. In the case of coastal cities, the seafront relation is always a key consideration element but there are others such as the typical agro-forestal mosaics encountered close to the coast as well as inland. This city-in-evolution paradigm with the distinctive phases of succession and colonization of the surrounding space is visible and readable in the contemporary fabric of most cities. The successive overcoming of the respective city-limits, integrated to different extends by the expanding urban fabric, experience transformations of diverse types and intensity but nevertheless in many cases achieve to maintain certain aspects of diversity and intensity of activity that attest to the inherently special nature of limits, ecotones. This lecture of the urban region though a meticulous analysis of the ecotonal areas can offer a deeper and precise understanding of territorial logics and dynamics. The case study of the city of Thessaloniki situated in the region of Central Macedonia in northern Greece is an example of a mediterranean city with a long historical development, located in close contact with important ecosystems. Due to this fact the urban expansion has been in a constant confrontation with these ecosystems: the expansion over the wetland on the west part of the city, the close contact with the forest to the north, or the consumption of agricultural land along the plain to the east. At the same time the city has been subjected to the same socio-political and economical forces events that characterized the common Mediterranean diachronically as well as in the last century. The recent sociopolitical changes taking place in the wider area of the Balkans, created an unfulfilled potential for the city of Thessaloniki, to emerge as a centrality pole in the regional and interregional context restoring its traditional relation with the Balkan hinterland. Due to the formentioned conditions, a great amount of discussion / debate had been done for the need of a metropolitan-type of governance for the city of Thessaloniki, seeking the solution to many of the inherited problems of the city in a more efficient and coordinated manner of overcoming the bureaucratic and centralist limitations that have hindered progress recently.

The revision of the Thessaloniki Regulatory Plan, completed and currently waiting approval, is contemplating and planning the expansion of the city´s limits and future development. Taking advantage of this timely occasion, this paper will try to provide an integral analysis of the territorial mosaic of the city of Thessaloniki within its wider regional context, and provide critical and complementary arguments for debating future development.

Research Objectives

The case study of the city of Thessaloniki presents an interesting opportunity for studying and examining contemporary notions concerning the urban region in general and the mediterranean typology more specifically. Furthermore its historic evolution has marked discernible ecotonal areas that permit its lecture through the analysis of the evolution of these areas. Thus, as a general objective it aims to expand on the concept of the urban region and its definition as it emerges both through its historic evolutionary path as well as contemporary and emerging definitions. It comes to demonstrate the shift in the mentality or urban research from limits and homogeneity, to a more dynamic and at the same time abstract analysis, seeking unity and cooperation within the regional landscape, by establishing synergies that can take on renovated projects and common visions.

A. A first objective is to research the state of the art around ecotones, defining fundamental characteristics (ecological , morphological, functional) and methodological approaches and extrapolating this know-how to the urban environment, producing a synthesis of information on urban ecotones, while identifying gaps in information and understanding in applying the ecotone paradigm in the urban context.

B. Investigate the respective potential of urban ecotones with respect to their function as territorial indicators, (detecting human impact on functioning of landscapes/ systems, urban expansion tendencies) but also in their updated role as territorial interfaces managing flows and dynamics across the urban fabric, passing from static to dynamic considerations.

C. The third objective aims to examine whether the inherent characteristics presents in many natural / urban ecotones (diversity & intensity of activity) can also serve as instruments of urban reconfiguration and platforms of ecological restoration / integration of territorial systems, increasing resilience of the urban systems to external and internal shocks / impulses and building a more vibrant and coherent urban structures.

D. Finally, develop a research case study with testable hypotheses. (Thessaloniki´s urban region)

Structure

1. Thesis / theoretical & methodological approach
A brief definition of the research objectives and thesis proposed. Clarification of the main points of the research perspective and methodology adopted and detailing of the analysis steps / sequence to be followed. Explanation of the particularities and difficulties related to the case study.

2. Theoretical & Methodological background / references. Concepts & Instruments
A first in-depth analysis of the ecotone concept was done for one of the research seminars realized in the framework of the PhD course and the resulting study that was produced, titled "*Un parque civico para la Plaza de la revolución en Habana, Cuba*". This study focused on an ecotonal area formed in the city of Habana, between the Vedado and the Habana Central / Cerro districts. The concept of the urban ecotone was used as a tool and a leverage for envisioning a restructuring/reprogramming of the local as well the extended urban fabric.

The project thesis presented in April 2010 for the Master in Urbanism titled "*ON THE QUESTION OF LIMITS, Reticulating the emerging city: urban ecotones, spatial networks, and ecological structure as instruments of spatial configuration. A contemporary lecture of the territorial mosaic of the urban region of Thessaloniki, Greece*", served as timely opportunity to investigate contemporary notions of territorial mosaics and the role of ecotones (natural / urban) in their functioning.

The participation in the european program CREPUDMED (*Coopération Régionale pour une Planification Urbaine Durable de l' éspace Med - INTERREG MED-1G-MED-08-69*) as part of the Scientific Committee permiteed get exposed and investigate further on planning tendencies and practices within the MED space, since the program counted with diverse actors from four mediterranean spaces: Spain, France, Italy and Greece.

Additionally the participation as a member of the research team in the national research plan, "Cities, metropolitan territories and Urban regions. Strategies and proposals for the regeneration project of the territorial mosaic city after the *urban explosion*" (*Ciutats, territoris metropolitans i regions urbanes eficients. Estratègies i propostes de projecte per la regeneració de la ciutat_mosaic_territorial després de l'explosió de la ciutat* / BIA2012-35306) permitted to focus on issues related to territorial / landscape efficiency and parameters that enter in consideration. The territorial scale of the analysis and the multispectre analysis highlighted the key function that territorial elements such as ecotones have in maintaining structural integrity by controlling factors such as connectivity, networking, flow control and activity intensity among others.

3. The Thessaloniki city case-study, application of analysis instruments and concepts.
The case-study of the urban region of the city of Thessaloniki is the ground for the exploration of the formentioned of the concept of urban ecotones though the formentioned concepts and instruments. Previous to the initiation of any research effort was the recompilation of a knowledge / data-base regarding the region of Thessaloniki, regarding diverse aspects that could be relevant to the subsequent analysis. Similarly the collection of diverse historic and thematic cartography was another vital element in the process. Creating proper cartographies proved another necessary step, both to fill voids in accessible cartography but also as an intentional / synthetical graphical tool. The sources and tools utilized for this part are presented in a subsequent section.

- ***Regional / Territorial scale.*** A primer analysis realised as the project thesis for the Master´s in Urbanism course in April 2010, titled "*Reticulating the emerging city: urban ecotones, spatial networks, and ecological structure as instruments of configuration. A contemporary lecture of the territorial mosaic of the urban region of Thessaloniki, Greece.*" This initial work aimed at forming a precise impression of the regional mosaic of the city of Thessaloniki, both in terms of land use as well as structure and function. This served as the contextual base for initiating the following step and is included in summarized form.

- ***Ecotone analysis case studies***. This consists of the morphological and phenomenological analysis of the conditions and dynamics along the 6 ecotonal areas selected for analysis. These ecotones can be grouped into the first two consist of *historical limits*, associated with the city walls and the adjacent to the walls area; the limits linked with city limits during the process of its *modernization*; and finally the *contemporary* limits, that is the ring road infrastructure and the seafront respectively that close / complete the proposed analysis structure. The ecotone analysis structure is viewed in more detail in continuation and in the second book, *the Analysis Atlas.*

4. Discussion, Interpretation and interpolation of results.
Presentation of results of the six analysis areas with specific conclusions for each section. Followed by a synthesis of the individual results into a common plan. Both on a cartographic sense, mapping the sum of results but also on a conceptual plane where specific (location and case-wise) results can be interpolated in significant and transferable results.

Methodological Aspects

a. Case study selection - utility and significance

The selection of the city of Thessaloniki and its urban region correspond to a series of criteria such as its special characteristics as a coastal, mediterranean city with a long historic course (316 bC to today) of respective phase / periods that have produced distinct urban forms and situations. The absence of a recent territorial/regional plan for the city of Thessaloniki and at the same time the coincidence with the revision of the Regulatory Plan renders this research work as relevant and useful in providing insights and alternatives to current planning practices and aspirations. On a general level, the results to be produced are expected to be extrapolable and applicable to other cases of urban regions, within the mediterranean context or not.

b. Delimitation of the analysis area

As seen earlier the analysis on a first level opts for a wider regional delimitation in this case the region of Central Macedonia. A formal and administrative region, of which Thessaloniki is the capital and gravitational centre. This first analysis delimitation allowed to study the regional structure (natural & anthropogenic) in its entirety, while at the same time identifying the distinct bioregions included within and associated with the diverse territorial situations and landscapes encountered. The delimitation of the urban region and its contextualization within the extended regional context permitted a more integral subsequent analysis in the next phase.

Thus on a second level, the analysis focuses on the urban bioregion of Thessaloniki, delimited on the west by the Gallikos river and the adjacent estuary area, and stretching to the south-east, with the Chortiatis mountain range on the north, all the way to municipality of Thermi and even subsequent coastal areas, encompassing a series of municipalities (approx. 10-12). Approximately the extension that metropolitan region has considered up to now.

The six ecotonal areas chosen for analysis correspond to respective city limits in distinct historic periods that are still visible / readable in the contemporary urban fabric and that give hints of past and present processes and territorial dynamics.

c. Sliding between scales as an instrument of analysis

The utilization of different scales of analysis is a vital tool / methodology for observing the territory and discerning the distinct grain and detail / resolution present in each case. This *sliding between scales* process permits to correlate characteristics and dynamics between different scales, and ultimately define the hierarchy of scales present in the territory.

Thus for the territorial analysis an analysis scale of 1:250000 to 1:50000 was utilized to detect and identify the distinct territorial elements and regional dynamics. Subsequently the ecotone analysis opted for a more precise scale to detect finer details, ranging from a range of 1:25000 to 1:5000 and even smaller in selected cases for the verification of specific details.

d. Morphological analysis - patterns and dynamics

Another important research tool has been the morphological analysis concerning urban form and structure and its development patterns over time. The observation of evolutionary patterns along ecotonal areas can serve for identifying and understanding the key indicators of ecotonal processes and dynamics, focusing thus both on its spatial three-dimensional manifestation but adding in the consideration the factor *time*, the fourth dimension. This extra dimension can help set the guidelines for determining the respective succession phases experienced by urban patches and adjacent landscapes.

e. Phenomenological analysis - situations and logics

Following the initial morphological investigation of patterns and processes, the analysis aims to extend its scope and perspective by adopting an additional a phenomenological view on territorial processes. This enriched point of view permits to detect territorial phenomena - manifestations of dynamics processes and thus identify territorial situations, specific to the location and the respective conditions / conditioners. The adoption of a phenomenological philosophical standpoint can also aid in the advancement of the scientific discourse and enrichment expansion of territorial vocabulary to describe/understand situations and intuit the inherent logics present in the contemporary urban mosaics.

f. Sensing the intangible - listening to the voice of the territory

In order to dwell into this formentioned phenomenological analysis it is necessary to utilize a variety of tools and inevitably enter into a trans-disciplinary discourse that encompasses a wide variety of perspectives and an equally ample range of tools, transcending the pure technical tools / means traditionally used in the field and accepting them as equally acceptable tools in the intend to understand the territory, get a wind of its interior less visible - less cared for aspects, listen to the voice of the territory, its resonant vocation, harness the true potential in a collective and integral project.

Tools / sources utilized

In order to realise the analysis in the most efficient manner, a series of tools had to be utilized in the process to ensure the integral and scholastic vision set forth by the research proposal. These tools included more traditional physical / printed as well as digital tools and combination of the two. The following indicative list in continuation explains these tools and the sources that were used to get hold of the information in question.

i. Cartographic research

The cartographic research aspect for this investigative work was a key element and a challenge at the same time. On a first level, the limited cartography public access in Greece, restricting research initiatives, making obligatory the search for alternative mapping and cartography services. On a second level the object of study of this paper, ecotones, have been traditionally been analysed through the use of historic cartography and aerial imagery. Thus it was rendered obligatory to produce proper cartography utilizing the various open access online aerial imagery services.

In order to find alternative cartography sources for the research purposes of this paper, different means were to be sought. Traditional cartography was sought and found in a series of sources:

National

a. The Agency for the Master Plan of Thessaloniki - *personal visits & consultations*
b. The Urbanistic Archive of the Municipality of Thessaloniki - *physical & online consultations*
c. National Map Archives - *Publications*
d. The Spatial Development Research Unit of Aristotelian University - *physical & online consultations*
e. The Hellenic Ministry of the Environment and Public Works - *online*
f. The Egnatia Highway Observatory - *online*
g. The Region of Central Macedonia and the Prefecture of Thessaloniki portal - *online*

European / International

a. ***The European Environmental Agency*** (EEA) web site, that holds an extensive database of diverse data sets the majority with pan-european coverage, and a wide thematic range. Apart from generated maps, the EEA site has various useful tools. Specifically the Corine Land Cover Feature, is a very important tool, providing Land Use and natural resources mapping information, available for download and importing in GIS Software.

b. ***ASTER*** (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is another online source which proved quite useful. It is an imaging instrument flying on Terra satellite, as part of NASA's Earth Observing System (EOS) in a cooperative effort Japan's Earth Remote Sensing Data Analysis Center. The site provides access to the Global Digital Elevation Model (GDEM) on a worldwide scale in with a sufficient resolution for territorial scale analysis.

c. GIS Services

The utilization of the diverse municipali online GIS portals has also been a key element for the analysis. The portal apart from providing visualization of diverse attributes (land use, landmarks, indicators etc) a lot of them allow access to past and current plans within the respective municipal limits, permitting to follow the planning evolution aspect, and explain morphological manifestations. An indicative list of consulted GIS services are the following:

- GIS service of Municipality of Thessaloniki
- GIS service of Municipality of Sykies
- GIS service of Municipality of Pavlos Melas
- GIS service of Municipality of Korderlio-Evosmos
- GIS service of Municipality of Pylea - Hortiatis
- GIS service of Municipality of Kalamaria

ii. Aerial Imagery

Aerial imagery is as important of a resource as the available cartography. Contrary to the latter which contains an element of interpretation, aerial images (aerial photos, high & low attitude) allow for the proper interpretation and the creation of original and adapted cartography. There are numerous online services that allow free access to online aerial imagery (Google Maps, Bing Maps): These services also allow additional options such as isometric aerial view or a back catalogue of historic aerial images.

- Another important source for aerial imagery also utilized was the Earth Science Data Interface (ESDI) - Global Land Cover Facility of the University of Maryland, NASA and the Global Observation of Forest and Land Cover dynamics (GOFC-GOLD). The portal offers free access to high-resolution aerial imagery of various chronological periods of worldwide coverage and for the city of Thessaloniki specifically.

- The website, www.airphotos.gr, that offers a wide selection of low height photography from all over Greece and specifically for the city of Thessaloniki and the extended region.

iii. Bibliographical / Methodological research
Bibliographic research is a crucial element of the analysis investigating past and current state of the art. The term *state of the art* refers both to methodological practices as well as perceptual connotations and conceptions when it comes to talking about and describing urban and territorial processes. Bibliographic research was done with on-site visits of local or administrative libraries (ORTh, Urbanistic archives of Thessaloniki), the academic libraries of ETSAB, ETSAV and AUTh as well as a series of internet portals like **a)** Online Journal Portals (DirectScience, Scopus, SpringerLink, UrbaDoc) **b)** the ESTIA portal of the Spatial Development Research Unit of the Aristotle Univeristy of Thessaloniki (AUTh) that holds considerable amount of academic and research material concerning regional development and Thessaloniki. **c)** The Engatia Motorway Observatory, that holds the most recent data on spatial and demographic changes in the Region of Central Macedonia. **d)** various governmental and public administration sites. **e)** Thessaloniki Regulatory Plan (*ORTh*) organization website.

The basis for the bibliographical research was laid with the one of the PhDs research seminar works produced titled "Metropolitanism vs Regional Growth". The research provided important insight into the historical and regionalist tradition (including the works of important thinkers like P. Geddes, Lewis Mumford and the RPAA legacy, MacHarg etc) and the various alternatives that it had proposed and is currently proposing to metropolitan growth patterns characterizing if not plaguing modern cities. The regionalist tradition as formed through the lengthy bibliography produced up to now, constitutes a rich and important knowledge base for critical analysis of the territory and the territorial processes. Equally important effort was consequently put in researching current thinkers and practices in spatial planning, with a focus on regional development.

As mentioned earlier other activities also gave the opportunity to dwell deeper into the contemporary concepts and knowledge related to territorial / regional planning and more specifically the concept of urban ecotones. The research workshop in Havana Cuba was one occasion that aided in recompiling key information about ecotones while the posterior participation in the formentioned research programs also complemented with additional valuable bibliographical and methodological information the existing and ongoing collection.

iv. In-situ visits / research
Another key element, vital for the production of any significant conclusions were the on-site visits of the 6 sites under analysis. The purpose of these visits were to verify cartographic information (historic & contemporary) and record the existing conditions by means of observation and other media (notes, photographs) and ultimately getting a sense of the space by gathering sensory information on diverse aspects under investigation (habitability conditions, mobility / accessibility, activity diversity and intensity, and quality and perception of existing public space) .

v. Personal Interviews
This element was an important part of the research process, especially in the early investigation stages. A series of personal interviews were contacted with key personalities in the administration, educational and research sector that are in some way involved in regional and spatial planning for the city of Thessaloniki. These interviews provided necessary insight for development issues concerning the development of Thessaloniki, and the region of Central Macedonia and aided further with their recommendation and facilitation of source material. The list of people 1 interviewed for the initial phase of this research effort will need to further updated with repeated meetings with existing persons in the list to discuss initial conclusions, and new additional people that can contribute extra insight and information. An indicative listing of the interviewed people is the following: Dr. Giannakou A. (Architect and Professor in AUTh, member of the scientific committee for the Strategic Plan for the Sustainable development of Thessaloniki), Dr. Kaykalas G. (Professor of Urban and Regional Development, Coordinator of Spatial Development Research Unit, AUTh), Dr. Komninos N. (Professor , Urban Development and Innovation Policy. founder and director of the Urban and Regional Innovation URENIO Research Unit, AUTh), Dr. Matikas Architect, Head of Spatial Planning for ORTh), Dr. Nikolaou K. (Chemical & Environmental Engineer for the ORTh., Professor AUTH, Greek Open University), Dr. Papamichos N. (Architect, Economist, Professor AUTh, Scientific Coordinator for the Revision of the Thessaloniki Regulatory Plan)

IV. Key ideas & considerations prior to the analysis.

The recent rise in urban demographics has attracted increased attention to the urban environments, where the gigantesque proportions reached by many urban regions has alerted and triggered a new discussion on urban limits and consumption of the territory. On one hand the advanced ecological understanding achieved recently and the increased citizen participation and preoccupation over human impact on natural environment have served as vehicles for re-enacting the debate, enriching the discussion with new and older arguments, brought together and interwoven within the contemporary context. This paper pretends to tackle the urban expansion question by examining the role and effect of urban ecotones in the integration of city functions and their articulation within and in conjunction with the territory. Prior to embarking on the analysis of the issue at hand it is necessary to consider and present some fundamental ideas and concepts that will be everpresent in the subsequent discussion, some discussed in more detail while others serving as research guides for focusing the perspective, based on the needs of the analysis.

The contemporary regional survey, a multidisciplinary and multisensory process for analysis and lecture of the territory as fundamental knowledge base for any consequent research / design effort.
The regional survey should be understood as a detailed lecture of the region, the identification and structuring of regional landscapes and the analytical correlation of present forces and dynamics within. As Patrick Geddes advocated " *diagnosis before treatment* ". The survey has served traditionally as the basis for any design or research, and with the aid of contemporary technologies analysis methods and results it can be enhanced and improved significantly. The regional survey thus, is an important methodological part of this paper, adopting a multidisciplinary approach and a panoply of tools, utilizing cartography, aerial photos, site visits and digital and traditional bibliography as primary data sources. Posteriorly all this info is processed and interpreted to produce the different impressions / synthesis of the territory through the various maps/diagrams found throughout this paper.

The biophysical matrix as the physical support, and context for the natural potential of the territory.
The elements that constitute the biophysical matrix usually also structure city development the way that the local geomorphology or the hydrological functioning can impede growth. Apart from setting the physical stage on which urban activity develops, they also condition its path of development, given that cities were historically dependent on local resources for their survival. Food, material resources and energy potential, considering renewable and nonrenewable sources, are the most frequently mentioned in bibliography as far as tangible aspects are concerned but contemporary research has highlighted the importance of many other factors crucial in maintaining a vibrant ecological structure and for achieving ecological convergence on an urban and a territorial scale.

The city as a bio-dome/bio-topos
This research work takes as a basic axiom that cities are living places and places to live, habitats in the primordial sense of the word. That is to say, cities should be considered as bio-topes (βιο-τοπος), as any ecosystem, that host multiple and diverse ecological systems, each its proper organization and functioning, in nested hierarchies. This view of the city as an ecosystem is a long pending task for environmental and city sciences and a ongoing challenge for current research efforts. The lack of our current understanding cannot lead to a simplification of the phenomena and processes present in fabrics and the territory. As Jaume Terradas would state: *Cities are open, energy-dissipative and heterotrophic systems, a fact that distinguishes them from natural ecosystems that strive on energetic auto-sufficiency, and thus specifically when referring to cities we can use the term social ecosystems to make implicit the superposition of cultural infrastructures over the natural ones*[1].

The city as the civic realm of human activity.
The city as a physical and social structure is intimately linked with human development and has served as the stage for the complex processes related to urban evolution. The city as a synthetic vision can be understood as a solution of the three components that have configured the essence of human civilization: the place (*urbs*), the political community (*polis*) and as a encounter and cultural exchange place (*civitas*).[2] While historically these three functions were contained within the walled perimeter, but after the urban explosion they were splattered throughout the territory altering the traditional equilibrium relation between city and territory, and ultimately the relation of the human with his/her territory. The city is now dispersed and diffused as a multiplicity of heterogeneous urban forms.

The territorial mosaic city as a contemporary paradigm for observing / analysing urban regions
Contemporary urban regions, after the recent urban explosion are found in a fragmented state, result of years of uncontrolled expansion and infrastructural development diverging from the co-mutual evolution with the territory. The produced territorial mosaics with the diverse situations as well as urban morphologies that have emerged, consist of heterogeneous / differentiated sub-landscapes, that are in turn, made up of smaller patches of land. This territorial mosaic city is made up of historic fragments merged within the rural and urban environment, productive agricultural lands, industrial activity structures, drosscapes and marginal spaces [3].

1. Terradas, J. (2013)
2. Llop, C (2009)
3. Llop, C (2009)

The territory as chora

Chora (χώρα) is a philosophical term described by Plato in the dialogues with Timaeus presented as a receptacle, a three dimensional space, or an interval. According to platonic theory the nature of chora is caught in between the dualism of being (i.e. Idea) and non being or becoming (i.e. the perceptible). This conceptual interval, between the sensible and the intelligible, where "forms" materialize and are assigned attributes (physical and mental) specific to the space they occupy. Apart from Plato diverse authors have intended to address the concept of *Chora* such as Heidegger that viewed it as the stage on which processing happened or took place; Jacques Derrida that in a deconstructivist sense uses the term to name a radical otherness that gives place, space, a receptacle for being, ultimately a physical reality, a hospitable environment where the most fundamental symbolic, cultural and political conceptualizations take form[4]. Julia Kristeva on the other hand articulates the 'chora' in terms of a presignifying state: '*Although the chora can be designated and regulated, it can never be definitively posited: as a result, one can situate the chora and, if necessary, lend it a topology, but one can never give it axiomatic form*"[5]. deploying the term as part of her analysis of the difference between the semiotic and symbolic realms, that respectively symbolized the feminine and masculine forces present.

Chora in modern Greek has come to describe a whole country as a territory, or the relation of a central nucleus /settlement (Chora) with its surrounding space / environment, a denomination present today in the majority of Greek islands, and less in the continental part. For the purpose of this paper the definition of the territory will draw near the definition of the Chora as coined by Plato and enriched by posterior definitions, and that ultimately refers not only to a three-dimesional space / receptor but also to a contextual space within which meaning and symbolism is given.

Autopoiesis and the emergence of territorial systems / networks

Self-organization, that is to say the phenomena by which a system self-organizes its internal structure independent of any external causes, is a fundamental property of open and complex systems. Such systems tend to exhibit phenomena of nonlinearity, instability, fractal structures and chaos, all phenomena intimately related to urbanism and the planning experience[6]. The notion of social autopoietic system as conceived by the sociologist Niklas Luhmann, can provide a theoretical criterion relevant for conceptualizing the territory within the social research fields. The idea of a system according to Luhmann is based on thinking of the system in contraposition to its surrounding environment, thus objectifying the system, adding a symbolic reference to it[7]. When studying the territory as a social system, there are a number of issues /aspects that communicate the territory as a symbolic and differentiated element[8] (differentiating in and out of the system): What institutions make reference (latent or manifested) to the territory and how they define it. On another level the self-descriptions of the territory coming from its own organizations, bottom-up or not, such as local authorities, companies, associations, parties, leaders etc. Finally, the autopoetic social system approach over the territory, questions the lack of references with regards to the territory or their replacement by other socio-spatial realities /situations competing for protagonism[9]. Thus in this sense we can talk of the distinct territorial bio-domes (βιο-δομή = living structures) that have naturally formed / emerged in the territory over the passing of time.

The theory of *Ekistics* as coined and developed by Constantinos Doxiadis is a well fit example for understanding these patterns and studying them within a science of human settlements that encompasses an ample spectrum of territorial considerations: geography, ecology, human psychology, anthropology and aesthetics[10]. In an intent to systematize its study, Doxiadis proposed the establishment of a classification system for settlements, an *Ekistic Grid* organized in five ekistic elements: *Nature*, *Anthropos*, *Society*, *Shells*, and *Networks*, and a sixth line denoting their *Synthesis*. The ultimate goal of Ekistics was the harmonization of human settlements with their physical and sociocultural environments demonstrated through the various projects realized by Doxiadis as well as the extensive research conducted and published by the Ekistics research group in the 60s-70s. The wealth of knowledge, even more related to the Mediterranean and Greek context, is of great value and reference for this work.

Networking & a multi-nodal configuration of the territory.

Multicentricity is another objective set forth by the european spatial development agenda presented as a model that promotes social cohesion and achieves a even distribution of development on a regional level. In this respect Thessaloniki, is an interesting case study, given the apparent monocentric structure and the implied polycentric traits discerned after a closer investigation. Furthermore, expanding on the definition of multicentricity, this paper will explore the potential of a network configuration, a multi-nodal approach for reticulating the territory and increasing connection and interaction potential between the multiplicity of systems, anthropogenic and natural.

4. Derrida J. (1993)
5. Kristeva J. (1984)
6. Portugali, J. (1997)
7. Luhmann, N. (1998)
8. Pfeilstetter, R. (2011)
9. Pfeilstetter, R. (2011)
10. Doxiadis, C. A. (1968)

Industrial ecology & ecological convergence as a real-value development indicator.
The notion of convergence is being traditionally used to denote economic or social convergence based on set standards, such as the objectives set forth by the *EU* for the various regions of its country members, referring to a convergence with respect to a average european income. Ecological convergence is a notion that goes further than pure economic terms/considerations . It considers development as a phenomenon much more complex than the one that economic indicators can depict, including factors such as natural capacity of ecoregions, or human related activities and settlements with a certain ecological footprint. It understands ecological integrity as the basis for any development consideration and demands an adequate and well reticulated territorial structure that can sustain the development and existence of human or natural activity throughout its fabric, without compromising ecological integrity.

The work of John and Nancy Todd and the *New Alchemists* has been pivotal in the movement of ecological design and for the foundation of industrial ecology. Stand between the radicalism of fundamental thinkers and the pragmatic interpretations and theoretical re-workings of active practitioners, the New Alchemy Institute began by asking if there were biological analogues by which human populations might sustain themselves other than the present exploitative, dangerous, and biologically insupportable technologies, and whether humanity could co-exist in a mutually supportive and beneficial way within the biosphere [11]. Thus, they claimed that ecological design should always have or seek a holistic scientific point of view, informed and guided by humanism. Such an approach was outlined by John Todd in 'A Modest Proposal' of 1970. His proposed *biotechnologies for small communities* were first realized experimentally in the late 1960s and early 1970s and have since led to a numerous initiatives including the design and manufacture of *living machines* and *constructed wetlands* that treat sewage in various and diverse locations worldwide. In 1984 they put forward a set of *Emerging Precepts of Biological Design* which was reiterated and reinforced in 1994, and are listed below [12]:

1. The living world is the matrix for all design.
2. Design should follow, not oppose, the laws of life.
3. Biological equity must determine design.
4. Design must reflect bioregionality.
5. Projects should be based on renewable energy sources.
6. Design should be sustainable through the integration of living systems.
7. Design should be co-evolutionary with the natural world.
8. Building and design should help heal the planet.
9. Design should follow a sacred ecology.
10. The formulation of these early precepts as they are applied and tested will contribute, in time, to the creation of a science of applied ecology which will serve in turn as a foundation for future technological design

11. Downton (2008)
12. Todd, N. & Todd, J. (1994)

Towards a phenomenology of the territory
It is made evident both by the discourse developed as well the current state of the art that we are still in need of a coherent theory which comprehends the territory *in concrete, existential terms*. Gaston Bachelard's phenomenological psychology took human habitation as a fundamental given and as an abiding mystery of the human condition[13], what Heidegger described with the concept of *dwelling* and Norberg-Schulz enriched with his definition[14]:

> " Since ancient times the *genius loci*, or *spirit of the place* has been recognized as the concrete reality man has to face and come to terms in his / hers daily life. Architecture means to visualize the genius loci, and the task of the architect is to create meaningful places, whereby he helps man to *dwell*."

Dwelling is thus synomimous with identification. Bachelard would also use such interpretations in his epistemology, which he had conceived as a psychoanalysis of reason, and in his poetic analyses as a *psychoanalysis of the imagination* and especially the idea of the collective unconscious. He would see scientific tools as materialized theories, *phenomenotechnique*s, and therefore any theory was by default considered a practice as well. Additionally any epistemological study ought to be historical[15]. A phenomenology of the territory should be a phenomenology of the daily environment, tangible and intangible, able to identify correctly concrete territorial situations based on existential criteria, bring out the latent vocation of the territory, by expressing its inherent logic, what Husserl would call its innate reasoning.

The definition of the urban region in-flux.
The urban region and its delimitations is a complex notion that has received various definitions over time, and is currently receiving increased attention due to the intense urbanization taking place worldwide. The city-region can be defined according to diverse aspects and considerations, definitions that can be mutually exclusive or inclusive, or in a superposition. Increasingly though the attention has come to shift from the question of limits to the question of scale. Each scale permits a different grain for lecture and the identification of distinct limits / ecotones. Edges are now considered as active interface zones between patches and can potentially play a key role in seeking urban integration within the natural regional context. The fluxes and activity on the regional level are under constant adaptation and transformation, and this dynamic state could only be truly captured by a real-time territorial monitoring system, utilizing current mapping and detection technologies.

Urban ecotones as territorial interfaces - from confrontation to synergy
Between the diverse and distinct phenomenological territorial situations that one could detect and possibly identify, following a detailed observation and examination of the territory, are the territorial limits, the edges between (eco)systems and the corresponding ecotonal / transitional zones that are formed.

13. Thiboutot, C.; Martinez, A. & Jager, D. (1999)
14. Norberg-Schulz, C. (1980)
15. Bachelard, G. (1957)

These spaces are key areas for species diversity and interaction (activity). This idea of increased interaction taking place along a conceptual contact surface (membrane) between two differentiated patches promotes the conceptualization of these areas as territorial interfaces.

Although studies on natural ecotones has been quite extended the recent decades, the focus on urban ecotones has not received equal attention by any means, due to many inherent conceptual difficulties as well as increased complexity related with the subject. Researchers have tried to tackle the issue from different perspectives. Norman Long when speaking on *social interfaces* comments that although the word ' interface' tends to c*onvey the image of some kind of two-sided articulation or face-to-face confrontation, social interface situations are more complex and multiple in nature, containing within them many different interests, relationships and modes of rationality and power*[16]. And goes on to offer its definition: "*a social interface is a critical point of intersection between different life worlds, social fields or levels of social organization, where social discontinuities based upon discrepancies in values, interests, knowledge and power, are most likely to be located*[17]". Although Long is not necessarily making reference to concrete spatial entities/ situations his definitions could enhance / enrich our definition of ecotones, and urban ecotones in particular. We can then rethink of territorial interfaces in a renovated conceptual context as:

1. Interface as surface or conceptual membrane that transmits and receives information and energy/ material flows from contingent patches / biodomes.
2. Interface as indicator of territorial dynamics and change
3. Interface as a shared three dimensional space of interaction, communication and interchange resulting in increased diversity / intensity
4. Interface as a (territorial) instrument of reconfiguration, permitting the control of territorial dynamics and function to achieve desirable results and ultimately increased territorial efficiency.

Territorial efficiency as a collective contemporary challenge.
Indeed, if we are to measure the effectiveness of human stewardship over the territory, what elements would then need to be taken into consideration to make this consideration worthy. Most landscapes today can be characterized as anthropogenic, produced and maintained by continuous inputs of energy by humans on the territory, with diverse effects and consequences. If we are to think of the territory as a collective project, involving multiple actors and dynamics, a new term is needed to describe this synthetic vision. The term of territorial efficiency has been appearing in recent research, with different often sectorial manifestations like landscape efficiency or urban metabolism, but not as an integral notion that can encompass the complexity present on contemporary territories. A term for territorial efficiency should somehow incorporate the social capital incorporated and participating in the territorial morphogenesis; the organization schemes, policy and decision-makers and the capacity of planning and management to yield improved results and living conditions for dwellers and users of the territory.

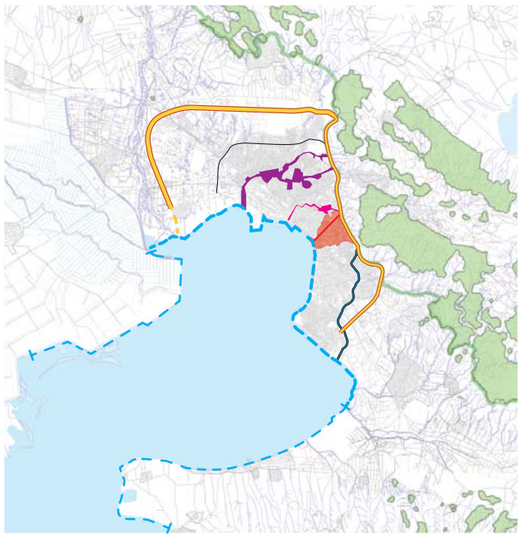
16. Long, N. (1999)
17. Long, N, (2001)

The city of Thessaloniki as a mirror of territorial phenomena
The case study of the urban region of Thessaloniki, situated in the gulf of Thermaikos in northern Greece presents many typical traits of a small metropolitan region with the multiplicity of forms and phenomena that characterize it; urban sprawl taking over agricultural land, a saturated urban centre, infrastructural development and concentration, diffused expansion of tertiary sector services on the outskirts of the city, all within a close distance to areas of high ecological value. The ecotonal areas in the case of Thessaloniki are presented with diverse characteristics, from the typical seacoast ecotone to the typical mediterranean zones of agro-forestal edges, or even between heterogeneous urban fabrics.

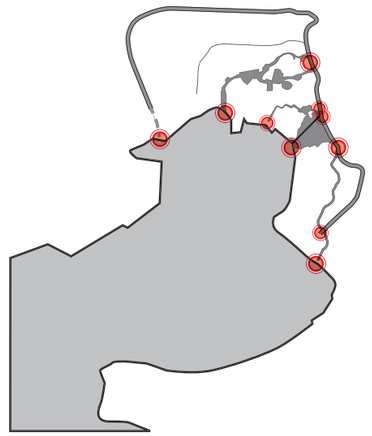
The city of Thessaloniki, traditionally the regional epicentre of activity, has a historical evolution connected with the wider development of the region and thus presents a rich and dense territorial mosaic full of references and connotations. Recent developments as well as plans in the region have opted for a simplified solutions for the territorial problems that resulted consequently in a degradation of its features and functioning. Current plans being revised at the moment, consider a important expansion of those limits, tipping the regional equilibrium towards the city of Thessaloniki, without paying the necessary attention in identifying and setting up a sound and coherent wide regional structure. The imposition of a typical metropolitan scheme on the existing regional fabric could have a considerable social-cultural and environmental impact.

Having presented the key concepts guiding and formulating the research perspective, the case study analysis is presented in detail in continuation, presenting respectively the six ecotonal areas under investigation within the urban region of Thessaloniki. The concepts and notions presented earlier will be present in the discourse and analysis developed throughout this paper.

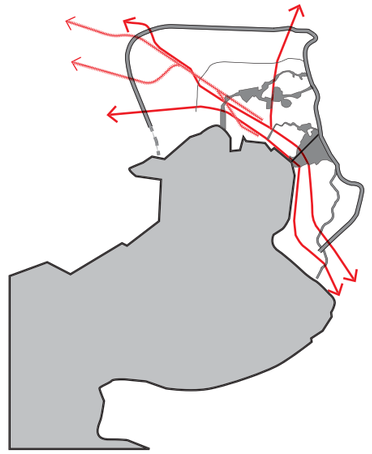
aerial



spatial structure



links



flows

V. Case study presentation: analysis - structure

The analysis consists of the investigation of 6 ecotonal areas in the Thessaloniki area. Each area presents its own intrinsic characteristics and developed distinct phenomenological and morphological traits over time. The first two ecotonal areas under investigation, are historic ecotones, focusing on the areas outside the city walls, the E-SE and *N-NW* parts respectively. The next pair focuses on subsequent city limits, associated with the industrial expansion and urban explosion of the urban fabric, and both related to a great extend with flood protection works realized on both parts of the city: the *Dendropotamos* stream on the west and the peri-urban canal on the east. Finally the last two ecotones have a more territorial scope, aiming to perimetrically enclose and complete the analysis structure: first the Ring Road infrastructure from the north and the seacoast - seafront ecotone accordingly from the south.

In each case the analysis will intend to follows a common methodological approach in looking at all six ecotones that is explained in the following section. The common thread is first looking at the origin of the emergence of the ecotonal area and the subsequent evolution patterns up to today, following a cartographic and morphological approach. In continuation the current conditions present within and the adjacent areas are analysed and registered concerning diverse aspects; from the existing and latent biophysical matrix to a combined analysis of the habitability - mobility - activity scheme, and a revision of past plans and interventions, The combined analysis permits to identify territorial situations, present and latent, through a phenomenological approach considering all the spatial and cultural layers present in the fabric The case studies are present briefly in continuation.

1. **Central Axis ecotone**
   The first ecotone in the analysis is the area formed in the area outside the SE-E walls. A wide ecotonal area with initially a historic character (city walls) has recently come to consolidate into a urban ecotone separating the historic centre (delimited by the city walls) from the eastern districts of the city, while simultaneously serving as a connector between the Seich-Sou forest and the seafront along the preexisting streams that existed in the area that indirectly served as limit lines for the formation of the area under analysis. The area currently holds quite a diverse and extended activity within its limits. This concentration of activities, especially those having a regional reach / influence gives the area a certain degree of centrality. The lack of coordination and shared planning has resulted in a great variability in activity intensity and the emergence of fragmented islets within the area.

2. **NW city walls ecotone**
   On the NW side of the historic centre and along the respective city walls another ecotone of initially historic character has formed, but with phenomenally distinct characteristics from the first case. The expansion of the urban fabric in the extra-mural area has given rise to the emergence of a narrow ecotone between the urban fabrics of the historic centre and the adjacent western districts. Starting at the Akropoli area, in close proximity to the Seich-Su forest, it makes its way downhill through a fabric dense with historic and cultural connotations, until it reached the *Top Hane* area next to the city port. The green areas adjacent to the city walls create a rudimentary corridor dotted with punctual facilities of urban /social use and a relatively low intensity of activity. The majority of the key historic / cultural monuments reside within the intra-mural area.

3. **West Arc ecotone**
   The next ecotonal area in analysis also resides in the western part of the city, this time formed along the *Dendropotamos* stream trail, before and after its diverse modifications (flood protection, cover up works etc.) that for certain time served as the western limit for the city, with many industries and other activities choosing to reside in this periphery. The subsequent urban expansion, especially after the 70´s, eliminated to a great extend this limit effect and soon consolidated the existing space into a dense but low-built fabric. The present day urban voids relicts of this past phase of urban explosion give testimony to the past activity present along the axis. These is a conceivable / legible corridor forming along what used to be the *Dendropotamos* stream, now found in diverse states, (open, covered, degraded ...) and its smaller tributaries. This is what is has come to be know as the West Arc though the various studies, connecting the Efkarpia peri-urban area with the seafront after crossing through diverse and distinct fabrics of western Thessaloniki.

analysis sequence

4. **Peri-urban canal ecotone**
The fourth ecotone lies on the east part of the city formed along the peri-urban canal constructed as part of the as flood protection infrastructure for the city and indirectly as a limit for the expansion of the urban fabric. Before the construction of the Ring-road it marked clearly the urban-periurban limit line on the eastern part of the city. After its completion, the area "trapped" between the two infrastructures has formed an ecotonal area of diverse characteristics and distinct from those encountered in the case of the West Arc. The canal also serves as a connector/corridor between the Seich-Su forest and the seafront of a key latent potential. The ecotone is characterized by a low intensity and the distinct uses on each of its sides.

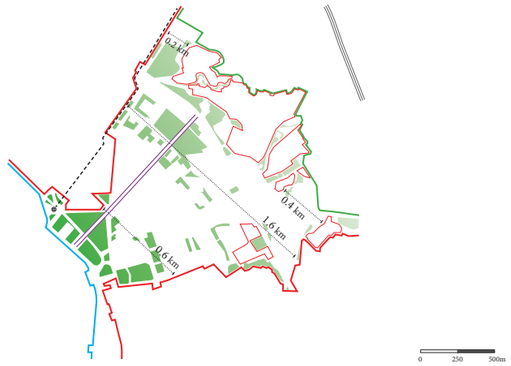
5. **Ring Road ecotone**
The fifth case is a contemporary ecotone formed along the completed parts of the combined exterior and interior Ring-Road and currently serving as the contemporary limits for urban expansion. The Ring road ecotone can be distinguished in three distinct parts: **i)** the western **ii)** the forest (Seich-Su) and **iii)** the eastern part, each of which present its own intrinsic characteristics, intensities and types of activity. The mobility advantage that the Ring-road offers has attracted the relocation of diverse types of activities, principally of bigger size areas and facilities, resulting in an increased rate of land consumption and fragmentation. The ring roads conceived and constructed as transport infrastructure never harnessed the true potential for structuring the peri-urban space of Thessaloniki. The ecotonal area along the ring-road is found in an unconsolidated state which makes even more urgent the investigation of past and current processed as well as dynamics and future tendencies.

6. **Seafront ecotone**
The last ecotone under analysis is the key ecotone by default for most mediterranean cities and that is the seacoast - seafront ecotone. A dynamic limit that fluctuates over time and has dictated human settlement patterns diachronically. Currently it is presented as a sharp limit line, an effect greatly due to the anthropogenic interventions along the coast and the degradation of wetlands and similar smoother transitional zones. The ecotone is of a territorial scale but can accordingly be divided into two subsequent parts, the urbanized part (from Kalochori to the Airport) and the Thessaloniki bay part. Today human presence and activity along the coastal ecotone is evident in most parts, except when occupied by infrastructure (airport, port) or areas of ecological interest, protected or not (Kalochori, Axios delta, etc.). Respectively, seen as a corridor there are certain discontinuities produced with respects to accessibility to/mobility along the coast mainly due to the formentioned infrastructural areas and a lack of a coordinated and integral plan for the seafront management.

As mentioned the sum of the six ecotonal areas completes a closed analysis structure that encompasses the entire Thessaloniki urban district. This inherently permits the identification of possible emerging networking possibilities in different respects: environmental, social, mobility etc. It also permits assess the different types and intensity of flows crossing these ecotonal areas, and understanding dynamics and tendencies present individually in each area, but also jointly for the extended urban region. This same structure will serve posteriorly in the conclusions section for realizing the synthesis of the analysis results. In continuation the 6 ecotones under analysis are demonstrated with a brief schematic representation and presentation of its basic characteristics.

ECOTONE ANALYSIS - Selected Case Studies

aerial view | **schematic view** | **info / description**



1. Central Axis ecotone

Origin / Type		*Spatial Structure*	
creation force	east city walls	stuctural element	zonification / fragmentation
time		(latent)	central axis
interaction	urban - urban	extend	1.6 km
edge activity	diverse	thickness (min/max)	0.5 - 1.6 km
character	historic / centrality	scale	local
		sharpness	sharp

2. West Walls ecotone

Origin / Type		*Spatial Structure*	
creation force	NW city walls	stuctural element	NW city walls
time		(latent)	-
interaction	urban - urban	extend	3.9 km
edge activity	cultural / social	thickness (min/max)	0.03 - 0.4 km
character	historic / social / intramunicipal	scale	local
		sharpness	sharp

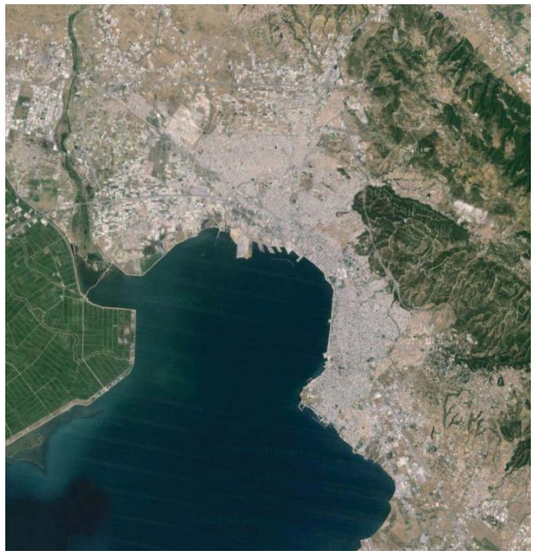
3. West Arc ecotone

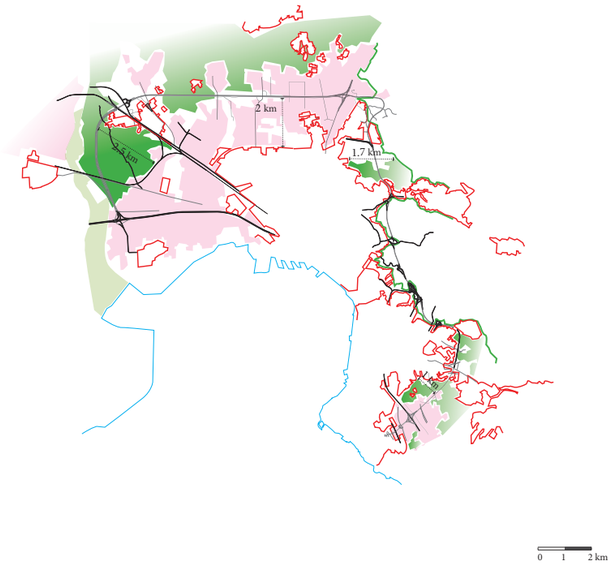
Origin / Type		*Spatial Structure*	
creation force	drainage works	stuctural element	-
time		(latent)	Dendropotamos trail
interaction	urban - urban	extend	7.3 km
edge activity	diverse	thickness (min/max)	0.05 - 0.7 km
character	urban / social / corridor	scale	local / regional
		sharpness	diffuse

aerial view | schematic view | info / description

4. East canal ecotone

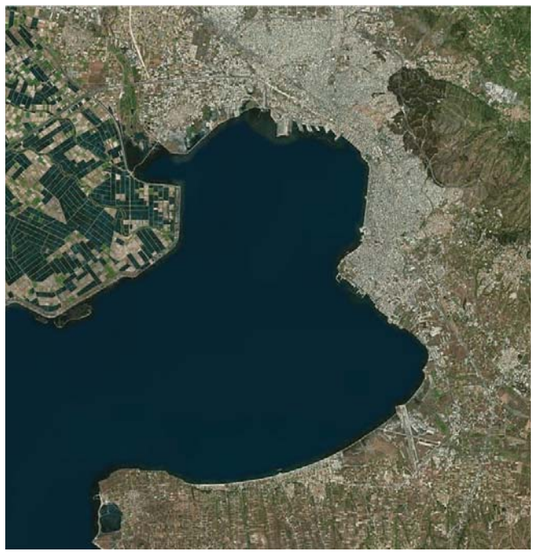
Origin / Type		*Spatial Structure*	
creation force	east periurban canal	stuctural element	
time	late 60s - 70s	(latent)	east periurban canal
interaction	urban - periurban	extend	7.7 km
edge activity	residencial / retail	thickness (min/max)	0.5 - 1.6 km
character	limit / interface	scale	local
		sharpness	diffuse

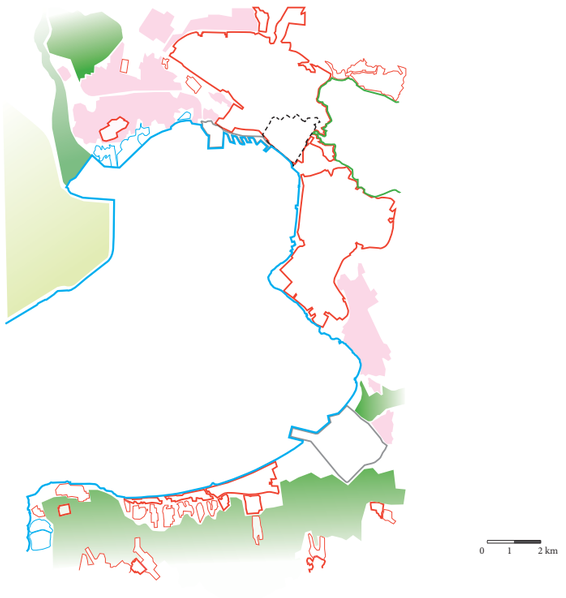




5. Ring-Road ecotone

Origin / Type		*Spatial Structure*	
creation force	interior exterior Ring Road	stuctural element	
time	late 90s - today	(latent)	Ring Road infrastructure
interaction	urban - periurban	extend	32 km
edge activity	diverse	thickness (min/max)	0.05 - ? km
character	contemporary / corridor	scale	territorial / regional
		sharpness	diffuse





6. Seacoast ecotone

Origin / Type		*Spatial Structure*	
creation force	hydrological processes	stuctural element	seafront line
time	-	(latent)	sea front activities
interaction	sea - terrestrial	extend	45 km
edge activity	diverse	thickness (min/max)	0.02 - ? km
character	default / corridor	scale	territorial
		sharpness	sharp

“Μα έτσι μονάχα, περιορίζοντας την απεραντοσύνη, μπορούμε, μέσα στα σύνορα του νεοτάραχου ανθρώπινου κύκλου, να δουλέψουμε.

Τί θα πει να δουλέψουμε; Να γιομώσουμε τον κύκλο τούτον με πεθυμιές, με ανησυχίες και με πράξεις, ν’ απλωθούμε και να φτάσουμε τα σύνορα, να μη χωρούμε πια, να ραϊζουν και να γκρεμίζονται. Έτσι δουλεύοντας τα φαινόμενα, πληθαίνουμε, πλαταίνουμε την ουσία.

Γι’αυτό, ύστερα απο την επαφή μας με την ουσία, ο γυρισμός μας στα φαινόμενα έχει ανυπολόγιστη αξία.”

Ν. Καζαντζάκης, ***Ασκητική***

But only this way, by putting a limit to the vastness, we are able, within the borders of the newly agitated human circle, to work.

What is it to work? To fill up this circle with wishes, concerns and deeds, spread out and reach the limits, not fit anymore, make roots and then crumble. Thus working with the phenomena, we multiply, we broaden the substance.

So, after our contact with the substance, our return to the phenomena has immeasurable value.

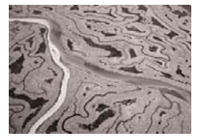
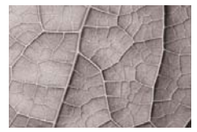
N. Kazantzakis, ***Askitiki***

Theoretical Background

Chapter contents

Hierarchy of ecological units for natural resource management

Hierarchy of demographic and functional organization

Hierarchy Level	Name	Planning and Management Area	Mapping scale (range)	Function	Demography	Physiognomy	
I	**Ecodomain**	*global biosphere inter-continental*	*> 1 : 20.000.000*				
II/III	**Ecoregion**	*continental / sub-continental*	*1 : 20.000.000 to 1 : 5.000.000*	**Biome**	Formation	Canopy form	
IV	**Bioregion**	*regional landscapes*	*1 : 5.000.000 to 1 : 250.000*				
V	**Landscape**	*sub-regional landscape ecosystems*	*1 : 250.000 to 1 : 25.000*	**ecosystem**	community	Life form	
VI	**Patch**	*ecosystem component*	*1 : 25.000 to 1 : 1.000*				
			1 : 1.000 to 1:100	**functional group**	association	Leaf group	
			1 : 1.00 to 1:10	**Species**	Individual		
					Propagule		
			10^{-10}	**Stomatal function**		Stomatal function	

grain

complexity

Theaters / Spaces of Hope (Harvey, D.)	Related / Nested Scales (Lefebvre, H.)
• **the moment of universality**	$G \{ g, m, p$
• **translations and aspirations**	
• **mediating institutions and built environments**	$M \{ g, m, p$
• **militant particularism and political action**	$P \{ g, m, p$
• **The politics of collectivities**	
• **the political person as social construct**	
• **the personal as political**	

g = global
m = mixed
p = private

Contemporary Regional Classifications (adapted by Neilson, 2006 & Brunkhorst, 2000)

The table above shows indicative regional classification used in contemporary literature, based on the different scales and focus. On the left the hierarchical framework of ecological units for natural resource management purposes, from global to local scales. While on the right, the **demographic hierarchy** is built from distinct organism and clusters of organisms. which are often mapped as communities, associations, or species. The function hierarchy on the other hand is more abstract and can include different kinds of organism. The correlation between the two hierarchies sugggest the presence of a third hierarchy, that of ecological response.

I. Contemporary Regional Classifications

Among the various types of regional classification that have appeared over the years, there seem to exist two typical methods of regional classification. The first type is the *formal* region, the other being the *functional* region[1]. The earliest definitions of the region were mainly based on the physical characteristics of the landscape, with early geographers believing that the survival of man was directly dependent upon his adaptation to the environment.

Thus geographers such as Herbertson, Unstead and Vidal de la Blache using criteria such as topography, climate, vegetation and population – divided, continents and countries into natural regions. All such approaches share as a philosophical basis the idea of environmental determinism[2], where the physical features and the climate determine, to a great extent, the pattern (structure), and functions of human settlements. The extent of man's occupation on the planet till today, particularly in the economically advanced countries, gave the impression that a never ending expansion and development with no apparent limits is possible. The limit to development, apparently, did not seem subject to nature's capacity but instead man's will. The present climatic crisis, problems of pollution and the rate of finite resource depletion are a result of this schism which divides nature and man. This philosophy undervalued the natural environment and consequently lead to its chronic over-exploitation. The impact of this exploitation extended beyond the 'natural world' to affect also human settlements creating socio-ecological inequalities. Soon, it became evident that it may be appropriate to give greater weight in the regional definition, to the physical environment and its ecology (*the biophysical matrix*), and in particular to the role of the environment in sustaining the local population, in order to maintain a more balanced relationship between a community and its local environment.

Later developments in the idea of the definition of the formal region included the analysis of economic activities, and certain activities such as industry or agriculture that were used as criteria for regional classification. In contrast to the formal region which is defined in terms of homogeneity, the functional region was concerned with areas which display an interdependence or interrelationship of their parts[3]. The functional region may consist of heterogeneous components such as cities, towns and villages but which are functionally related. The relationship of the parts is usually measured in the form of flows, such as journey-to-work, shopping patterns and bus services. The analysis of the functional region is mainly concerned with the movement of people, goods and messages. As such the concept of the functional region is important for any discussion of sustainable development, including transport planning, waste control, pollution and urban support systems such as food supply. Patrick Geddes, was aware of the importance of the interdependence of components within the region, with his famous diagram 'Place–Work–Folk' and his phrase ***City Region*** illustrating perfectly this understanding. In Europe, at the same time Christaller developed his Central-Place theory based upon a hierarchical relationship between centres in southern Germany.

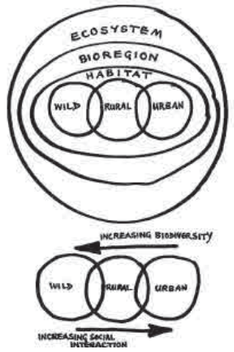
Following on the idea of the formal region, the *ecoregion* concept, specifically highlights biological distributions over a large area[4]. The ecoregion is a large unit of land and water typically characterized and delineated by climate, geology, topography, and associations of plants and animals[5]. Hence it divides the land surface biophysically rather than by political boundaries. It also has been used for planning and conservation by various agencies worldwide. But in general, ecoregions are unfamiliar and difficult to grasp for policy makers and the public. Normally urban regions are much smaller than an ecoregion, though the location of an urban region may have considerable impact on processes across and outside a given ecoregion.

The idea of linking the bio-physical and cultural/mental dimensions in regionalism (*the formal and the functional*) is well-illustrated and strengthened in literature and art with numerous examples like the English poet Wordsworth or Henry David Thoreau and New England. This way of integrating the geographical terrain and the terrain of consciousness in a common narrative gave birth to the idea of *bioregionalism*, that came to bridge the two. Usually, a major hydrological drainage basin delimitates the bioregion, while one portion of it is occupied by the inhabitants who sink in over time. As a place-based sensitivity, the meshing of ecology and culture at this spatial scale provides the bioregional dimension, usefully grounded between local culture and a global outlook[10]. The bioregion concept found an apt application in the case of the city and its region, where a culturally and economically diverse population congregates in one spot, to produce a diverse range of activities and artifacts. In that case, is its sense of place the City, or is it the city with its surroundings? In a place-based bioregion, care and attention to the region is fundamental and the analysis of the intertwined threads of culture and ecology run deeply in both space and time. What is a bioregion? How is its boundary defined? There is no easy or universally accepted answer to these questions. A start can be made with the definition of Mumford about the concept of the region, that says[6]:

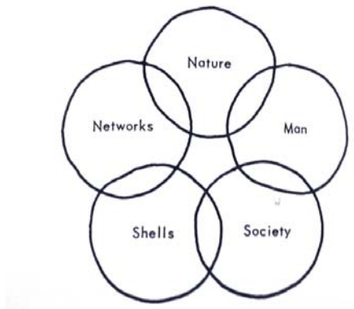
> *"The human region, in brief, is a complex of geographic, economic, and cultural elements. Not found as a finished product in nature, not solely the creation of the human will and fantasy; the region, like its corresponding artefact, the city, is a collective work of art".*

1. Moughtin (2005)
2. Ibid.
3. Williams (2007)
4. Forman R.T.T. (2008)
5. Bailey, R.G. (1996)
6. Mumford, L. (1938)

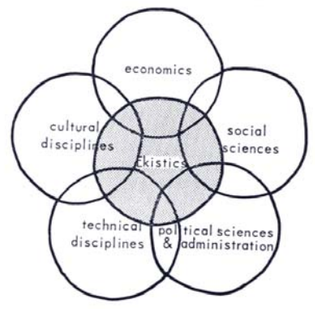
nesting of scales
source: Downton, P.F. 2008)



ekistics & society
source: Doxiadis, C. A. (1968)

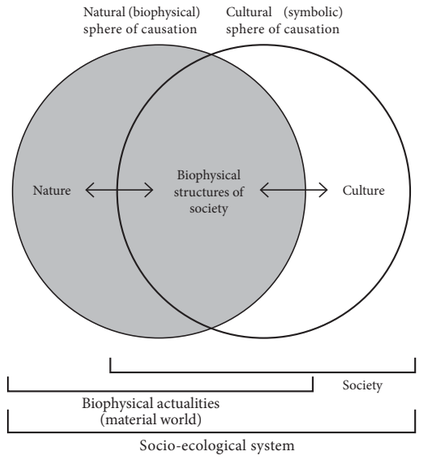


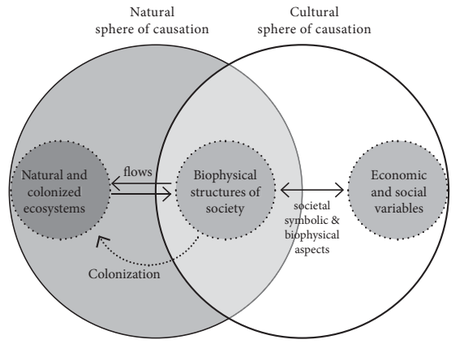
The goal of Ekistics is to achieve a balance between the elements of human settlements



Ekistics and the sciences directly contributing to it

biophysical structures of society
source: Tello, E (2012)





In terms of regional size and boundary definition, Mumford recognizing the organic in nature, is circumspect; he recognized the disappearance of the boundary between the inner and outer, the conscious and unconscious, the external and internal. Later, he applies this organic way of thinking specifically to the natural region who unlike the old-fashioned political areas they have not, except in isolated cases, any definite physical boundaries. The region he claimed may be defined and delimited in theory, but more for practical reasons. As far as regional size is concerned, Mumford says:

> *"In conceiving of a region, then, it is necessary to take an area large enough to embrace a sufficient range of interests, and small enough to keep those interests in focus and to make them subject to direct collective concern"*[7]

Recent writers became divided on the nature of the bioregion[8] . One school of thought saw natural regions as a series of nesting bioregions while others see them as a series of overlapping functional regions. Brunkhorst for example supports the idea that natural forms, whether they are coastlines or organisms, reflect miniscule, self-similar building block, the basic elements of form that are called *fractals*[9]. Fractal geometry is based on the relationship between form and its elementary building block. He suggests the following regional ecological framework, starting at the largest unit the *Ecodomain* or the global biosphere; the *Ecoregion* level at the scale of the continent or sub-continent; the *Bioregion* or the large regional landscapes; the Landscape or subregional landscape ecosystem; and finally the smallest building block, the Patch or the ecosystem component. This size classification is quite dominant in current scientific bibliography and is the one that will also be used for the purposes of this paper.

This view of a system of nesting ecological units, is nevertheless not universally accepted as being practically useful by people active in ecological planning. The concept of overlapping and fluid boundaries represents the actual state of ever-changing ecosystems as opposed to rigid human constructed boundaries. Such type of boundaries may be an impediment to a true analysis of the relationship between man and his use (or abuse) of regional natural resources. In order for a bioregional plan to be truly effective it must be based on some kind of boundaries that reflect the transient realities and characteristics of the ecosystems. It sets out by mapping critical issues of sustainability such as water, energy, waste treatment or those factors considered to be limiting systems in the region. The use of Geographic Information Systems (*GIS*) today makes it now possible to map these crucial systems separately and analyze areas of conflict as well as potential synergies.

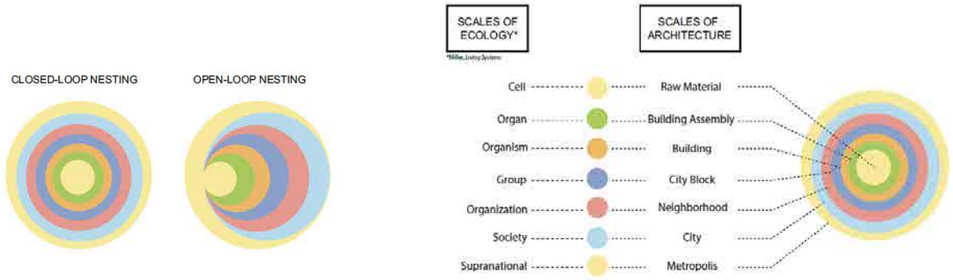
Despite differences in approach, in general terms bioregional planning begins from a different premise from that of conventional planning. In conventional planning the process for choosing between potential regional developments is regulated according to the best or most economic use of land, accommodating growth in the sense of transforming nature, and accommodating for some nature conservation if the price is acceptable or if it is politically expedient. In contrast, bioregional planning starts from, "*. . . the recognition that humans are biological entities who need systems for living in that are designed to meet their cultural, economic, and physical needs, and also in ways that foster symbiotic relationships with complex ecological systems in the bioregion. Human cultures have co-evolved with and out of nature, a relationship which has been integral to both human survival and biological evolution. Therefore, lifestyles, cultures, industry and even systems of regional governance are rooted in and should conform with, the natural conditions of the region* [10]".

Bioregionalism as an idea and an ideal plays an important and supportive role in the regional theory and its further evolution, but at the same time it needs to be considered from a critical viewpoint. It appears that an overexaggerated sense of place can give way to social pathologies, especially when allied to proprietary and authoritarian power structures[11]. The capacity of an ecological world-view to counter this tendency must be critically considered. It is difficult to neglect residual concern regarding the use of cultural regional concepts as the basis for planning, something that seems inherent in bioregionalism. But the same time, it embodies the ideals of decentralization and biospheric responsibility associated with more integral and considerate outlook.

Almost by common agreement, the region is seen as a flexible concept and its size and boundaries vary according to its purpose. Any regional system of government, therefore, will might present some anomalies given that for a good governance fixed boundaries are necessary, and for continuity purposes they should have a degree of perma-

7. Mumford, L(1938)
8. Moughtin, C. (2005)
9. Brunckhorst, D. J. (2000)
10. Ibid.
11. Downton, P. F. (2008)

synchronized scales
source: Petia Morozov, (2003)



The Ekistic grid
(source: Doxiadis, C. A., 1968)

COMMUNITY SCALE		i	ii	iii	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
EKISTIC UNITS		ANTHROPOS	ROOM	HOUSE	HOUSE GROUP	SMALL NEIGHBORHOOD	NEIGHBORHOOD	SMALL POLIS	POLIS	SMALL METROPOLIS	METROPOLIS	SMALL MEGALOPOLIS	MEGALOPOLIS	SMALL EPEROPOLIS	EPEROPOLIS	ECUMENOPOLIS
EKISTIC ELEMENTS	NATURE															
	ANTHROPOS															
	SOCIETY															
	SHELLS															
	NETWORKS															
SYNTHESIS: HUMAN SETTLEMENTS																
POPULATION T (Thousands) M (Millions)		1	2	5	40	250	1,5 T	10 T	75 T	500 T	4 M	25 M	150 M	1,000 M	7,500 M	30,000 M

nence[12]. The concept of a regional boundary *per se* for administrative purposes should raise governance related questions within the context of sustainable development. As far as sustainable development in rural areas of the bioregion, they are not to be considered in isolation from the total rural and urban settlement structure. The purpose of the rural hinterland as seen by traditional models is to service the urban settlements while an ecological outlook would emphasize sustaining the biosphere of which human beings and their settlements are a part of and giving an added value to open non-urbanized land as key element of the biophysical matrix. The sustainable settlement is the one that is in ecological balance with the regional territory on which it is located. That is, the ecological footprint of the city and the boundary of its hinterland are coterminous. Sustainable design at the regional scale begins with gaining a working knowledge of the ecological system at that larger scale. It is also at this scale that the relationships, interactions, and interdependencies between the three elements of sustainability (economic, social, and environmental) can be recognized and established. Urban and regional planning practices that incorporate ecological thinking can lay the foundations for a community, and an economic and environmental sustainability. The scales inherited in the concept of bioregionalism are a vital part of the sustainable design process. According to Williams, D.E this design process should incorporate the following three steps in its methodology[13]:

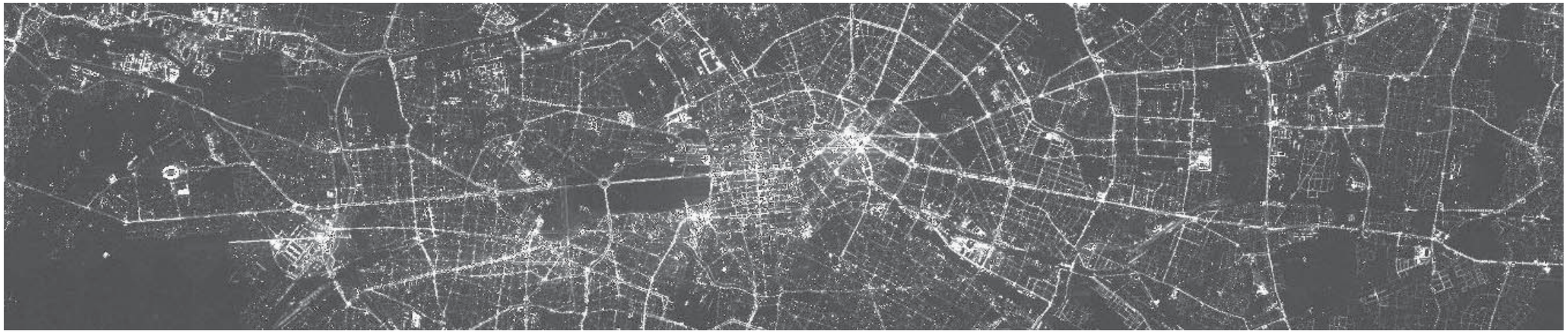
1. Bioregionalism involves researching and understanding the natural system at a scale larger than the project scale and applying that bioregional knowledge (in climatology, biology, soil science and ecology) to the interaction of the various urban components.

2. Incorporation of the free work of the natural systems including the ecology, biology, physics, climate, hydrology, and soils of the region, using natural processes rather than technology, for water storage and treatment, for microclimatic control, and for the establishment of local and regional resources use, reuse, and recycling.

3. Respectively an Biourbanism involves designing the connections to make use of place-based energies and resources and integrating them into the urban and community scale.

As commented, design and planning at the regional scale can have the greatest impact with regards to these general goals. The layout of utilities and infrastructure, power production decentralization, mobility, zoning ordinances, the existing biophysical matrix, all present multi-criteria conditions for sustainable development[14]. Contemporary urban phenomena put such type of development under serious test. For example urban sprawl, leads to a greater dependence on automobiles and insidiously increases pollution, consumes prime agricultural land and critical ecological areas, ultimately reduces time and space available for activities that increase the quality of life and thus of the territory. These losses are a direct result of zoning codes informed solely by real-estate values and unaware / insensitive to local particularities and necessities. This planning, or rather lack of quality planning, is no longer acceptable due to the rising energy consideration, pollution and environmental degradation associated with urban development and all the collateral phenomena that it entails.

12. Williams, D. E. (2007)
13. Williams, D.E. (2007)
14. Ibid.



II. The Urban Region under a contemporary spectre

"The second generation of ecological design must effectively weave the insights of literally dozens of disciplines. It must create a viable ecological design craft within a genuine culture of sustainability rather than getting entangled in interdisciplinary disputes and turf wars. It is time to bring forth new ecologies of design that are rich with cultural and epistemological diversity.[1]"

The urban region is a distinct and increasingly important type of region. In most cases a single major city is of central importance and all surrounding land is closely linked with the city in some way. The predominant role of the city is the main difference between an urban region and a geographic region. An added cultural dimension is also present in an urban region[2]. Typically an urban culture exists in the city, promulgated by a particular population formed by and committed to city life. People of an urban culture can move rather seamlessly from city to city, where they may thrive and contribute. However, normally people/residents have little commitment to the urban region surrounding the city. A sense of place, either for a particular city or its urban region, may be limited, and usually that is the root of many contemporary urban problems[3].

A city is not a discrete object , although ancient walled cities could be described as objects clearly bounded and defined. Cities are part of a regional network of parts and processes that procure, manage and distribute resources for the mutual benefit of their inhabitants. Consequent land-use patterns express the city-region morphologies and processes, the transformations over time[4]. As we have seen, with their biotic and abiotic components, cities are in reality constructed ecosystems that have some of the characteristics of organisms. It has been demonstrated that city-making, with all related processes, creates the greatest human impact on the biosphere. As part of evolving the extended phenotype of our built environments so as to sustain our species survival, it is logically necessary for us to make those constructed ecosystems contribute to the ecological health of the biosphere. Thus for ecological balance to be achieved, the urban systems need to be consciously integrated into the processes of the biosphere in order to optimise the overall functioning. Achieving this goal though, depends greatly on the sociocultural processes that are politics.

1.Van der Ryn, S. & Cowan,S., *(1996)*
2. Forman (2008)
3. Forman (2008)
4. Downton (2008)

Adopting features from both systems of geographical classification (formal & functional) may prove necessary for thinking of a political structure which can give legitimacy and potential to programmes for balanced local development[5]. Since Geddes first coined the term *city region* the concept has become a part of the planner's language, used frequently by many authors. Howard's earlier idea of the Garden City, as seen, was in effect a proposal for the management of the city region, comprised of clusters of cities linked to each other and to a central city by a carefully and strategically designed transport network. The basic idea was the development of a functional arrangement of settlements with clearly defined physical identity but with social and economic interdependence. It is ideas such as the city region which hold out a prospect for managing some aspects of a sustainable urban environment, such as its transport network. Clearly the city region would be the polity responsible for the management and development of the transport system. This would include achieving the balance between different modes of transport and the relationship between public and private provision. The management of transport at city region scale facilitates the implementation of innovations such as regional, annual and family ticketing of public transport, and the coordination between different transport modes. Proposals such as these would, of course, involve a radical re-thinking of current transport patterns in most urban regions with greater emphasis being given to public service rather than private gain (in the transportation sector.)

The Size of the Urban Region.
Urban regions house more than half of the world's population, approximately a staggering amount of three billion people, and at the same time are ground for many problems characterizing urbanity, whether of socioeconomic character, or of ecological one, or a combination of all. Yet a city's urban region is a useful scale for addressing such problems and offering solutions that can have a lasting effect. Cities usually grow in population, today commonly at a 3-5% annual growth rate, with some cases growing at an annual rate of 5-10%[6]. With cities occupying the major portion of urban regions, many of these trends also apply widely to urban regions.

A debate on regional government often returns to the question of the correct or appropriate size for a city region. The answer that seems to prevail in current thinking is that there is not one correct size for a city region. Aristotle in *Politics* was far more circumspect when discussing city size. He said: ' . . . *ten people would not make a city, and with a hundred thousand it is a city no longer*'. His idea was that the city should

5. Ibid
6. Forman R.T.T, (2008)

left: Berlin (source: Google images), **right:** Chicago (source: here.com)

be big enough and self-sufficient enough for its citizens to lead a good political life. It should, however, not be too big for citizens to lose personal touch with each other and perception of the larger whole[7].

The discussion about city size has changed considerably since the times of Plato and Aristotle. Writers and planners deliberating about ideal city size tended to increase its size as the twentieth century developed. Howard, at the end of the nineteenth century, was suggesting satellite cities of 32.000 and a central or core city of 58.000 people. The planned sizes of new towns built after the Second World War were increased progressively from 50.000 to 250.000. While arguments about the ideal size of cities have occupied the minds of some scholars, cities have grown at a very rapid rate, many times surpassing planning and administrative developments, so that many cities having a multimillion population are now common worldwide 93. Lynch sums up the position on city size concisely[8]:

> *The concept of a limit size is of course an integral component of the organic model. Arguments of optimum size are based on its effects on social intercourse, on political and social control, on the vitality of the environment,etc [...] Unfortunately, the evidence that there is a* ***general optimum city size*** *is weak indeed [...] Many effects that we attribute to city size are more correctly associated with the* ***general density*** *of a city [...]. There are modifications to this question [...] any single city can might have an optimum size, based on its geography, culture, economy, political system, way of life etc. [...] most likely if a basis for optimum size can be found, it will be in the form of a series of sizes, for different functions and especially for the different preferences of residents for such dimensions as identity, access and control."*

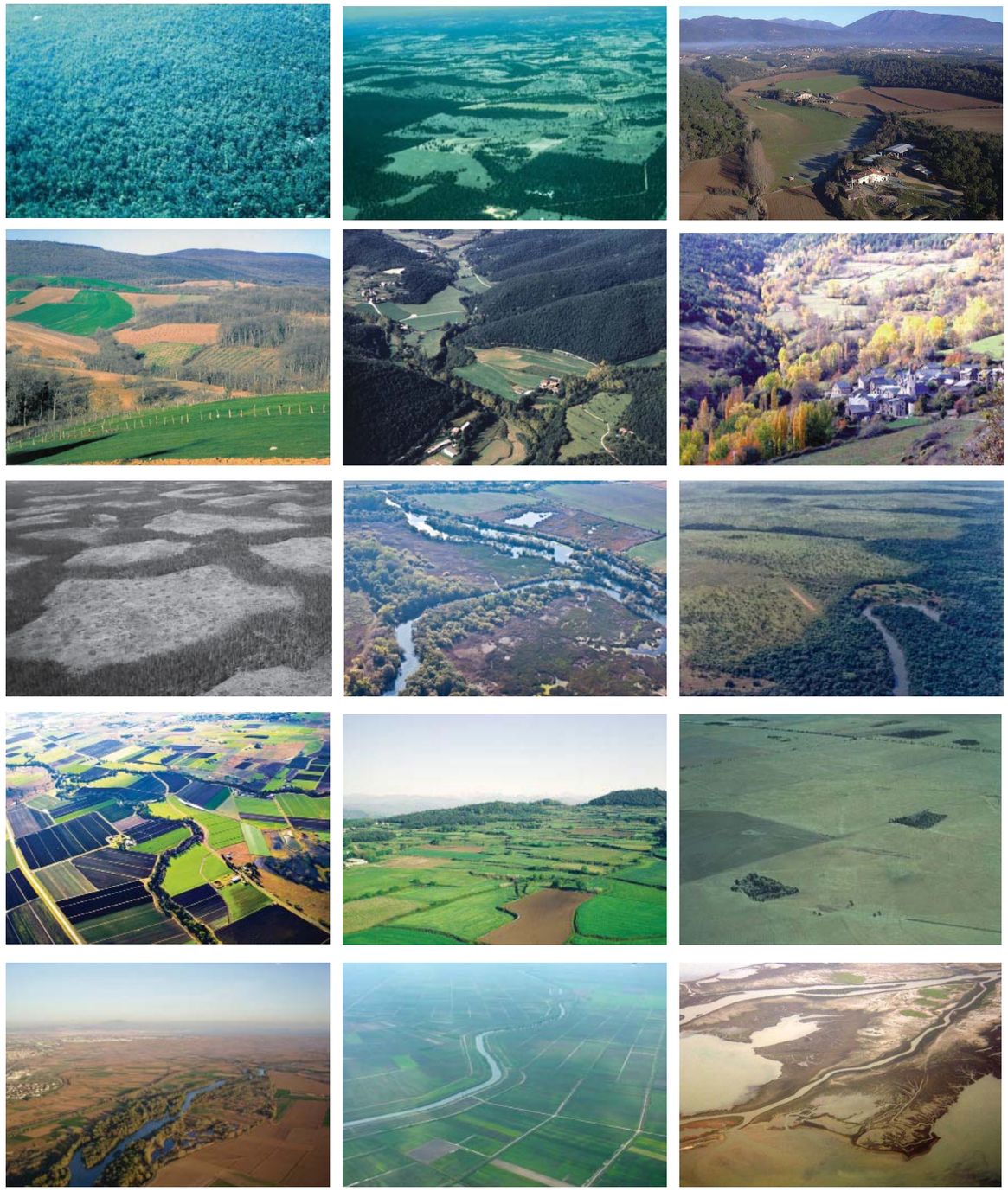
It is not the aim here to dispute this view, but instead enrich this view, adding a new dimension to the discussion. The city region appears to be the most appropriate structure for the delivery of some of the aspects of sustainable development. The size of the city region to some extent appears to be less relevant. The flexible proposition suggested by Aristotle to determine city size may well be appropriate today for the city region: it should be big enough and self-sufficient enough for the citizens to lead an active political life. "More important than crude size is the population's sense of belonging to the place and to a particular polity, so that meaning is derived from citizenship"[9]. The other important aspect of Aristotle's prescription for the good city would be the inherent feature of political life in the neighbourhoods / district lievel through the work of local citizen agencies and participatory mechanisms.

So, focusing the lens on patterns and processes within an urban region reveals a dynamic mosaic of people and natural processes. Nature on a territorial scale, shows heterogeneity, a great variation varying from large natural areas to multiple dispersed units. Society in the same manner is arranged in a single huge central agglomeration plus numerous and dispersed ones. The urban region can be seen as a system, with flows and movements across its mosaic. This greater mosaic changes over time, especially as human presence expands and natural elements shrink or go extinct, leaving nature further degraded, and the fundamental human dependence on nature's resources riskier and ultimately less sustainable[10] .

Concepts concerning regionalization and network cities will never succeed without clear concepts and strategies concerning the meaning of the region for the development of the present and future civic society. The only way that urban regions can become sustainable is if they succeed in being recognized as a relevant domain for the identity of the civic society[11], meaning that spatial elements should be designed and developed so that they can play a role as carriers of a collective identity at the regional scale.

In the process of developing a new practice of design and planning at the regional scale, the big question is to find the most relevant regional context and the way to develop a coherent policy, together with the numerous regional public authorities. Regional coherence supposes not only a spatial concept of a region, but also a political consensus in the region itself, and a regional identity, the identification of the people with their region. These three elements spatial - political - mental play an important role in the process of regionalization and are strongly interwoven[12]. The regional authorities can and should take the lead in regional spatial developments, since it has become clear that the big cities themselves are the only institutions with enough power to take the lead in the planning for a new regional coherence. However this development is possible only if the cities do not abolish their expertise and skill in planning and design on a regional level.

7. Moughtin , C.(2005)
8. Lynch, K. (1984)
9. Downton, P.F. (2008)
10 Forman (2008)
11. Meyer, H. in Rosemann, J. (2007)
12. Ibid.



Territorial Continuities
Diverse examples of territorial continuity
(sources: CREAF, Google, Generalitat de Catalunya, airphotos.gr)

III. Greenspaces and natural systems as regional infrastructure

The term ***natural systems*** refers to elements related to nature and natural processes, focusing principally on its structure, functioning, and dynamics (change). Nature, in all its manifestations, presents some form or anatomy[1]. Nature functions regularly, as energy, material, and species flow and move throughout the territory. And Nature changes and evolutions both its form and functioning over time based on relative inputs and outputs. The concepts of natural area, natural habitat and natural land denote a specific type of space, almost utopic, untouched or with small intensity of human impacts. Today almost all territories are to some extent anthropized, that is to say modified and adapted by human. At least that is the case in the western context. Only remote areas or areas of great importance are often salvaged in the process. To enhance readability of the mosaics semi-natural areas are commonly lumped under the term natural area or natural land. Thus a wood lawn area, same as a mowed grassy space often with scattered trees and shrubs, (e.g. a golf course) or a city park, although not natural area are considered to serve similar, although adopted purposes.

Greenspaces are thus the unbuilt areas in a region or an urban region of a considerable extend that can present continuity or not and contain / host different types of human activity. Key greenspaces can be parks, sport fields, wetlands that reduce floods, nature reserves that protect biodiversity, tree corridors and peri-urban agriculture that produces fresh vegetables and fruits in proximity to the city[2]. Greenspaces can range in size and form, from small city parks to extensive woodland landscapes, and from rounded spots to linear greenways and river corridors. Greenspaces, may or may not be protected or and may or may not have public access and use. Greenspaces exist and affect nearby built areas whether residential commercial, or industrial. In the majority of cases when handled adequately vegetation can have a positive impact and for this reason the relation of greenspaces and built areas is an important and useful element for planning and ultimately the functioning of cities.

An infrastructure powered by natural energies, that is to say a green infrastructure, can provide environmental services such as flood and coastal protection, climate control,air and water purification, aquifer recharge and quality landscapes among others. The preservation and protection of these areas and their natural functions add economic value to the land[3]. The preservation of natural territorial processes should be in the foundation of every region's planning processes emphasizing its importance for biotic and human activity. Maximizing the interconnections between the two realms is an essential step in the development of a territorial culture but at the same time of a sustainable economy[4]. The entire system tends to suffer, demonstrating stress symptoms when too many resources are taken away from the system (e.g., energy dissipation, reduction of wetlands and trees, destruction of soils, loss of biodiversity) and

1. Forman (2008)
2. Ibid.
3. Williams (2007)
4. Ibid.

too much returned (sewage, discharge and degraded energy) at a too fast of a rate to be assimilated. In a natural system, this stress can be recognized and is measured by decreased diversity, increased air and water pollution, etc. At the same time there is the theory / hypothesis of the ***intermediate disturbance***, that claims that species diversity thrives at an intermediate level of human settlement / intervention[5]. Nevertheless, and far from this hypothetical equilibrium it is a fact that the natural capital of cities worldwide is declining, creating a collateral stress on the human economic and social systems[6]. We can hardly speak of boundaries to the city when all the constrictions on the urban dimension imposed by its own territory have been hypothetically removed by technological surrogates and the importing of resources from far by regions without any constraints apart from economic restraints. Modern environmental outlook has oughtfully set out to re-propose the limits and boundaries necessary in planning practices. Maybe out of an inherent need to explain and at the same time propose alternatives to the potential and imminent technological failure facing humanity, or the intrinsic human need to delimit its region, give it a purpose, explain it and plan it out accordingly.

All types of regions more or less share a common type of internal ***structure***. In the diversity of types of landscapes found in contemporary territories, from suburban developments to forested extensions, industrial areas to peri-urban croplands, in any case there is an inherent structure, a manifested spatial arrangement and organization that is key to understanding the region´s ***function***. In addition, many processes, natural and human generated, tie these landscapes together. The linked landscapes work as a region, and are occasionally planned as a region. A region is larger and inherently more stable than a landscape within it. Therefore planning a region as a sustainable environment or place provides a higher probability of achieving success[7].

The ***land-mosaic perspective*** has emerged out from landscape ecology and related fields in the past couple of decades. It provides a coherent body of theory and principles focusing on the spatial arrangement of land uses for meshing and sustaining both natural systems and people. Like most living organisms, the landscape exhibits three broad characteristics, structure, function, and change. Landscape structure or pattern is simply the spatial arrangement of the elements present, that is the distribution of natural areas and human related land-uses. Landscape functioning accordingly makes reference to the dynamic element; the flows of water, materials, information, species, and people throughout this spatial pattern. Lastly, **change** refers to the manifested dynamics or transformation of the pattern over time, a slideshow of historical sequential images seen consecutively. Methodologically speaking, the mosaic structure (pattern) may be modelled or understood utilizing solely three main types of elements:

5. Marzluff, J. M. (2005)
6. Williams (2007)
7. Forman (2008)

i) *patches* **ii)** *corridors* and **iii)** a background *(matrix)*.

These three structuring elements are the universal elements and the handle for comparing highly dissimilar landscapes and describing basic landscape principles[8]. This *patch - corridor - matrix* model is also the handle for land-use planning, since spatial patterns strongly influences movements, flows, and changes of both natural systems and people[9]. The simple spatial language is further highlighted when considering how patches, corridors, and the matrix combine to form the variety of existing land mosaics on Earth, existing or planned. The matrix finally can be single or subdivided, variegated or relatively homogeneous, perforated or dissected. These spatial descriptors are common dictionary definitions and familiar to most researchers and designers in the field and will accordingly be utilized by this paper. Accordingly in recent research of landscape / ecological studies a number of related topics have emerged with regards to spatial patterns of living organisms, are shown in continuation[10] :

A. **Patch size & heterogeneity**:
In general, larger more heterogeneous patches support more species.

B. Habitat connectivity:
Connectivity is a scale-dependent, threshold phenomenon.

C. Effects of landscape context:
Characteristics of the surrounding landscape can strongly influence local populations.

D. Ecotones & effects of boundary shape:
Shape of boundary can influence species' relative abundance.

Patches.
Territorial patches are volumes that can be distinguished compositionally, structurally, or functionally from adjacent volumes at given scales. The conception of a patch is to a great *extentintuitive*; most people seem to understand and agree on what constitutes for example a patch of forest. Forman and Godron defined a patch as "*a nonlinear surface area differing in appearance from its surroundings*"[11]. Patches do

8. Forman (2008)
9. Ibid
10. Turner et al, (2001)
11. Ibid.

tend to exhibit a degree of isolation, the effect varying depending on the factor under consideration. Early ecologist thus initially and naively considered landcape/habitat patches analogous to islands, only to soon discover the fallacy of this hypotheses[12].

The key formal attributes of patches can be large or small, smooth or convoluted, round or elongated, few or numerous, disperse or clustered, and so on. When analysing patches in contemporary analysis they tend to be described / categorized in terms of[13]:

i) size (*large / intermediate/small*)
ii) number (*numerous / scarce*)
iii) location (*beneficial / deleterious*)

The definition of the patch in each case is question / parameter depended: if the investigation focuses on forest fragments, then the landscape can be divided into patch types that are forest and those that are nonforest. The patches defined as forest are assumed to be structurally similar and to contrast with the structure of patches defined as nonforest. However, the forest patches are not necessarily internally homogeneous in terms of characteristics such as tree density or species composition[14]. According to Dramstadt et al, there are respectivelly four origins or causes for the emergence of vegetation patches[15]:

- ***remnants*** (of more extensive patches)
- ***introduced*** (small pasture withing a forest, a new residential settlement)
- ***disturbance*** (forest fire, windstorms etc.)
- ***environmental*** resources /functions (oasis in a desert)

Patches can be discerned accordingly at different scales[16]. Ultimately, as mentioned what constitutes a patch is determined by the research question in play and is based on characteristics perceived or postulated to be relevant to the answer. Because patch delimitation is guided by questions, different questions can result in different patch arrays, even for the same physical space[17].

12. Dramstad et al (1996)
13. Turner et al, (2001)
14. Cadenasso et al, (2003)
15. Dramstad et al (1996)
16. Cadenasso et al, (2003)
17. Ibid.

Corridors & Connectivity

Corridors accordingly can be narrow or wide, straight or curvy, continuous or disconnected, etc. Corridors are relatively narrow patches of land that connect similar patches but that differ from the surrounding matrix. They have been identified in conservation plans as a means of maintaining connectivity between otherwise isolated patches of habitat. As noted corridors are appealing in a patch-based view of the world in which habitat is either suitable or unsuitable where corridors provide a physical bridge linking islands of habitats. At the planning stage, it was assumed more than 30 years ago that isolated reserves, independently of how well they are designed and managed, are unable on their own to conserve all components of their biodiversity or to meet other important ecological and social functions[18]. The presence of corridors is assumed to increase population persistence by providing for an exchange of individuals among a population that was previously connected but that is now fragmented[19]. However, there has been much controversy regarding their effectiveness as far their effectiveness is concerned.

> *"In landscape systems, corridors create connectivity between different habitats. A system of corridors can lace together two distinct ecosystems, or two pursuits such that the impact of one on the other is not purely incidental. "Channelled movements of matter that are spatially differentiated from an adjacent static area may produce or maintain an observable corridor. Here, movement of objects is greater within a strip than in the surroundings. [...] Corridors in the landscape are "strips that differ from their surroundings; (and they) permeate the land."They are movement paths for species, for water, for wind, for material of the landscape. They exist as qualitatively different zones of conduit that connect two ecosystems, end to end. But in addition to connectivity, they also provide distribution as they open up their contiguous surroundings to the stuff that is moving within them, whether species, air, information, or creative practices[20].*
>
> Richard T. T. Forman

Functional corridors may not necessarily be discrete structures. Past research has simulated dispersal and patch colonization on heterogeneous landscapes and identified the regions of the landscape in which flows were funnelled and that, therefore, functioned effectively as corridors. They found that in some cases actual "corridors were diffuse and difficult to identify[21]. Reduced contrast between habitat patches and the intervening matrix may enhance connectivity more than would a discrete typical corridor. Evaluating the actual effectiveness of a linear habitat patch as a corridor requires a three-step evaluation of whether organisms can find, select, and successfully move through the patch. Enhancing our understanding of how organisms move through heterogeneous landscapes (along corridors or through the

18. Pino, J. & Marull J (2012)
19. Turner et al, (2001)
20. Forman R.T.T., (1995)
21. Turner et al (2001)

matrix) is a key component of understanding the responses of organisms to spatial pattern[22]. According again to Dramstadt et al, the corridors have 2 basic controls / indicators: ***width*** and ***connectivity***. Accordingly they are attributed five major ***functions***[23]:

i) habitat **ii)** conduit **iii)** filter **iv)** source and **v)** sink

and respectively based on the degree that they fullfill the above functions they can be categorized in two broad categories[24] in terms of their ecological functioning:

biological corridors - a lineal element of the landscape with limited width with the function of canalizing flows (of energy, material, information) adapted to the presence and conditions of the corridor. These corridors are more vulnerable to perturbations that can alter their structure or continuity.

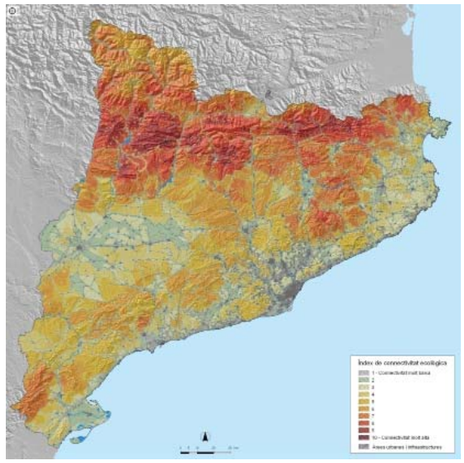
ecological corridors - the second concept of the corridor, amplifies that of the earlier category in two important aspects: **i)** its larger dimensions and **ii)** its general objective of permitting diverse flows both biotic and abiotic. Thus these corridors provide habitat, and more specifically multi-habitat for diverse species. They constitute landscape elements much more strongly pronounced territorially speaking.

Landscape connectivity is generally accepted as a highly significant landscape attribute for conservation biology, as it enhances population viability and species richness; thus setting up habitat corridors has been a classic approach to landscape connectivity management that has been advocated as a key conservation strategy in human-modified landscapes where urbanization, infrastructure development and other activities frequently sever natural connections[25]. Indeed, connectivity stands out as being one of the most widely used metrics of landscape function. Some authors consider it a single attribute while others tend to distinguish two aspects: ***connectance*** and ***connectivity*** [26], where the former refers to connection from a structural point of view (based of physical attributes), while the latter describes functional aspects of the connection between landscape elements, such as patterns of organism movement and migration, or the response of organisms to the presence of barriers. For many species, connectance and connectivity are indeed quite distinct[27].

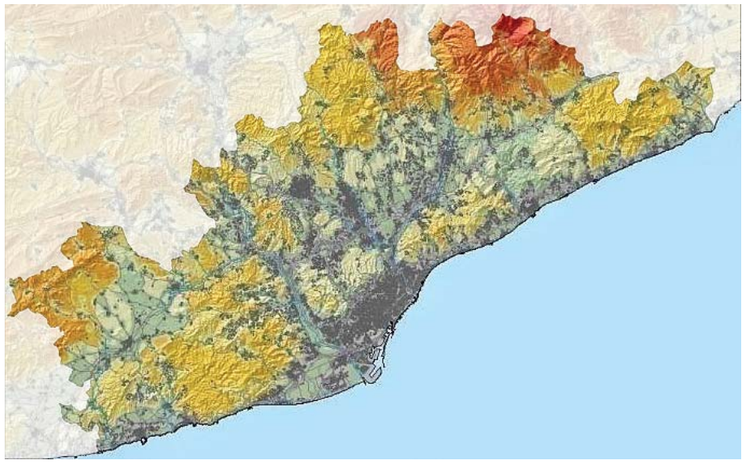
22. Ibid.
23. Dramstad et al (1996)
24. Rodá F., (2003), *La matriz del paisaje* in Folch, R. (2003)
25. Forman R.T.T., (1995)
26. Marull et al, (2008)
27. Ibid.

Territorial Fragmentations
Examples of contemporary territorial fragmentation phenomenas
(sources: Google, Generalitat de Catalunya)

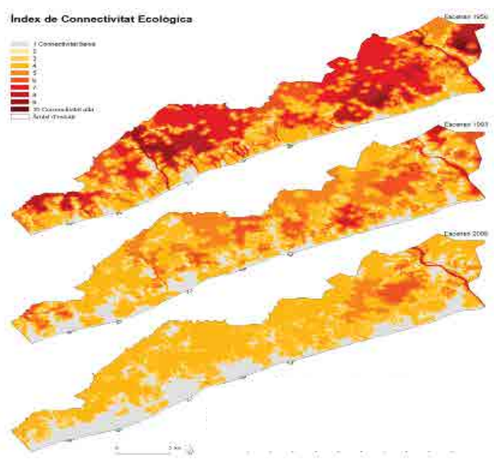
Catalunya scale (source: Marull & Pino, 2011)



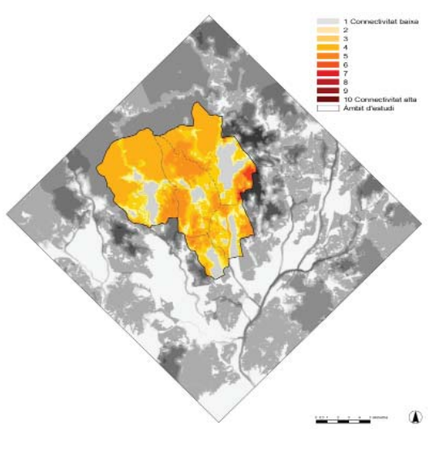
Metropolitan Region of Barcelona (*RMB*) scale (source: Marull & Pino, 2011)



Maresme (*comarca*) scale (source: Tello, E. 2013)



Municipal scale (source: Tello, E. 2013)



The important idea about habitat connectivity is whether the habitat is connected, disconnected or inconnected and the change between these states occurs at a ***threshold*** of habitat abundance[28]. For an organism, in practical terms, this means the qualitative difference between being able to move about the landscape to locate suitable sites for foraging, nesting, and dispersal and being unable to do so. This has important implications for conservation. The negative effects may occur suddenly when the organisms can no longer meet their needs within the fragmented landscape. Exactly where this threshold lies depends on the organism, the amount of habitat, the spatial clustering of the habitat, and the nature of the supporting matrix; different species might perceive different thresholds within the same landscape[29].

Connectivity is thus a ***scale-dependent threshold*** phenomenon. The connectivity of suitable habitat can accordingly constrain the spatial distribution of a species by making some areas accessible and others inaccessible. Plants and animals need suitable areas in which movement and dispersal can occur to maintain their populations[30]. Both plants and animals have varying degrees of mobility, although plants, of course, usually move at the seed stage rather than as mobile organisms. Whether habitat is connected or not is a threshold phenomenon that depends on both the abundance and spatial arrangement of the habitat, as well as the movement or dispersal characteristics of the organism. A threshold refers to that point at which the habitat suddenly becomes either connected or disconnected. The important idea about habitat connectivity is that a habitat can be either connected or disconnected and the change between these two states occurs at this threshold point of habitat abundance. For an organism, this means the qualitative difference between being able to move about the landscape to locate suitable sites for foraging, nesting, and dispersal and / or being unable to do so. This has important implications for conservation, because suitable habitat might be lost for a while with no apparent negative effect on a plant or animal of interest until this threshold is passed. Then at the same time negative effects may occur suddenly as the organisms can no longer meet their needs on the fragmented landscape. Exactly where the threshold is depends on the organism, the amount of habitat, the spatial clustering of the habitat, and the nature of the matrix; different species might perceive different thresholds in the same landscape[31].

28. Turner et al (2001)
29. Ibid.
30. Ibid.
31. Ibid.

But as mentioned the effectiveness of corridors at landscape scale has been debated for the last three decades, with a large number of reviews taking contrasting and alternative stances. Beir and Noss conducted an extensive research of past studies that addressed the issue of corridor conductivity [32]. At landscape scale, some studies propose alternatives to corridors such as stepping stones or managing the entire landscape. Observational methods are more effective at proving this connectivity effect than controlled experiments or probabilistic models[33]. However little evaluation/research has been performed on the connective value of corridors at the regional / territorial planning scale[34]. This paper aims to extend the debate on the use of corridors from landscape scale, to the regional planning scale. Empirical evidence supporting the value and use of corridors in land management has been reported and checked with numerous recent studies demonstrating the effectiveness of corridors at landscape scale[35]. Corridors often interconnect with one another to form networks, enclosing other landscape elements. Networks in turn exhibit:

i) connectivity, **ii)** circuitry and **iii)** mesh size.

In the recent years, the creation of ***ecological networks***, (sets of protected areas connected by protected areas by corridors or landscape linkages) have become increasingly popular and they have been proposed at multiple spatial scales, from local to continental[36]. Opdam et al. (2006) proposed the ecological network as a useful concept *for inserting biodiversity conservation into sustainable landscape development, through a coherent, adaptive large-scale structure that preserves functionality and facilitates stakeholder decision-making on an effective spatial scale*[37].

Human impact on the natural environment is profoundly present, whether conscious / intentional or not. Conservation efforts with regards to connectivity and the preservation of corridors (and their func-

32. Beier, P. & Noss, R.F., (1998)
33. Ibid.
34. Pino, J. & Marull, J (2012
35. Pino, J. & Marull, J (2012), Beier, P. & Noss, R.F., (1998), Forman, R. T.T. (1997)
36. Pino, J. & Marull J (2012)
37. Opdam et al, (2006)

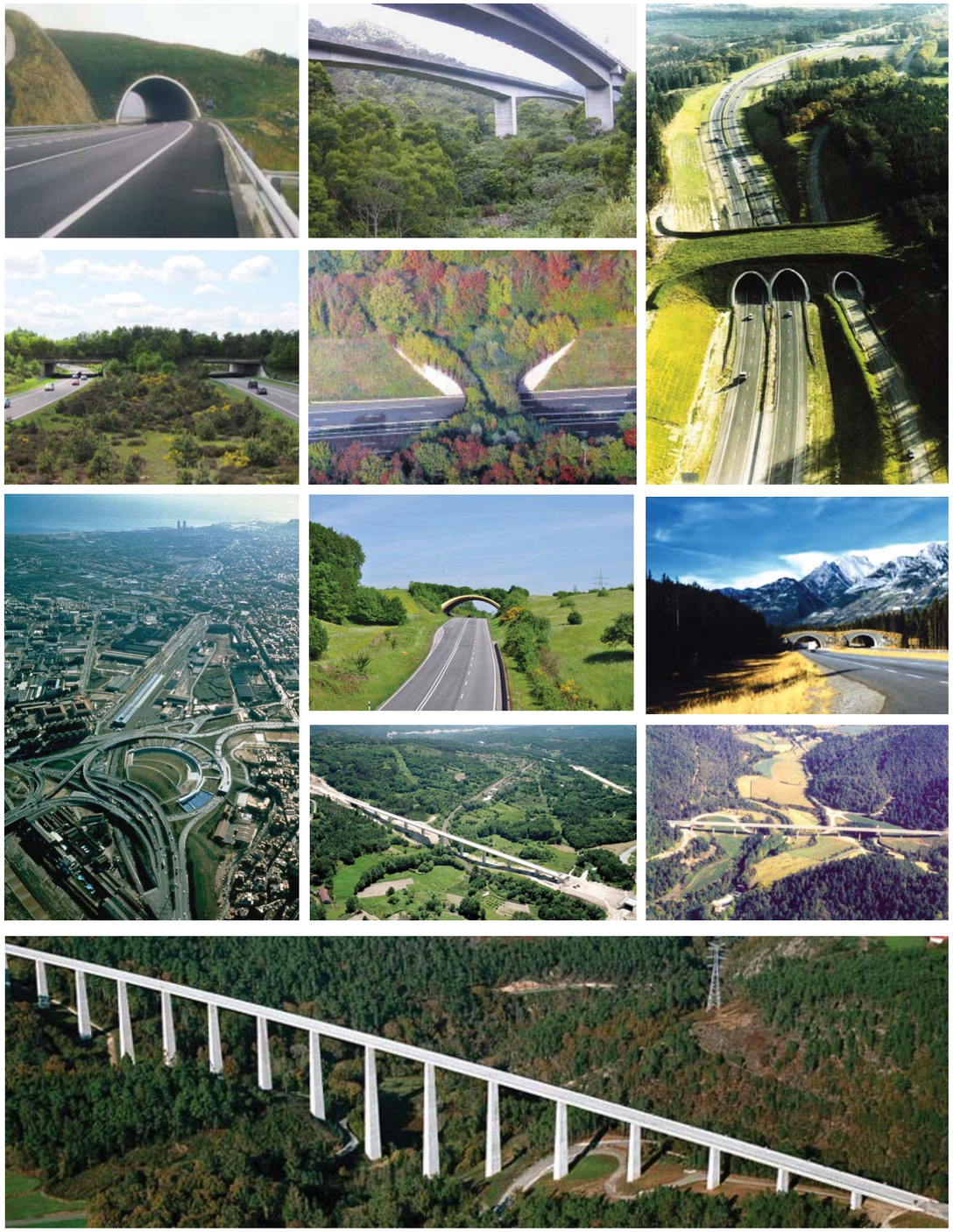
tions) have proven essential in order to prevent species extinction and guarantee optimal landscape functioning. The advancement in scientific insight in also extending our current understanding of natural processes and in this way deeper levels of functionality and integration can be achieved. The notion of continued connectivity in regional and urban level is now regarded as essential for the long-term health both of human and natural ecosystems. If ecological corridors are a prerequisite for all land use planning, then the imperative for increasing social interaction may similarly demand 'equity corridors' as the basis for city and regional design. There are issues of equity and biophilia in the idea that cities should be designed for people and nature. Researchers have demonstrated that green areas, even small, and especially wild areas, are highly valued as places that give pleasure and provides spaces and places for children amusement and re-connection with the natural world. All in all, despite problems of management associated with open spaces in the inner-city, green spaces are seen in a positive light, leading the researchers to recognize their important role in improving urban conditions. Ecological and social equity seem to emerge as two interwoven notions, that enhance the current understanding and perception of social justice, in urban and regional contexts. Given these beneficial fuctions that they behold it is natural to consider these elements as an enhanced ***ecological infrastructure***.

Matrix - Landscape Context

Characteristics of the surrounding and containing landscape can strongly influence local populations. The presence or, even better, the abundance of organisms at a given location (or sampling point) can be explained / justified by the characteristics of the immediate local or by attributes of the surrounding landscape[38]. The landscape matrix has a decisive role in the ecological functioning and its indices of quality, from an ecological / biological and social point of view. The matrix supports the greatest part of the ecological services that a territory can generate[39], apart from providing extensive habitats for the diverse organisms.

Various processes and dynamics can shape and transform land mosaics, altering the preestablished threshold conditions and contributing in this way to the continuous morphogenesis process taking place. ***Fragmentation,*** often associated with the loss and isolation of habitat, is such a key land transformation

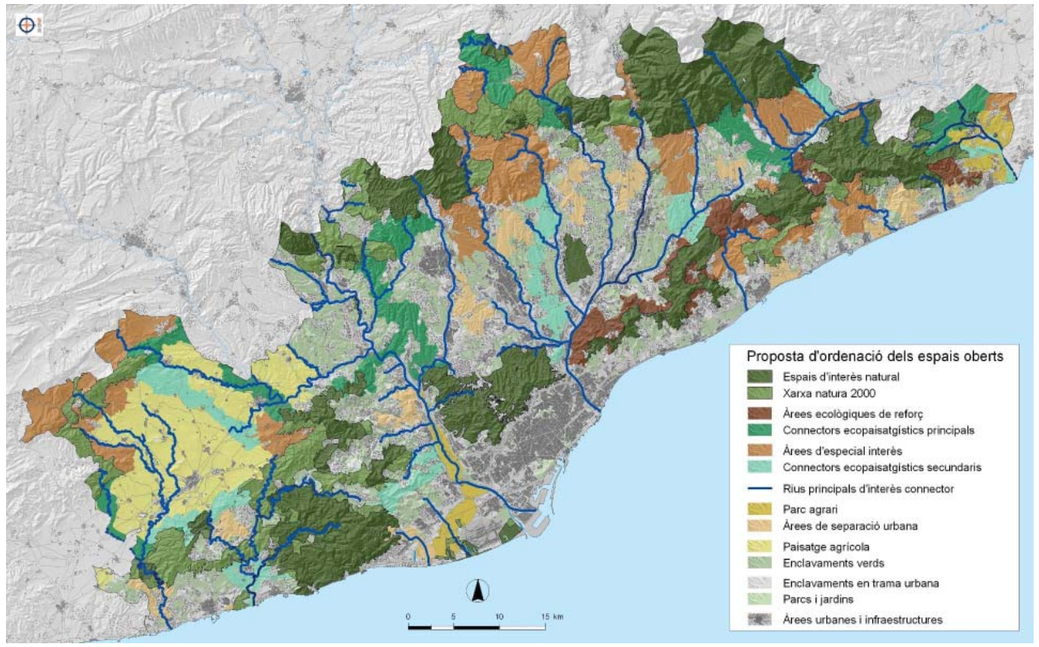
38. Turner et al (2001)
39. Rodá F. La matriz del paisaje en Folch, R. (2003)



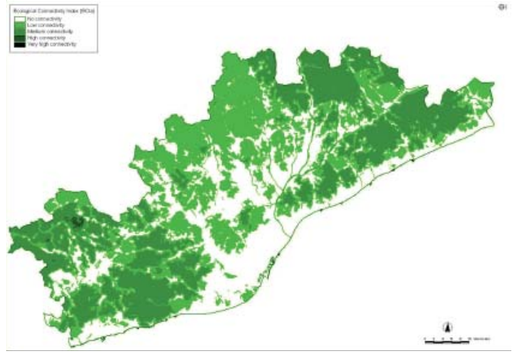
Maintaining territorial connectivity

Examples of ways to conserve or restore territorial connectivity
(sources: Google, CREAF, Generalitat de Catalunya)

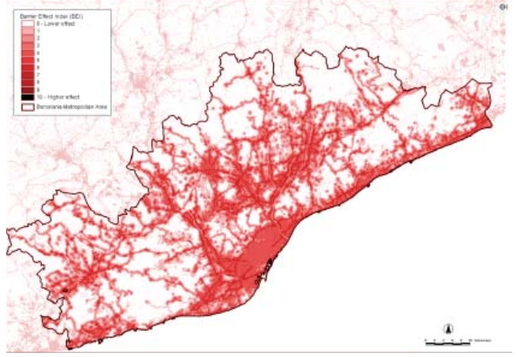
Management of open spaces in the RMB based on the territorial mosaic model.
(source: PTMB)



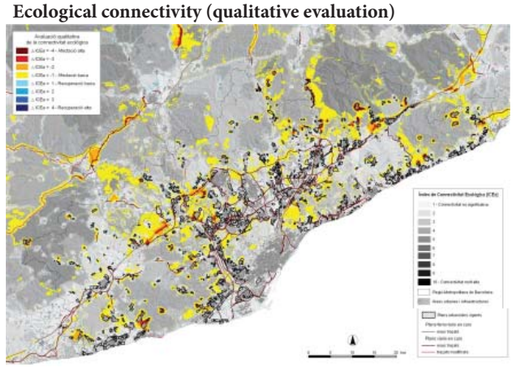
Ecological Connectivity Index



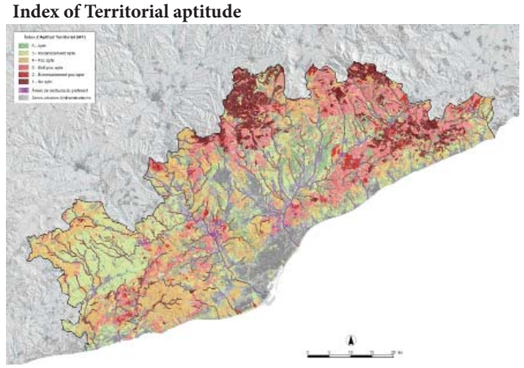
Barrier effect Index



Ecological connectivity (qualitative evaluation)



Index of Territorial aptitude



Planning for connectivity and networking

The Territorial Metropolitan Plan of Barcelona and related studies
(sources: IET, CREAF)

process. Fragmentation can occur from man induced interference / impacts like the construction of infrastructure barriers or from natural disturbances like forest fires[40]. The spatial scale at which fragmentation occurs is another important factor, since fragmented habitat at a fine scale, may be perceived as intact habitat at a broader scale[41]. In order to identify and select adequate strategies one needs to recognize and address landscape changes across different scales, sliding through the scale hierarchy with a critical and investigative intention / perspective. Fragmentation eventually gives rise to heterogeneous land mosaics, typically found in most contemporaneous city regions. At the same time and as a general rule, fragmented landscapes tend to become more suitable for opportunistic edge species that do not require special ecological conditions, and thus become a fertile ground for intrusive exotic species, a fact that explains the facility of exotic species intrusion in urban / -ized landscapes. The end-result is, therefore, a simplification in the quality and quantity of the landscape as an ecosystem (with an accompanying decrease in complexity). This loss of ecological functioning in these *ill-structured landscapes* becomes apparent as they lose their capability to host and connect complex ecological processes[42].

It is essential to consider landscape context along with local site attributes when trying to explain local ecological processes[43]. This insight has substantial implications for land management, because it suggests that what happens in small local areas may be influenced considerably by the surrounding landscape at a broader scale. Ecologists are focusing current research in understanding better when and over what scales the overall landscape influences are important or may even dominate, and when the local conditions act as predominant factors. The influence of spatial heterogeneity on organisms adds a substantial degree of complexity to any study of a population or community, and there remains the important question of when space really must be considered and when it might be prudently ignored. Instances where space (size, shape, and arrangement of habitat across the landscape) simply must be considered include the following[44]:

1. when habitat is rare or fragmented
2. if edge effects are important / key to the process and questions being studied, and
3. if dispersal limits movement between patches and meta-population dynamics are likely to occur.

Among the various indicators used to assess the ecological functioning of the land matrix, the majority focuses on two aspects / points of view:

- the capability of landscape units to host processes[45] and
- their capability to connect with other landscape units in a not completely independent way.

40. Dramstad et al (1996)
41. Ibid.
42. Marull et al (2008)
43. Turner et al (2001)
44. Ibid.
45. Forman R.T.T. (1995); Marull et al, (2008)

Marull et all point to the fact that *there is an apparent relationship between these two perspectives, given that the capability of an area as a habitat depends largely on its connectivity, and vice versa*[46]. *They point out three key characteristics of the territory* that need to be taken into consideration in analysis or planning efforts[47]:

i) ***Ecological Functional Areas.*** *These determine the natural spaces to be connected according to their affinity, and two fundamental criteria: their minimum surface and local topology [...] The definition of ecologically functional areas has an intrinsic value: according to the ecological theory of percolation, significant problems for the conservation of biodiversity may ensue when the share of ecologically functional areas in a given landscape is reduced below a certain threshold.*

ii) ***Barrier Effect.*** *The ecological disturbance that urban areas and infrastructure can cause exceeds those recorded in their immediate surroundings. In fact, the urban spaces, the peri-urban settlements, and the facilities that link them together fragment the agricultural and woodland spaces, and this has a major impact on the landscape's ecological functioning. To this we should add the impact of the emission of polluting agents into the atmosphere, noise, sewage, and the dumping of waste, all of which, in one way or another, have a detrimental effect on natural systems.*

iii) ***Ecological Connectivity.*** *Ecological connectivity is the quality that allows distinct ecosystems, communities, species, and populations to come into contact. This index hence measures the complexity of a network on which basic ecological processes depend: matter, energy and information. It constitutes a parameter of paramount importance, since it has been shown that isolated protected natural spaces, no matter how well designed and managed, are unable to conserve their biodiversity and comply with other important socio-ecological functions.*

Ecotones & effects of boundary shape.

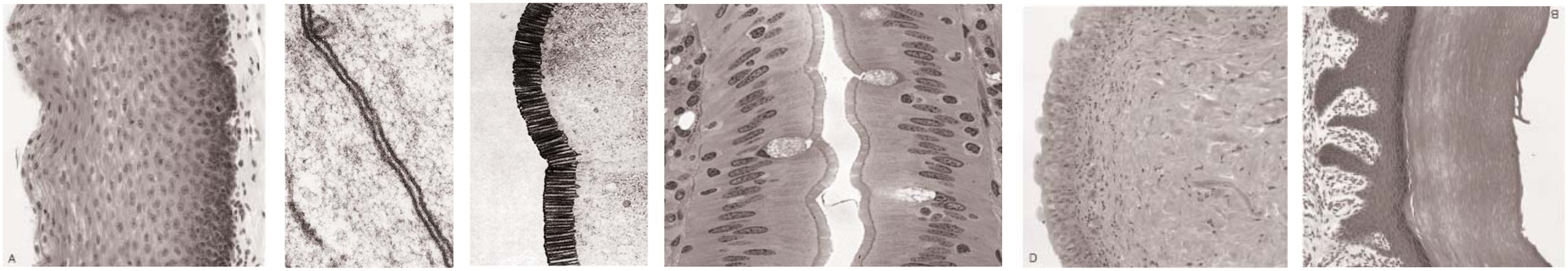
"Biological systems are ***metastable,*** *meaning that the properties of the landscape remain stable only over a limited range of conditions. As those conditions reach a* ***critical threshold****, the system may reach a discontinuity resulting in a radical change in the system state."*[48].

There´s one last question / factor that affects landscape ecological functioning and that is the landscape boundaries / ecotones and their respective shape / form. The shape of a boundary, closely associated with the respective patch size, can influence species' relative abundances / interactions and overall landscape processes /functions[49]. Alternatively to the typical patch-corridor-matrix paradigm described earlier, landscapes can also be analysed and understood using two kinds of structures: patches and boundaries[50]. Though frequently depicted on maps as two-dimensional, patches and boundaries are physically and functionally three-dimensional structures, extending above and below the earth's surface[51]. Accordingly both corridors and boundaries represent critical zones of interaction (*interfaces*) within landscapes, mediating fluxes between adjacent landscape patches. Moreover, both boundaries and corridors, viewed as two different conditions that exist as a continuum of ecological flux control, influence the flux of energy or materials across landscapes[52]. Conduits may in fact be embedded within boundaries, and the spatial relationships between corridors and boundaries are topics of special research interest[53].

Finally some structures may serve as a boundary or a conduit depending on the parameter that is being measured/observed, demonstrating the context-dependent character of boundaries. Respectively specific locations/areas in a landscape can serve as a boundary for one research question and as a patch for a different question. For example, an estuary is a patch when examining its function as a nursery ground for fish, but it can also be considered a boundary between freshwater and saltwater systems if different questions are in play. Similarly, a riparian zone may be a patch in the landscape if the research question focuses on the flow certain nutrients within the riparian zone, but it may be a boundary between upslope habitats and the stream if the focus is on the flow of nutrients in groundwater between adjacent uplands and the stream. These examples demonstrate that it is critical to clearly identify clearly the respective patches and boundaries on the basis of the research question[54].

Nevertheless the patch-boundary paradigm is an interesting shift in our perspective of looking towards the landscape and the territory as well as the increasing importance that the ecotones have come to hold in contemporary research and planning. The question of the boundaries/ecotones will be looked in detail in a posterior section after looking first at the metabolic functions of landscapes and consider the implications of the term of territorial / landscape efficiency in our understanding of contemporary landscapes and ultimately the role and functioning of ecotonal areas. Taking into consideration these additional factors will enhance the perspective of ecotones as territorial/landscape indicators; open possibilities for taking advantage of their structure and functioning favourably to reconfigure the contemporary fragmented & heterogeneous mosaics, utilizing ecotones as re-programmable interfaces / membranes.

46. Marull et al, (2008)
47. Ibid.
48. Gosz, J.R. (1993)
49. Turner et al (2001)
50. Cadenasso et al (2003)
51. Ibid, Forman R.T.T (1997)
52. Cadenasso et al (2003)
53. Strayer et al, (2003)
54. Cadenasso et al, (2003)



Epithelial cells / membranes. Epithelial tissues line the cavities and surfaces of structures throughout the body, and also form many glands. Functions of epithelial cells include secretion, selective absorption, protection, transcellular transport and detection of sensation. (source: W.B. Sounders)

IV. The Search for Limits: The Boundary as a debate

"Living system boundaries are not simple lines through the landscape, they constitute significant zones in themselves. The 'edge' is a place of transition which varies in extent according to the type of ecosystem it is associated with. These edge zones may be ecotones, where two vegetation associations join. There is an 'edge effect' when, instead of mutually evolved associations there is a boundary created by intrusion, e.g. when a housing development is set in cleared woodland [1]".

Ecologists use the term boundary (or edge) to refer to a wide range of conceptual and tangible structures. Usually ecologists use the term boundary to make reference to structures that are two-dimensional or three-dimensional, whether mental or physical, microscopic to regional in size, step functions or gradients, reflective, absorptive, permeable and so on[2]. As long as usage and application is so varied, it is important for ecologists to specify the type of boundary they are investigating and the question in hand. This chapter will intent to formulate a classification of ecological boundaries, exposing the wide range of typologies and scales encountered in the field and making a first intend to expand the scope of inclusion of the definition to cover urban or urbanized type fabrics. Different kinds of boundaries may have very different structural and functional characteristics. Ecologists who compare empirical studies of boundaries need to be careful that the boundaries defined in these studies are truly comparable. Likewise, phenomena such as diffusion, boundary layers which may be essential to measure or model in studies of small boundaries, may be dispensed within studies of large boundaries. Comparisons of structural characteristics of boundaries must be made utilizing comparable grain sizes and scales[3]. This careful specification of boundary traits will aid in the direction of understanding the structure and function of ecological boundaries in an intend to extrapolate the methodology & perspective to urban & anthropized boundaries.

How and where do we find the limit to draw the line for human settlement is an implicit question guiding this very research effort. In searching for limits we have to comprehend integrally the limits set and conditioned by biological processes, territorial or small scale. These ecological and biological, organic limits may go beyond what we traditionally think of as limits. In many ways today human mosaics have transcended the immediate limits of place, using resources and strategies to breach boundaries that older technologies simply did not have the capacity to. If the city is part of its region, then if its capacity to consume resources outstrips the natural capacity of the region to provide those resources, it will have to import them, or eventually degrade. For cities to stay alive, they must find and fit within the limits of their place, region of which they are part of. Equally and for the same purpose, the need to have the capacity to map, measure / quantify and eventually comprehend the impacts of urban entities is essential in our search for a better urban design.

1. Ibid, Pendleton-Jullian A. (2009)
2. Strayer et al, (2003)
3. Ibid.

As the boundary conditions of all ecosystems shift and change in response to outside forces / impulses there is a need to urgently consider the effect of human settlements on and along these edge areas. As shorelines recede, do our cities retreat, or do they stand their ground by remaking it? Natural systems must be open to receive solar energy in order to thrive, but they also need boundaries in order to grow and at the same time regulate movement or flows though them[4]. It is along the edge of species ranges where plants and wildlife are the hardiest and most tolerant of diversity and change. Consequently, those edge species are more adaptive and will survive an impact even when those at the centre of a patch will not [28]. There are no hard boundaries in nature, all edges are permeable to some extends, acting as agents of connection and interaction. Thus instead of defining places and spaces primarily in terms of their separation, we have the possibility and should start defining them by their degree of connection. Landscape characteristics would not then be defined necessarily in terms of their differentiation from other places but more by the way certain its characteristics connect it to particular qualities, functions and dynamics of both an imminent and broader context. In nature, boundaries mark patch limits, delimiting intermediate zones, ecotonal areas between two neighbouring patches. All this in consideration, boundaries are complex and multidimensional entities / elements, that can be described / comprehended by the following six general characteristics[5]:

1. Boundaries may have some characteristics in common with the patches that they separate, or they may be completely distinct.

2. Because the patches that the boundary separates are distinguished from each other by some defining characteristic, the gradient in that characteristic is steeper in the boundary than in either of the neighbouring patches.

3. Boundaries may be wide or narrow, depending on the gradient of change between patches.

4. A boundary for one characteristic may differ in magnitude and location from a boundary defined by another characteristic.

5. The function of a boundary is determined by an organism or by material, energy, information, or some process that is affected by the boundary gradient.

6. Boundaries are best construed as three-dimensional.

4. Ellin, N. (2006)
5. Cadenasso et al (2003)

ecotonal areas in the Thessaloniki urban region (source: Bing maps)

The functionality of urban environments ultimately depends on the successful articulation of these relations, connection and/or separations, between heterogeneous patches of the urbanized fabric. Just as natural boundaries do not have hard edges but form zones of transition between one state and the other, so the transition from one type of space to another in the design of human space should not be regarded as passing through a 'hard' boundary, but thought as more of a step function[6]. Being the place of interaction, transaction and transition, this interface, edge, boundary zone or what this paper will come to call ***urban ecotone,*** it is a critical area for consideration, analysis and management. In urban design, these places of transition may be more, or less expressed with boundary markers; aspects of moving through, experiencing and comprehending spaces such as nodes, landmarks, gateways, pathways, courtyards, centres and gathering spaces [7].

The real potential of ecotones lies in the role they can play as formal and functional planning tools while at the same time serving as quality indicators of the urban and regional space. In the long term city planning efforts will have to address through design the capacity of urban places to perdure through time by having the sufficient inherent flexibility to adapt to changing circumstances, that is to say the embodied ***resilience*** of the system. Thus planning and design of ecologically sustainable environments should reflect this awareness of these transitional spaces at all scales as a means of demonstrating environmental and experiential sensitivity.

Whereas modernism aspired to transparency manifested in and through a structural honesty with the establishment of the open-plan and the ideal of an open society, at the end it resulted in an overexposure, homogeneity, and overall lack of legibility[8]. Post/modernism on the other hand reacted eventually with a reactive opacity, accompanied by cynicism, a growing sense of fear and anxiety, and a declining sense of community all under the pressure of diverse simultaneous and radical transformation processes in sociopolitical level. In contemporary urban and planning theories the current attitude toward edge zones contrasts with the modernist attempt to eliminate them as well as with the post-modernist tendency to fortify with/behind them. Contrary to both they do not eliminate nor fortify borders, boundaries, and edges, considering them as mere elements. Rather they intend to engage and enhance them in order to serve as means / tools of territorial reintegration, conserving and respecting all these particularities that emerge in the interaction, in the mixture, in blunting the distinctions and relating / associating different activities across the regional mosaic´s extension.

People are instinctively drawn to these boundary zones, the urban thresholds because they are vibrant, unpredictable, and ultimately distinct; at the same time inherently diverse, dynamic, and self-regulating. Practically and unsurprisingly its for the exact same reasons that animals are to them. The challenge for urban design is to conserve the integrity / complexity and wealth of individual parts, producing something greater than their sum. As always it is a question of inclusion: what to allow in and what not. This dual temptation is endemic to architects and planners as is the search for a contemplated equilibrium. The last century particularly was dominated by attempts to plan cities as buildings / as machines for living, through the application of master planning techniques and by adhering to the general tenet of *form-follows-function*[9] . Master planning practices within modern Urbanism ultimately have fallen short in achieving their goals, realized often only partially at the end, while producing fragments of cities with difficulties of integration into the urban fabric. Widespread dissatisfaction with these efforts has inspired alternative approaches that selectively abandon some of the control that twentieth-century planning and architecture proclaimed in the past. In addition to emphasizing relationship rather than isolation, complementarity rather than opposition, and substance rather than surface, these new approaches ultimately emphasize a ***process*** over a product[10].

Just as conventional/traditional urbanism is informed by design guidelines derived from an understanding of socio-cultural requirements, contemporary practices need to construct a framework for making cities more resilient, design guidelines that are inclusive for human and nonhuman species, that encompass the ecology (logics) to the economy (rules). Consideration of the edge effect can have a positive and innovative effect on the way we perceive and practice urban planning. Prerequisite to this process is the identification of cities as living structures (biodomes) and the recognition of natural / ecological area as natural infrastructure, providing essential services to the territory as well as human settlements.

> "*Edges are the liner elements not considered as paths: they are usually, but not quite always, the boundaries between two kinds of areas. They act as lateral references [...] Those edge seem strongest which are not only visually prominent but also continuous and impenetrable to cross movement.[...] It is difficult to think of Chicago without picturing Lake Michigan. It would be interesting to see how many Chicagoans would begin to draw a map of their city by putting down something other than the line of the lake shore. Here is a magnificent example of a visible edge gigantic in scale, that exposis an entire metropolits to view.*[11]"

6. Downton (2008)
7. Ibid.
8. Ellin (2006)
9. Ibid.
10. Ibid.
11. Lynch, K. (1960)

Ecotones / Past research & state of the art

At the beginning of the 20th century, Livingston (1903) first defined an ecotone as: "*A stress line connecting points of accumulated or abrupt change is an ecotone*." This definition of the ecotone even predates the ecosystem concept as conceived by Tansley in 1935[1]. Ecotones can be found in many forms and across a range of scales, from a few centimetres to several kilometres. Definitions through the years intended to define boundaries between biomes or ecosystems, and even reached the point of making direct comparisons to the membranes-interfaces of living cells[2]. Ecotones have a profound influence on adjacent ecosystems[3]. Furthermore, as an ecotone is a dynamic entity with both spatial and temporal properties, its width and position evolve with time during succession phases or environmental changes on both a local and a global scale [4] with the rate of change in ecotones reflected by dynamic factors such as fluxes between neighbouring / interacting systems[5,6].

Aside from their role in material flow between ecosystems, researches have highlighted other properties. Ecotones play an important role in speciation, and harbour more species than core areas of ecosystems and are also indicators of local and global changes[7,8]. Most ecotones are described as either physical or functional units, or as a combination of both and thus ecotone research can be linked to landscape ecology topics such as edge penetration, edge effects, interior habitat, and ecological gradients as patches in fragmented landscapes are spatially defined by their physical limits, or borders[9] . Both biotic and abiotic properties of the patches are influenced by and subjected to spatial dynamics across these borders while increasing fragmentation of the landscape will also increase the importance of these dynamics within the related patches. Typical examples of ecotones can be found in diverse landscapes the arctic forest-tundra transition, the forest-woodland transition, forest-savannah transitions, maritime-territorial systems, wetlands or elevational gradients in mountainous areas. Due to the diverse nature and topics tackled by ecotone research, it is necessary to narrow down applicable and useful results / conclusions of past research. To establish a common denominator, the definition of ecotone as proposed by Holland et al. (1991) will be used as the basis for developing further for the papers purposes,

> *"Ecotones are zones of transition between adjacent ecological systems, having a set of characteristics uniquely defined by space and time scales and by the strength of interactions between adjacent ecological systems[10]".*

This working definition is different from that of Odum in its consideration of space and time scales as well as in its attention to the strength of the interactions between adjacent ecological systems[11]. This definition explicitly includes the spatial as well as the temporal aspects of the ecotones that are governed by the interaction between adjacent ecological systems and thus is the most inclusive of the definitions so far[12]. Ecosystems have, strictly speaking, no absolute units and are subjected to the normative rationale and judgement of the observer, however, the term is often used with certain connotation of a fixed and defined unit. As ecotone processes can be characterized in space and time, the ecotone is considered to be multi-dimensional. Consequently, the ecotone is not confined to one or two dimensions, and more often than not, has a temporal component[13, 14].

Many researchers considered the above mentioned definition of Holland et al. (1991) as applicable to any hierarchical level from a few centimetres to a few kilometres, or from the population level to the biosphere level depending on the perspective of the researcher[15]. Ecotones are often referred to as ***edges*** [16] or ***boundaries***[17,18]. Ecotones are sometimes also described as ***broad areas of transition*** [19], whereas edges are often considered at more local scales, such as the boundary between two patch types. Therefore, the term *edge* is frequently used when interpreting effects of anthropogenic change, whereas the term *ecotone* is commonly used in studies of more natural transitions between ecological systems[20]. The term *boundary* is often used as a synonym for an edge, but implies relative (or absolute) impermeability, which may or may not be the case for an edge (Fagan et al. 2003). Although different definitions exist, researchers tend to use these definitions synonymously because all ecotones share some common boundary characteristics. They will be looked more methodologically in a subsequent section.

1. Hufkens et al, (2009)
2. Naiman, R.J, & Décamps, H. (1997)
3. Laurance et al. (2001)
4. Forman R., (1995)
5. Naiman and Décamps (1989)
6. Cadenasso et al, (2003)
7. Risser, P.G. (1993)
8. Smith et al (1997)
9. Forman R., (1995)
10. Holand M.M & Risser, P.G. (1991). The role of of landscape boundaries in the management and restoration of changing environments: Introduction *in* Holland et al, (1991)
11. Ibid
12. Hufkens et al, (2009)
13. Cadenasso et al (2003)
14. Wiens et al (1985)
15. Ibid.
16. Ries et al, (2004)
17. Turner et al, (2001)
18. Kent et al (2006)
19. Holland et al, (1991)
20. Hufkens et al, (2009)

stochastic (- adj)

- *statistics*
  a. (of a random variable) having a probability distribution, usually with finite variance
  b. (of a process) involving a random variable the successive values of which are not independent
  c. (of a matrix) square with non-negative elements that add to unity in each row

(Collins English Dictionary, 2013, 10th edition)

The table on the right summarizes the most common terms, definitions, and their associated dimensionality produced in the last 100 years. The table shows the evolution of definitions and terms produced. Furthermore, the same terminology can have different definitions, and comparable definitions can have different terminologies used by different authors. The variety in these definitions often originates from different interpretations, different scientific objectives, scientific backgrounds, or even the experimental setup/methodology chosen[21]. This variable and non-exclusive use of terms and definitions can be a source of confusion when interpreting and comparing different studies. Ecologists and scientists comparing empirical studies should be careful to ensure the comparability of the different studies, thus a concise and coherent use of terminology would be beneficial for scientific purposes[22]. For example, in order to avoid confusion Strayer et al opted for the use of the term '*ecological systems* at all scales, instead of the term *ecosystem* that is more scale and function specific.

Looking back at past research and definitions produced, a series set of guidelines or common characteristics for the term *ecotone* can be formulated, based upon a synthesis of key components and classifications proposed in the various studies[23]. Many times the representation (conceptual & graphical) of the ecotone is often limited by the dimensionality of the technique used to characterize its multi-dimensional properties. Furthermore, ecotones are created by processes driving an ecological response where often multiple processes are simultaneously driving this response and conditioning the manifested ecotone´s characteristics. Therefore a definition should highlight the importance of a this multivariable approach. Based upon the previously mentioned characteristics and the definition of Holland et al. (1991), Hufkens et al (2009) provide an updated definition of the ecotone as[24]:

> *'An environmentally stochastic interaction zone between ecological systems with characteristics defined in space and time, by the strength of the interaction and their driving processes".*

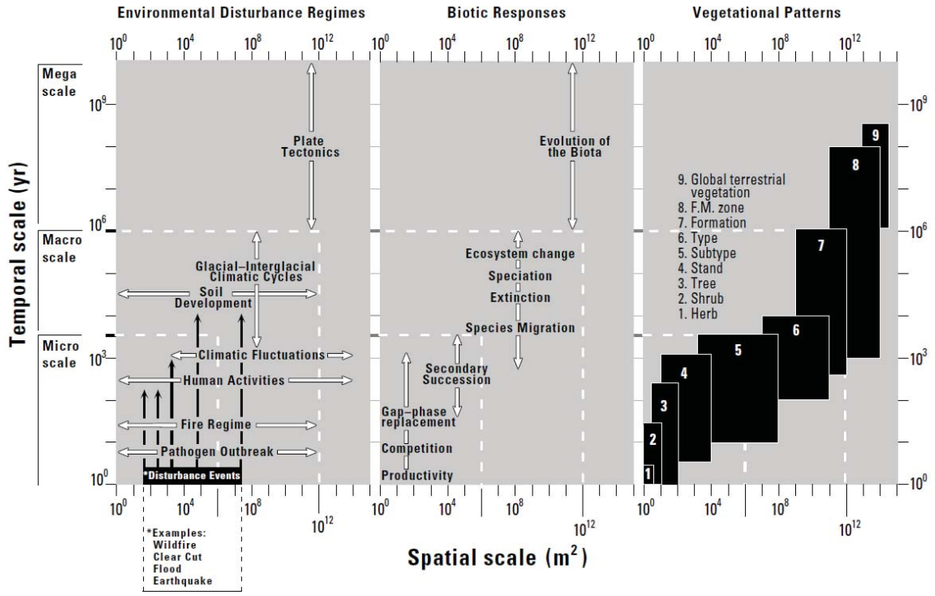
This definition adds the stochastic element - the probability/randomness factor attesting to the inherent dynamics of heterogeneous land mosaics.

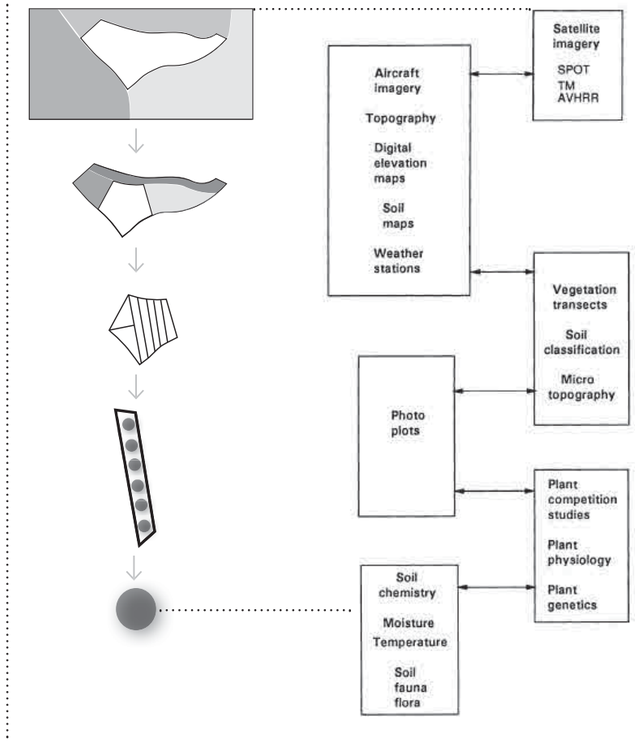
Chronological overview of terminology and definition used in ecotone research
(adapted by Hufkens et all, 2009)

Author	year	Terminology	Definition	Dimensions
Livingston	1903	Ecotone	*A stress line connecting points of accumulated or abrupt change is an ecotone*	1D
Clements	1905	Ecotone	*An environmentall stochastic stress zone*	1D
Whittake	1967	Ecocline	*A gradient zone which is relatively heterogeneous but environmentally more stable*	2D
Odum	1971	Ecotone	*Transition zone between two adjacent ecosystems with a greater species richness*	2D
Allen and Starr	1982	Ecotone	*A gradient between vegetations with two different physiognomies*	2D
Frochot and Lobreau	1987	Ecotone	*a gradient zone which has other properties than the adjoining areas*	2D
Di Castri et al.	1988	Ecotone	*A zone where spatial or temporal rates of change in ecological structure or funcction are rapid relative to rates across the landscape as a whole*	2D
van der Maarel	1990	Ecotone	*An environmentally stochastic stress zone*	2D
van der Maarel		Ecocline	*A heterogeneous gradinet zone that is relatively stable*	2D
Holand et al.	1991	Ecotone	*A zone of transition between adjacent ecological systems, having a set of characteristics uniquely defined by space and time scales and by the strength of interactions between adjacent ecological systems*	Multi
Forman	1995	Edge	*A zone composed of the edges of adjacent ecosystems*	1D
Metzger and Muller	1996	Boundary	*A transition zone between landscape units*	2D
Naiman and Décamps	1997	Interface	*Analogous to a semi-permeable membrane regulating the flow of energy and material between adjacent enviromental patches*	2D
Cadenasso et al.	2003	Ecological boundary	*A boundary is a three-dimensional zone of transition between contrasting systems; the gradient in the feature setting up the contrast is steeper in the boundary than in the two adjoining systems; and boundaries can be wide or narrow, reflecting the steepness of the gradient*	Multi
Fagan et al.	2003	Ecological boundary	*A zone between constrasting habitat patches that delimits the spatial heterogeneity of the landscape*	2D
Ries and Sisk	2004	Edge	*An edge is defined as a boundary between distinct patc types of a variety of scales*	2D
Hufkens et all	2009	Ecotone	*"An environmentally stochastic interaction zone between ecological systems with characteristics defined in space and time, by the strength of the interaction and their driving processes"*	Multi
Lampin-Maillet et al	2009	Interface	*Generally an interface regulates the functioning of space and society, it is a regulator between the cause (socio-spatial interaction) and effect (spatial transformation) coming to balance flows and seemingly contradictory functions "*	Multi

21. Hufkens et al, (2009)
22. Strayer et al, (2003)
23. Ibid
24. Hufkens et al, (2009)

Space-time hierarchies (source: Turner et al, 2001)





Ecotone Hierarchies Adopted by Gosz, J.R. (1993)

The figure adapted demonstrates the multi-level, nested hierarchies, relating plant-edge ecotones to the dynamics of the biome ecotone and probable constraints that can be dominant on the different hierarchy levels. At a biome scale, climate interacting with macrotopography condition more while in contrast, at the scale of individual plant edges the specific controls are likely to be factors such as microclimatology, microsite factors (soil moisture, chemistry etc). Thus, different constraints operate at different levels, and studies need to integrate this factor.

Scales & types of ecotones

Early discussions about ecotones raised the issue of the proper spatial scale for defining an ecotone; for example, was it reasonable to call the local transition between a forest and an adjacent grassland an ecotone and also to call the continental-scale transition between the deciduous forest and tallgrass prairie an ecotone. It is now clear that since their essential characteristics are determined by the phenomenon under study, ecotones can be defined at any spatial or temporal scale. Some processes appear to operate at all scales and are scale independent; other processes depend on the scale of observation. Thus, when answering a specific question or testing a hypothesis relating to ecotones, the spatial and temporal scales must be defined.

Risser, P. G. (1993)

The definition seen in the previous section proposed for ecotones by Holland et al was commonly recognized as being quite general but was agreed that it was a necessary launching point for development of the theoretical base necessary for future discussions of the ecotone concept[1,2]. Given that ecotonal phenomena are evident over a broad spectrum of space and time scales, studies need to adopt accordingly a multi-scale perspective performing studies at diverse scales[3] while focusing on linkages between domains of scale, setting the foundation for what Meentemeyer called a *science of scale*. Often a hierarchy of scales is proposed; however, such arrangements do not mean that we understand how to translate the pattern-process relationships associated with ecotones across the nonlinear spaces between different domains of scale[4]. We are only likely to recognize such linkages when we identify how the different hierarchical levels constrain one another as well as the different types of contraints that dominate at the distinct scales. These scale-dependent constraints are related to different strengths of interactions between adjacent systems[5] at the same scale.

1. Risser P. G. (1993)
2. Holand M.M & Risser, P.G. (1991). The role of landscape boundaries in the management and restoration of changing environments: Introduction *in* Holland et al, (1991)
3. Gosz, (1991). Fundamental ecological characteristics of landscape boundaries *in* Holland et al, (1991)
4. Ibid.
5. Gosz J.R. (1993)

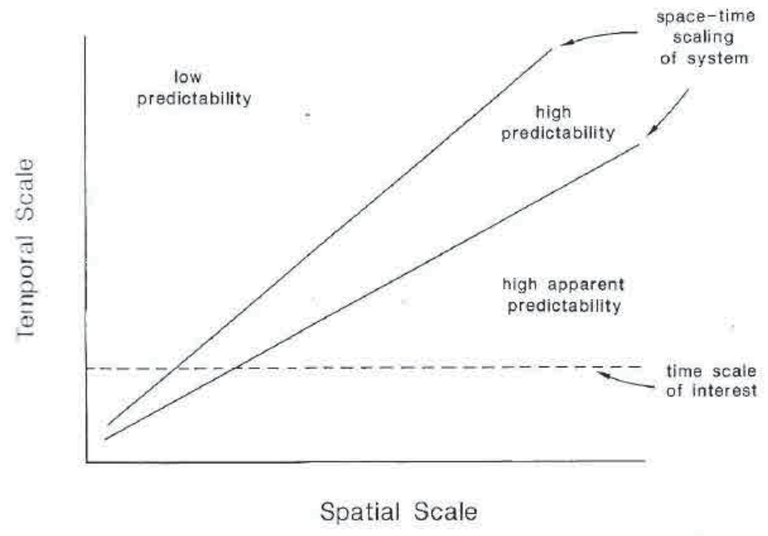
The table on the left page (adapted by Gosz, 1993) depicts a hierarchy of ecotones ranging from the biome ecotone (i.e., biome transition area) to the plant ecotone. The types of ecotones included are the traditional patch and biome ecotone as well as additional levels going down to the transition that occurs at a plant edge, increasing in this manner the potential number of scales of study and consequently the possibility / ability of extrapolating between them. As Gosz set its[6]:

> *For example, the landscape ecotone relates to a transition in the mosaic pattern that is characteristic of an ecotone between two biomes. The mosaic pattern is made up of variations in the number and sizes of patches that represent the two biome types. There are many patch ecotones in a biome ecotone, and it is likely that there is a spectrum of patch-interaction processes depending on the juxtaposition, size, substrate patterns, and distances between patch types. A study of one patch ecotone cannot completely characterize or be extrapolated to the biome ecotone.*

At the other end of the hierarchy is the plant-edge ecotone. At this micro-scale the two differentiated ecological systems are defined by the different microclimates, soil chemistries, soil fauna and flora that are present. The level between the patch and the plant ecotone is identified as a population ecotone. This represents the spatial pattern of the population of individual of a certain species and is similar conceptually to the spatial pattern (mosaic) of patches in the landscape ecotone. Where landscape patches are dominated by one plant species, the population and patch levels are identical. The strengths of the interactions between populations are influenced by population sizes, spatial arrangements, distances from other sub-populations, etc.. The challenge is to *develop procedures to interrelate processes and constraints at these different levels to allow interpretations at the rest of the levels*[7]. Another point made evident by the table is that, in addition to different controls dominating the finer scales (e.g., plant ecotone), there is an increase in the number of probable controls and interactions between them as one goes down the scale. *This contributes to the increased variation as well as the difficulty in modelling and predicting responses. Much of the fine-scale variation is integrated or averaged out at broad scales, leaving only the broad-scale*

6. Ibid.
7. Ibid

Scales & predictability
source: Gosz, J.R. (1991)



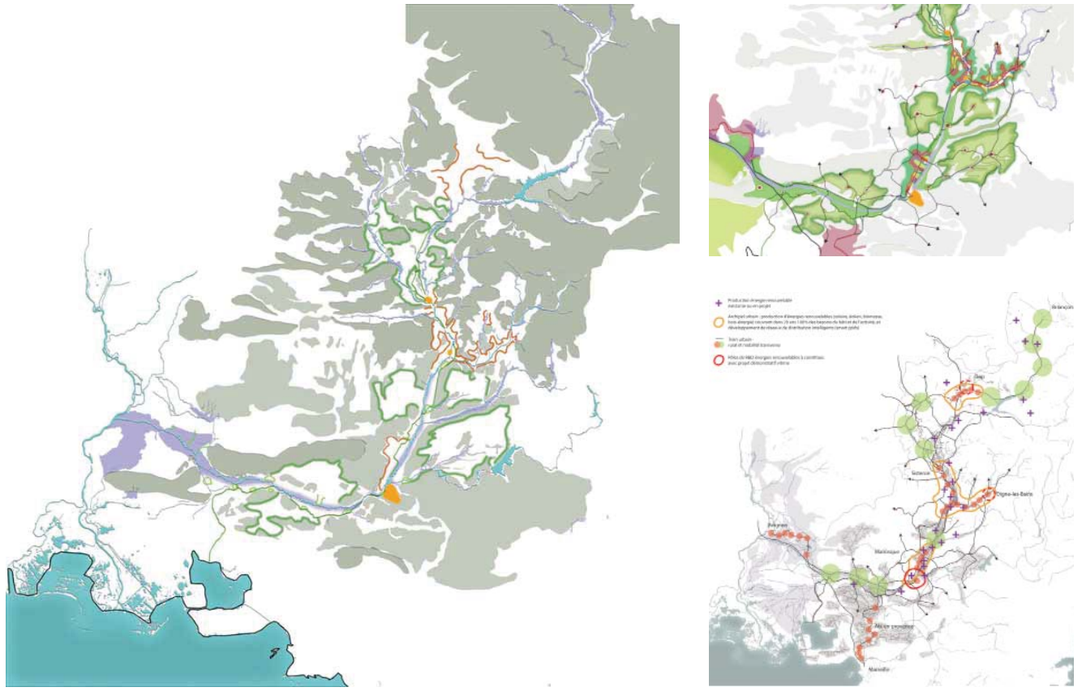
constraints correlated with broad-scale ecotone patterns that change over broad (long) temporal scales[8]. For the purpose of this paper, focus will be given on three specific scales, that lie within its research scope, providing specific examples of types of ecotones encountered in each scale, and presented in continuation.

1. Large-scale (biome ecotone)
The edge effect of a biome ecotone can easily discernible be at a large scale. Climate is usually the principal factor in classifying different zones at this level. The vegetation classification at global level is mainly decided by climate, and accordingly it gives form to the distinct vegetation regions[9]. The distribution of vegetation corresponds pretty much with horizontal climate zones including latitudinal and longitudinal distributions of zonal vegetation. The latitudinal vegetation distribution is mainly decided by thermal elements, such as annual solar insolation. The longitudinal distribution of zonal vegetation on the other hand is mainly driven by water, the regional hydrological scheme as well as precipitation patterns, reflecting the pass from distinct phases, eg. from an oceanic humid climate to a continental arid climate. The altitudinal distribution respectively tends to correspond to the equivalent latitudinal vegetation distribution[10]. The vertical / elevational distribution of zonal vegetation is also result dependent on the change of altitude.

However, the borderlines between the climate zones are not distinct, but most often transitional areas. Typical of ecotonal areas, a type of zonal vegetation is replaced by another type of zonal vegetation in the transitional area between biomes, where the vegetation type changes greatly and in a relatively shorter distance. Research at this scale focuses on identifying the zone limits and studying the borderlines of these extended climatic regions (warm temperate zone/northern sub-tropics, southern sub-tropics/edge tropics, temperate semi-arid and sub-humid zones). The edge effect at the biome ecotone level is mainly caused by abiotic effects / factors, involving changes in environmental conditions that lead to structur-

8. Ibid
9. Neilson, R. P., (1991). Climatic constraints and issues of scale controlling regional biomes *in* Holland et al, (1991)
10. Ting, Z. & Shaolin, P. (2008)

Val de Durance - Biome Ecotone



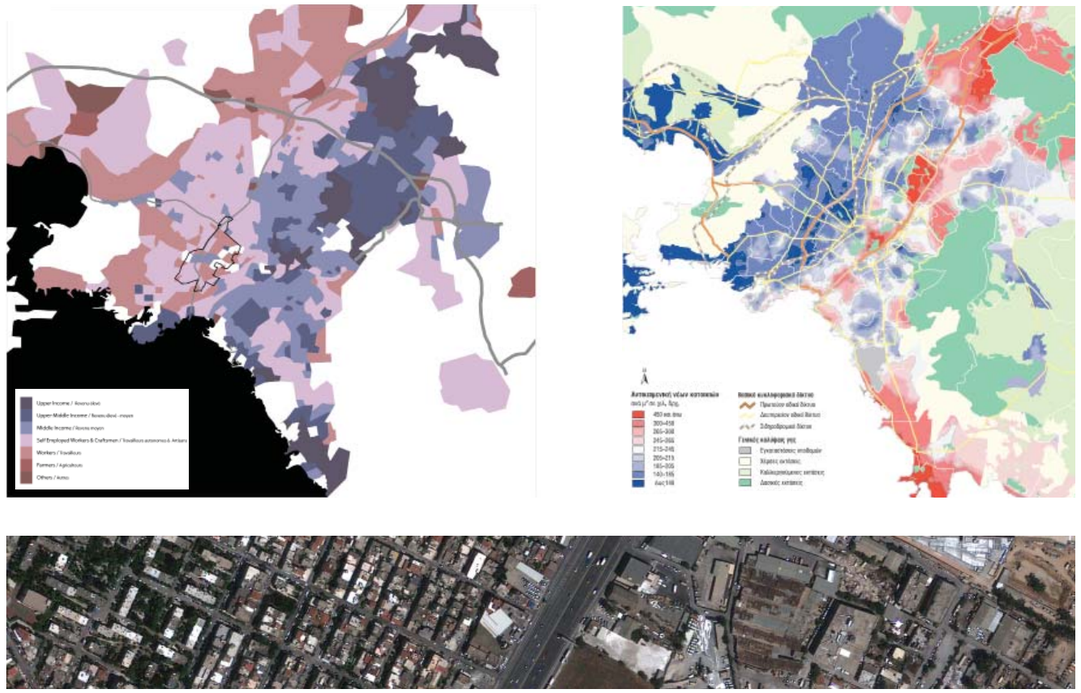
ally heterogeneous land matrix / mosaics found worldwide[11]. However, the same transitional - zones are result of the interactions between the diverse kinds of landscapes, each with its complex and distinct characteristic. The biome ecotone scale presents respectively a magnified edge effect in certain aspects such as vegetation, community compositions, soil ingredients / consistency and so on. There are several methods in the research bibliography on the measurement / detection of biome ecotones[12]. Quantitative measurement of species diversities and distribution gradients, the application of Geographic Information Systems technologies, quantitative classification, determination of the floristic relevance, or indices such as the thermal synthetic index, can all be utilized to demonstrate this ecotonal effect.

The *Val de Durance* (Durance river valley) one of the areas under investigation in the CREPUDMED programme is an example of such a biome-ecotone formed in this case along the Durance river in the region of Provence-Alps-Côte d'Azur separating alpine habitats from the respective mediterranenan and inland habitats. This pronounced and narrow ecotone presents a vibrant edge effect in terms of activity and types of uses, with an extended regional reach / impact in diverse aspects.

2. Meso-scale type (ecological ecotone)
The second scale of ecological ecotones refers to the transitional area connecting different ecological systems at a landscape scale. The edge effect is one of the essential characteristics of the ecological ecotone, acting often as transitional area among ecosystems or as a membrane controlling the flows of energy, material and information between ecosystems / biodomes. Examples of ecotones encountered at this level are:

11. Ibid.
12. Hufkens et al, (2009)

Athens - Metropolitan scale



Forest - grassland ecotone
A typical and often encountered ecotone, the forest-grassland ecotone is situated in the transitional area between forest and grassland habitats and its characteristics are the coexistence of both kinds of vegetation and the high biodiversity in the ecotonal area. At the same time, the species diversity associated with the forest and grassland community interact in a different manner within the ecotone. The diversity of the forest decreases from the forest zone to the grassland zone. The grassland diversity, however, is characterized by a higher values as one approaches the edge.

Agricultural - pastoral ecotone
The characteristics of the agro-pastoral ecotone are determined principally by the interaction of farming activity and animal husbandry such as vegetation cover, animal distribution, soil ingredient. The agro-pastoral ecotone is a ecologically frail system, and is influenced by natural as well as human activities´ impacts. Consequently, this pronounced edge effect presents little resilience especially when human impact and dissipating increases, affecting both land cover and activity as well as species diversity[13].

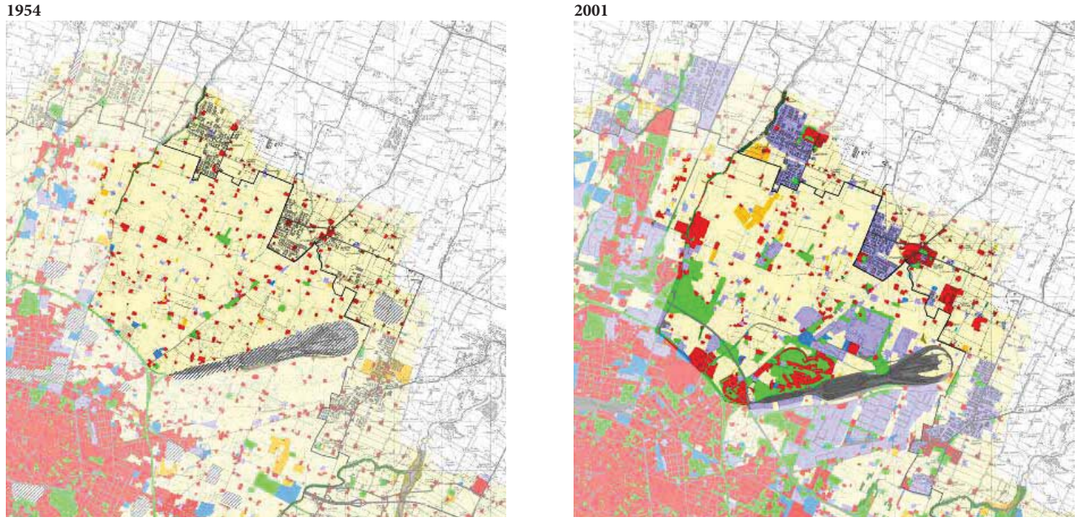
Forest - Agricultural ecotone
The characteristics of the forest-farmland ecotone involve the interactions between a relative natural and consolidated system (forest) and a social / anthropized system (farmland). There are many differences in the species composition and the community structure between the boundary and the adjacent ecosystems, with species density and abundance usually lying on the forest side. Moreover,similar to the previous case there are certain metabolic dynamics caused by the amount of energy inverted by humans through agricultural activities (crop sowing, growing and harvesting

13. Ting, Z. & Shaolin, P. (2008)

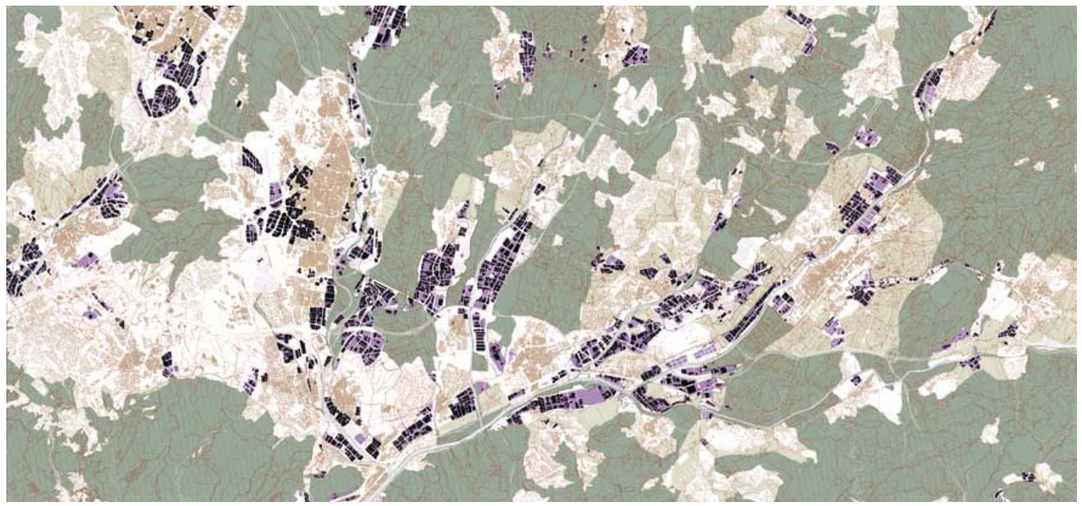
Bologna - peri-urban scale

1954

2001



RMB - patch scale



source (all images): Crepudmed

the land, fertilizers etc). For this reason the forest-farmland ecotone is a also a frail ecosystem and provides representative and typical snapshots of cultural succession phases in human impacted landscapes. The principle of edge effects in the forest-farmland ecotone has been widely applied in traditional agricultural production systems taking advantage of the threshold diversity present in agro-forestal mosaics and scientifically researched by the agro-forestry and agro-ecology sciences.

Water - land ecotone

The water-land ecotone is the border area between terrestrial and aquatic ecosystems. It is by defect the predominant ecotone in the average mediterranean cultural context. It acts as a dynamic interface of material and energy flows between ecosystems, and present an edge effect which is pronounced and intense in ecological and social terms, greatly due to the extensive connectivity it can provide[14]. However, the water-land ecotones are always in a constant dynamic state resulting from the continuous interaction taking place between the water and terrestrial ecosystems. Wetlands play a key role in maintaining a relative equilibrium between these profoundly distinct ecosystems apart from other performing / providing other key ecological functions. (water purification, aquifer recharge, refuge etc.)

Urban - rural ecotone

The urban-rural ecotone is an area between the built-up urban area and the peripheral countryside. The urban areas gradually extend from the city centre to the peripheral rural areas passing from consolidated fabrics to less consolidated fabrics of smaller densities. The urban-rural ecotone is by default a region of transforming landscape in urban regions. It is not simply the perceived continuum between urban and rural areas, but instead a special constituent element almost a territorial sub-system reflecting manifested the relationship between urban-rural systems presenting its own structure, function and transformation. The urban-rural ecotone possesses typical ecological edge effects and characteristics which are influenced by the present space-time interactions. Increasing research at the urban / regional as well as at the landscape scale reveal that urban - rural ecotones can host high levels of biodiversity, besides the increased amounts of dissipated energy and the often and the heavy ecological impact associated urban expansion / development. Efforts in mitigating global biodiversity loss often focus on preserving large, intact natural habitats. Similar for mitigating the increased urban growth effect goal special attention should be paid in these urban - rural areas, and more importantly in highly urbanized areas where natural habitat is found under pressure and ecological footprint of urban regions increasing in an alarming rate. Research on urban-rural ecotones should further involve sociological factors and considerations of other factors often intangible that define the relations and dynamics along these ecotones. However due to the inherent complexity related to the flows of material and energy through these areas, further applied research is needed in order to enhance our understanding as well as capacity to adequately comprehend and manage these key elements.

Urban - forest ecotone

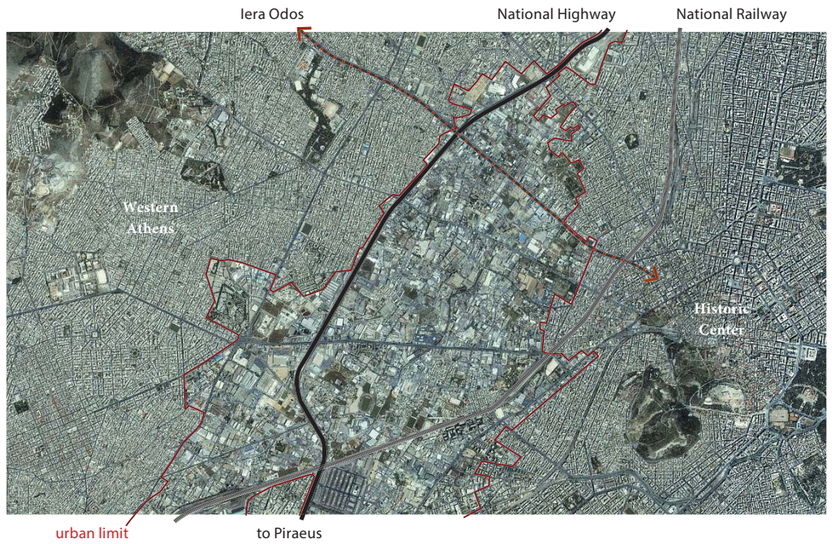
A great part of the research performed on ecotones although indirectly has focused on the urban - forest ecotones More specifically forest fire-prevention in the vicinity of urban activity[15,16]. In this case the concept of Wild-urban interfaces (*WUI*) has been a great focus point especially in fields like forest management which has impulsed a great great part of the research. It presents similar behaviour to the agricultural - forest ecotone, but with greater intensities given the increased inputs of energy and complexity presented by the urban biomes.

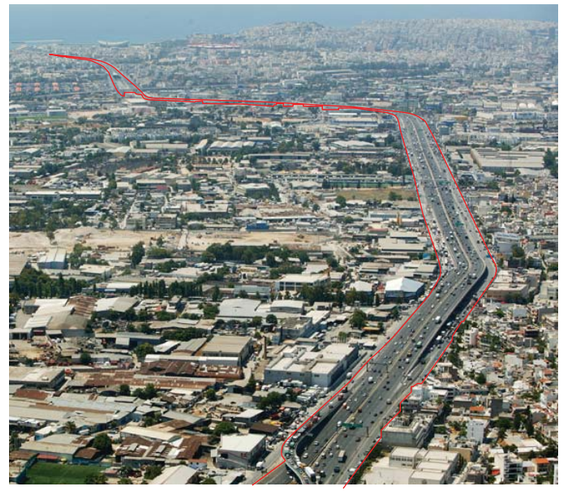
14. Naiman et al (1989)

15. Platt, et al (2010)

16. Stewart et al (2007)

Athens - Metropolitan scale





Urban - urban ecotone

This type of ecotone is the less researched of the formentioned typologies / examples of ecotones in this scale. It involves the emergence of ecotonal areas between distinct urban patches /biodomes that hold distinct morphological as well as socio-ecological characteristics. Considerations could include morphological criteria such as urban form structure or consider more complex intangible factors such as socio-economic, local networks or other social diversity indicators. Social ecotones are a specific subcategory where the social differentiation of the two patches plays a predominant role in determining living conditions within and interaction between the two urban biomes. The example of Eleonas in the city of Athens is a representative example where the concentrated infrastructure running across the central axis of the city has divided it respectively in two distinct social sides situated on an east-west axis. This ecotone, of variable width and intensity, presents it maximum width at the area of Eleonas that had been one of the area under investigation in the CREPUDMED programme.

3 Small-scale (community / patch ecotone)

The edge effect at the patch / community scale is caused by the interaction of the biotic and abiotic components of the communities. Attention so far has been given to the edge effect produced by patch fragmentation. The influence of the edge effect on the organisms and non-biological process is diverse and often pronounced. Research focuses on measurement methodologies of the edge effect, the emergence of structures / organizations and the development of functioning schemes of present interactions. Examples of this type of ecotone can be the following:

Urban / Community edge

This edge area can be a subset of different types of ecotones presented in the previous category /scale and is referring to the exchange region between an urban patch / biome and a natural / semi-natural environment and especially with concern to questions such as species dispersal, material and information flow. The structure and development of the edge in relation to the natural community reflects the impact of the interaction between the two systems, and at the same time determines the tendential landscape succession / transformation. The proper dispersal of the community edge effect is a direct result of this succession with the distinct phases of urban development. The much studied topic of peri-urban sprawl in contemporary metropolis is in reality a manifestation of this particular edge effect at various scales. Landscape / habitat modification and fragmentation, energy dissipation, and socio-economic pressures are the key driving forces behind these ecotones[17]. At the same time this type of ecotone can play an important role when used to accelerate the restoration of adjacent to the city ecosystems, and the integration of urban fabric within the regional context, acting as active membrane regulating the space-time succession of ecosystems. The peri-urban area of Bologna as studied in the CREPUDMED programme is a representative example of this type of ecotone. On one hand the exploding urban fabric of the city of Bologna expanding to the north (bounded to the south by local geomorphology) where it encounters the peri-urban land, a complex and historically rich rural mosaic found today in a perturbated and altered state.

Urban Interstices

This category refers to a special sub-category of urban ecotones, the urban interstices that are created within the urban fabric and between two distinct urban fabrics. The conditions (micro and macro) often give rise to areas that can usually and easily be perceived as urban voids but when examined in their context present special characteristics, are creating intra-urban interfaces of different scales. The example of Eleonas in the metropolitan region of Athens is an example of a large size interstice created in the centre of its urban fabric along the territorial ecotone that transverses it. At Eleonas this ecotone demonstrates its greater intensity and width, product of the continuous fragmentation and transformation processes present. The intra municipal character of the area and presence of major transport axes acting as infrastructural barriers (highway, railway line, local grid) are one of the driving forces behind the morphogenesis of this interstice.[18]

Forest gap edge

Forest gaps are usually results of earlier perturbations (forest fires, logging etc.) experienced by the ecosystem that result in the creation / appearance of these spaces. The increased edge effect due to the emergence of these gaps / clearings enhances species richness / diversity (encouraging mutual

17. Ting, Z. & Shaolin, P. (2008)
18. Lampin-Maillet et al (2010)

RMB - patch scale

source(all images): Crepudmed

penetration of species) and also affects the spatial allocation of environmental gradients[19]. Thus forest clearings are key areas for conservation restoration of degraded forest biodiversity. Species diversity, ecological dominance, and strength of edge effects are some of the factors that change dynamically influenced by human disturbance. Forestry and landscape research has been studying the effects and functions of these special ecological areas extensively the last years.

Treeline ecotone

The treeline refers to the vertical distribution forests and their respective canopy. It refers to the specific species compositions and interactions (biotic & abiotic) particular in this ecotonal scale. The vegetation types and distribution, the soil composition and hydrogeological processes are key conditioners for the processes taking places within. Moreover, the shape of the treeline ecotone is related to the spatial dynamics (complexity, resilience) and spatial composition of species in treelines, as well as the adjacency contrast with neighbouring patches[20].

Infrastructure barriers

This next category refers to the situations and conditions created along infrastructure axes such as highways, railway lines, powerlines etc. These elements often serve as barriers increasing the mosaic fragmentation, while decreasing connectivity and at the same time dividing original species´populations into meta-populations[21]. At the same time they can selectively act as conduits for disturbance-tolerant species (eg. roadside vegetation) and also as sources of erosion, sedimentation or acting as windbreakers. Anyway they serve as clear demonstrations of human intervention and presence on / in land mosaics.

Natural / Antrhopized Patch ecotone

This category refers to the interaction of individual patches with their landscape context. The patch boundary in itself can be considered an ecotone with respect to the rest of the landscape, controlling the interactions and the degree of integration of the patch within the general context. In the case of anthropized patches the interactions become more complex due to the exogenous energy invested, with the resulting increase of complexity but also energy dissipation to surrounding patches as a result of inefficient metabolic practices. The proposal for the Economic Activity Area of the Meanders within the Metropolitan Region of Barcelona, as it was formulated during the CREPUDMED program, is an example of an intend of integration of obsolete anthropized patches into the local landscape. Apart from increasing efficiency of the proper installations (renovating / rehabilitating / innovating) the proposal also sought a socio-ecological integration of the area into the rich and already complex local landscape.

The combination of studies at different scales and over different time intervals allows the extrapolation between different scales a process, as seen earlier, necessary for understanding the controls / functions of the dynamics of the ecotonal areas[22]. The particular discussion over ecotonal hierarchies emphasizes this scale-dependent nature of patterns and processes associated with ecotones. As commented an edge at one scale may be indistinguishable at a different scale but the processes that occur at one certain scale can nevertheless have significant influence / impact on both broader and finer scales[23]. Measuring and understanding these cross-scale influences represents a significant challenge for ecotone studies. The edge effect in these ecological environment-sensitive regions can be a key indicator of the interaction of the diverse ecological systems as well as a topic of importance for their careful and holistic management. The fact that there is so much choice in the scales and boundaries of ecosystems, and how to study and relate the processes within them, indicates the profound degree to which the ecosystem represents a research approach rather than a fixed scale or type of analysis[24]. These synthetic approach of analysis offers the capacity to identify the emerging tendencies / dynamics present or latent within a mosaic. Such a multi-scale, multi-technology and trans disciplinary approach will be a necessity and a challenge for modelling ecotone dynamics[25] and one undertaken by this paper for its research purposes. An additional knowledge on edge responses can contribute meaningfully to the management and conservation strategies, particularly in landscapes undergoing rapid change such as urban regions and their respective ecotonal areas.

19. Ting, Z. & Shaolin, P. (2008)
20. Ibid.
21. Dramstadt et al, (1996)
22. Gosz, J.R. (1993)
23. Ibid.
24. Pickett et al, (2001)
25. Gosz, J.R. (1993)

Classification / description

As will be demonstrated in continuation ecological boundaries can be classified in different ways and according to distinct criteria. Strayer et al (2003) proposed a classification system that encompasses most of the boundary characteristics. According to his classification we can consider four main classes of boundary traits[1]:

1) origin and maintenance, **2)** spatial structure, **3)** function, and **4)** temporal dynamics.

These attributes are related to each other, but for the purpose of the classification can be intentionally isolated. The distinct attributes of the ecological boundaries are presented in continuation in detail:

Origin and maintenance of boundaries.
Boundaries can arise / emerge in various ways. We first distinguish between what we call ***investigative*** boundaries and ***tangible boundaries***. For ecologists, boundaries are often considered as human constructs: drawn lines on a map that may or may not correspond with physical discontinuities in nature. In fact, the arbitrary placement of boundaries for the convenience of a scientific study has been a principal tool for ecology and other sciences[2]. There are other ecologists that think of boundaries as tangible structures that can be indeed identified in nature. At the same time political or administrative boundaries are often used by ecologists as investigative boundaries. Both investigative and tangible boundaries are widely used by contemporary researchers, both being useful but it is necessary to make the distinction between the two when defining research objectives. In practice, most boundaries that ecologists study are a mixture of investigative and tangible boundaries, involving the imposition of human order onto some real natural structure[3].

Focusing on tangible boundaries, the first question / issue to be investigated is the ***origin***, that is to say the morphogenetic process that gave rise to the appearance of the boundary. Boundaries emerge due to discontinuities between patches (a consequential boundary, such as a forest–field boundary), or may themselves cause discontinuities between patches. Existing boundaries may have arisen from forces still in operation (contemporary boundaries) or from forces no longer operating at that site (relict boundaries). Many boundaries are difficult to classify as contemporary or relicts because their structure has formed from a mixture of current and past forces[4]. It may often be useful to subdivide boundary origins further, depending on the purpose of the study. For instance, one might distinguish between ***natural*** and ***anthropogenic*** boundaries, which may have very different spatial structures and functions[5]. More generally, we could classify boundaries as having exogenous or endogenous origins, arising, respectively, from processes outside or inside the system of patches and boundaries being studied. Of course, many boundaries arise as a result of a combination of exogenous and endogenous factors.

Likewise, ***exogenous*** or ***endogenous*** forces may tend to maintain or destroy a boundary through time. A boundary between two vegetation types that is reinforced by the grazing preferences of herbivores is an example of an endogenously maintained boundary. There are several problems that prevent the unambiguous classification of boundaries as exogenous or endogenous. Firstly, exogenous and endogenous boundaries should defined with respect to the study system. Second, many boundaries originate and are maintained not by exogenous or endogenous forces alone but by an mixed interaction between exogenous and endogenous forces. Finally, control of the boundary structure and function may shift between exogenous and endogenous forces over time. Nevertheless, a general distinction between exogenous and endogenous origin and maintenance may be useful for generating hypotheses and comparisons[6].

Spatial structure
A graphical classification of the possible spatial structure of ecological boundaries can be seen in the figure on the right. The characteristics listed are independent of one another, and provide a relatively complete description of the spatial structure of boundaries. As is the case with many features in landscape ecology, boundaries may be defined or studied using different ***grain sizes***. When different grain sizes are used, the same physical structure may appear to be very different at different levels or may not appear at all at others [7].

The second scale attribute considered is the boundary ***extent***, referring to the absolute physical size and scale of a structure[8]. Ecologists have studied systematically researched micro-boundaries, (microbial biofilms, soil crusts, leaf boundary layers, and rhizospheres) whose extent is measured from micrometers to centimetres. At the other end of the spectrum, boundaries such as forest edges, the boundaries of biomes may be kilometres long as seen in the previous section. The extent of a boundary is especially relevant when the boundary interacts with a process that has its own characteristic physical scale[9].

Boundaries may be construed as having a finite ***thickness*** (and therefore having the same dimensionality as the patches they separate) or as being infinitesimally thin. Thus, when considering two-dimensional patches on a map, one needs to identify whether the boundaries are zones/spaces between the patches or as infinitesimally thin lines along the patches´ limits? It is important for researchers to think carefully and

1. Strayer et al, (2003)
2. Ibid
3. Cadenasso et al, (2003)
4. Strayer et al, (2003)
5. Turner et al, (2001)
6. Strayer et al, (2003)
7. Turner et al. (2001), Gosz, J.R. (1993)
8. Ibid.
9. Strayer et al, (2003)

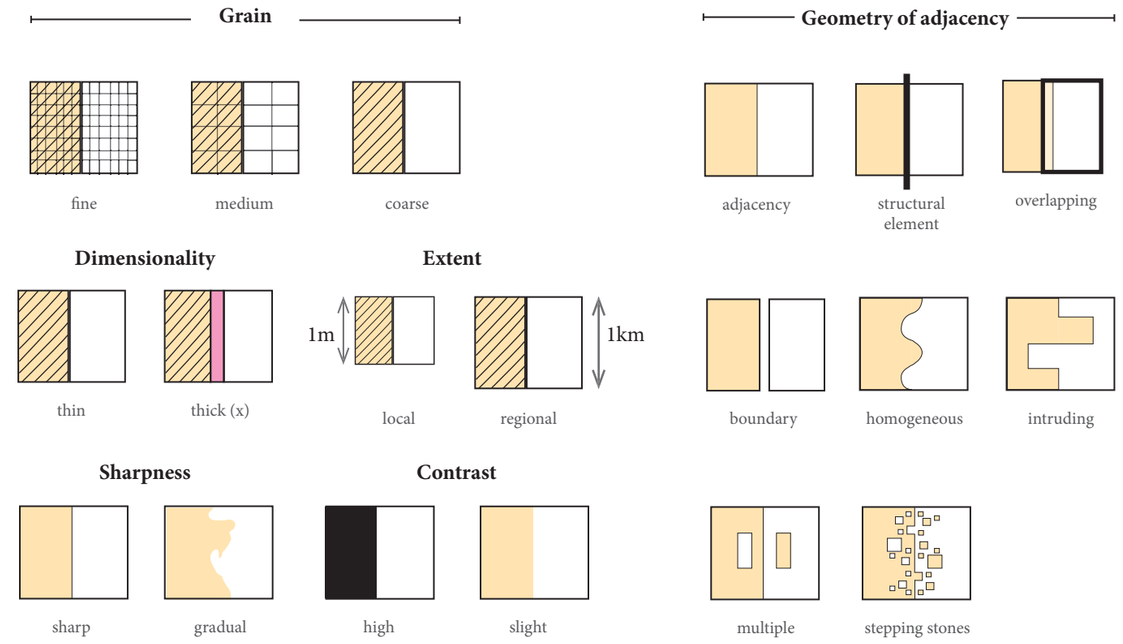
decide which boundary dimensionality is more appropriate to their research and to be clear about what boundary dimensionality is being used in their study, as different study designs, models, and theories may be applied to boundaries of different dimensions. To some extent, the choice of boundary dimensionality may be set by the abruptness, grain size, and extent of the boundary, as well as by perspective and methodology utilized by the investigator[10]. Both conceptions of boundary dimensionality are widely used in empirical and theoretical studies in ecology. The detailed **geometry** of adjacent patches can result in different kinds of boundaries. In the simplest case, two neighbouring patches physically adjoin one another. Adjacent patches may be separated by a third, distinct structure (a fence, road, or stream), may overlap or not quite meet along the boundary (e.g., a forest and a field). The detailed geometry along the boundary between two patches will have important consequences for natural processes and for the design and interpretation of models and field studies.

Some people think of boundaries as necessarily being step functions, and some ecological boundaries indeed fit within this model. On the other hand, especially in the case where boundaries are thought of as having a finite thickness, the change in ecological conditions across a boundary may appear to be gradual[11]. The boundary separating a forest from an aging old field as well as the shift from a riffle to a pool in a stream course are examples of gradual boundaries. Further, the perception of a boundary as abrupt or gradual will depend on the grain size at which the boundary is being measured or modeled; a boundary that appears abrupt at a coarse grain size may appear gradual at a fine grain size[12]. The change in ecological conditions across a boundary may be large or small, demonstrating a lower or higher ***constrast***[13]. In fact, it is the magnitude of this cross-boundary differentiation / contrast that determines whether the researcher idemtifies the existence of the boundary in the first place[14]. Many mechanisms that regulate the exchange of materials, energy, and organisms across boundaries depend on this contrast between neighboring patches and thus often influences boundary function[15]. Examples include the movement of organisms from one patch to adjacent ones and the transfer of water dissolved or airborne substances[16].

Boundaries may be unbroken or perforated by conduits. The **permeability** of a boundary may be determined in large part by the existence and properties (size, spatial arrangement) of such conduits. Again, the perception of the integrity of a boundary may depend on the grain size of the selected scale at which it is measured or modelled[17].

10. Ibid.
11. Cadenasso et al. (2003), Fagan et al. (2003)
12. Strayer et al, (2003)
13. Ibid.
14. Fagan et al. 2003
15. Cadenasso et al. (2003)
16. Wiens et al. 1985
17. Strayer et al, (2003)

Attributes of boundary spatial structure.
(adapted by Strayer et al, 2003)

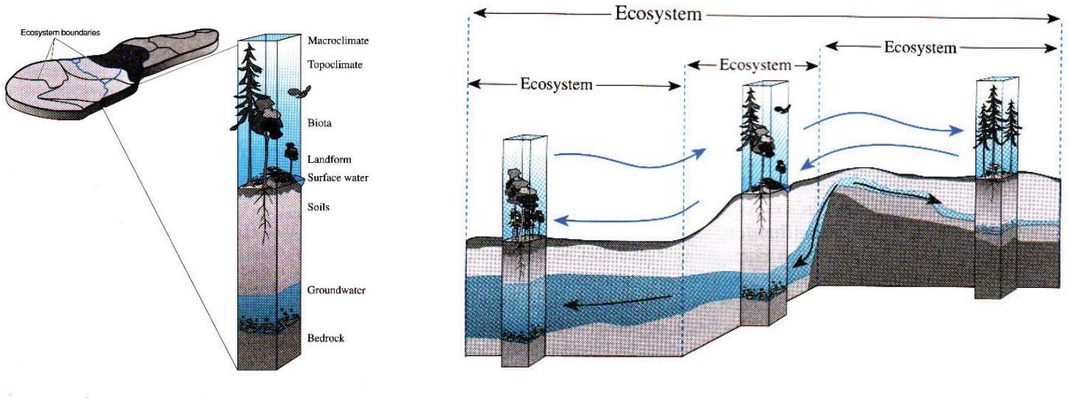


In order to determine its properties of the shape of the boundary, it needs to be observed above. Boundaries may be simple or convoluted. The degree of ***convolution*** (*tortuosity*) can be measured by using an index such as the ratio of the actual distance along the boundary to the straight-line distance between the ends of the boundary. Highly convoluted boundaries allow increased interaction / exchange across patches. Furthermore, the shape of a boundary may determine and indicate its temporal dynamics and succession patterns[18].

In most investigations, the boundaries are assumed to be defined by a single ecological property but most real ecological boundaries are defined by a change in several congruent ecological properties: A forest edge, for example, could be defined by vegetation height, vegetation species, animal species, wind resistance, or light penetration at the same time[19]. Similarly, many ecological factors may come in play along vertical or horizontal grand gradients in lakes, across shorelines, or along elevational zones in-mountainous zones. Thus, one could also distinguish between **single** and **multiple** boundaries. Probably few ecological boundaries exist as purely single in structure. In cases where multiple ecological properties jointly define a boundary, these properties may be spatially congruent with one another, or they may be offset. Cadenasso and Pickett found that physical factors such as temperature and humidity, as well as herbivore activity, were significantly offset from the position of a forest edge as well as from one another. Thus offsets along boundaries may have important ecological consequences[20] beyond manifested properties.

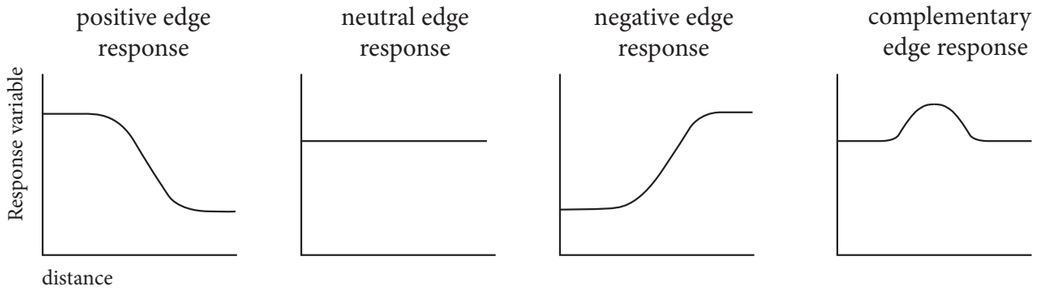
18. Strayer et al, (2003)
19. Ibid.
20.Cadenasso et al (2000)

Edge responses
source: Bailey (1996)

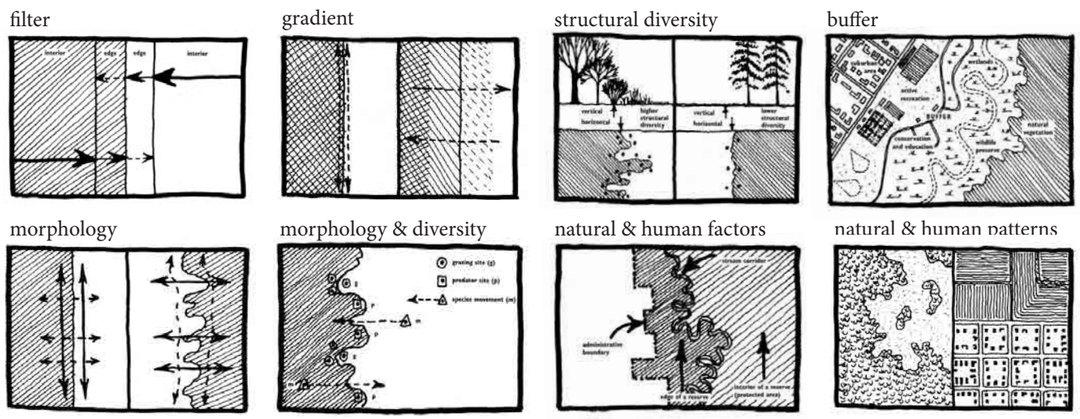


left: vertical structure of an ecosystem, **right:** Boundaries between ecosystems are set where different vertical structures occur. Ecosystems are netsted with permeable boundaries, open to transfers of energy and material to or from other ecosystems.

Edge responses
adapted by Ries et al, (2004)



Landscape ecology principles & edges
source: Dramstad W. E, Olson J.D. & Forman R.T.T (1996)



Function

Habitat and landscape boundaries profoundly influence the structure and function of landscapes, influencing ecological processes both locally and over larger scales. In addition, boundaries themselves are, as seen, dynamic entities whose changes can influence diverse populations, communities, and ecosystems by way of feedback effects/process. These two issues, scale dependence and spatio-temporal dynamics, are the two parameters that have received more attention in the quantitative study of ecological edges and boundaries[1]. The spatial patterns of ecotones provide a spatial analog for these temporal dynamics. A transect across an ecotone is expected to show increased spatial variation (e.g., increased numbers of small patches of different species) at the ecotone. Temporal studies are expected to show the greatest variation in spatial change at the ecotone as micro sites change from one community to another. Away from the ecotone the changes are primarily an increase in the diameter of the patch rather than a state change[2].

> *In addition to edge residents, (ecotones) often contain multihabitat species, those requiring or frequently using two or more habitat types. These organisms capitalize on the complementarity of resources provided by the zone between two ecosystems or land uses. Though subject to disturbance regimes of both ecosystems, these locations offer ready access to diverse resources, plus stability during stress periods. [...] (Ecotones) are often biological cornucopias. High species richness and density, or biomass, are documented for many groups… Edges may also play an important role in species evolution[3].”*

Although many times there is no pronounced geographic barrier between the two populations, the species living along the edge are distinctly different from those living in the interior of the adjacent patches. In fact, the morphological differences between the two can reach to be more pronounced than those found between separate species living within the same habitat. These characteristics confer competitive advantages in survival terms against predators. Ecosystem edges are inherently environments of increased predatorship due to the greater density and diversity of species. For example, birds living within

1. Fagan et al (2003)
2. Gosz, J.R. (1993)
3. Forman R., (1995)

a forest edge can develop distinctly different song pitch from those that live within the forest patch. This change in pitch allows them to overcome the different ambient sounds of the home patch, thus influencing mating choices and ensuring reproductive success.[4] Biologists studying ecotone diversity have also witnessed another important feature, that ecological gradients encourage species adaptation and experimentation and are specifically known for being sources of evolutionary novelty[5], encouraging species evolution and generation. Ecotone species evolve / adapt to the conditions of both adjacent patches to such a degree that they can no longer occupy any of the formentioned habitats but the ecotone area, which is distinctly different from either bounding/adjacent habitat[6].

The focus on boundaries as structural features can mistakenly over-emphasize their static or descriptive aspect. Boundaries are functional elements of the landscape but frequently their functional importance is disproportionate to the space they occupy[7]. Patches in the landscape interact through the flows of organisms, material, and energy moving between them. Gosz (1991) suggested that spatial patterns in landscapes have non-normal, spatially autocorrelated, non-stationary, discontinuous, and irregularly spaced parameters. The dynamics of ecotones in landscapes also are likely to be nonlinear, perhaps chaotic, and can behave in ways that are not simple averages of adjacent resource patches and that threshold dynamics are expected to occur near boundaries [8]. Certain micro-sites or landscape edges are at a threshold with respect to the prevailing conditions allowing the persistence of a certain community. Relatively small changes that exceed these threshold conditions can cause certain sites to change to a different type of community while others remain unchanged[9].

> *Ecotones function like the membrane of a cell, negotiating the movement of materials and conditions around them, and are subject to competition, conflict, and friction, even in their most stable states. When disturbances of significance occur, the impact on the ecotone is greater than on the bordering ecosystems. A storm does not have as great an effect on the marine ecosystem at sea as it does within the tidal zone. The edge of a rainforest is more fragile than the interior because its proximity to the savannah creates sun and wind conditions that penetrate the canopy, drying out the soil so that fire is a greater risk and more destructive on the edge than in the interior. Therefore, species that live in ecotones have greater adaptability. In fact "generally species of an ecotone (actually) require a level of disturbance for regeneration[10]."*

Because boundaries exist in-between patches, they are necessarily traversed by and interact with diverse types of flows. Consequently, boundaries may control exchanges between patches in the landscape, preventing a flow from between two patches or facilitating that movement. How the boundary interacts with a specific flow depends on the identity of the flow and the features of the boundary itself. These factors determine the permeability of the boundary. Two central questions frame the scope for understanding boundaries[11]:

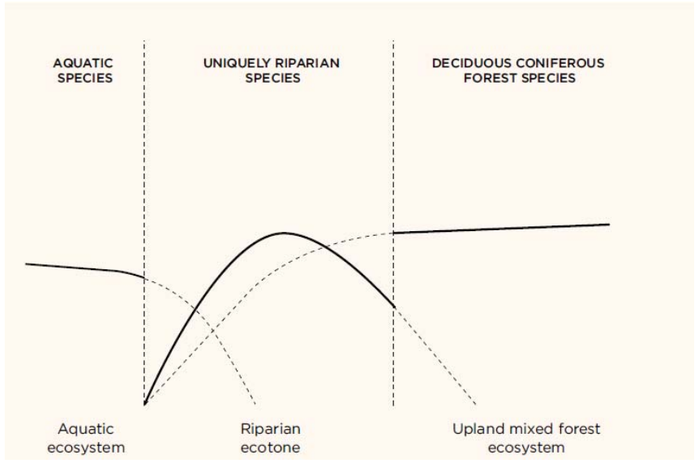
1. Do boundaries modulate flows between patches and, if so, what is the nature of the modulation and what characteristics of the boundary contribute to that modulation?

2. If the boundary modulates flows between patches, does the modulation influence processes inside the interacting patches?

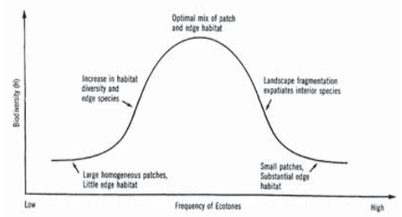
To address these two questions, it is useful to have a framework that organizes the concepts and data and helps generate hypotheses at the same time[12]. Strayer et al[13] proposes a characterization of boundaries based on their boundary function**.** Boundaries may themselves affect ecological phenomena. Ecological boundaries are commonly differentially **transmissive** or **permeable**; that is, they may allow only some

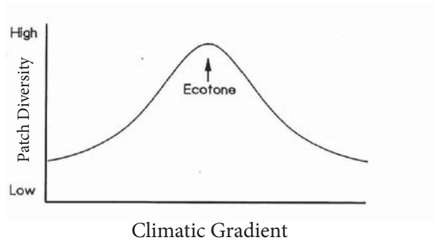
4. Pendleton-Jullian A. (2009)
5. Smith et al (1997)
6. Pendleton-Jullian A. (2009)
7. Cadenasso et al, (2003)
8. Gosz, (1991). Fundamental ecological characteristics of landscape boundaries *in* Holland et al, (1991)
9. Gosz, J.R. (1993)
10. Parr S. in Pendleton-Jullian A. (2009)
11. Cadenasso et al, (2003)
12. Ibid.
13. Strayer et al (2003)

Species distribution for a riparian ecotone
source: Pendleton-Jullian A. (2009)

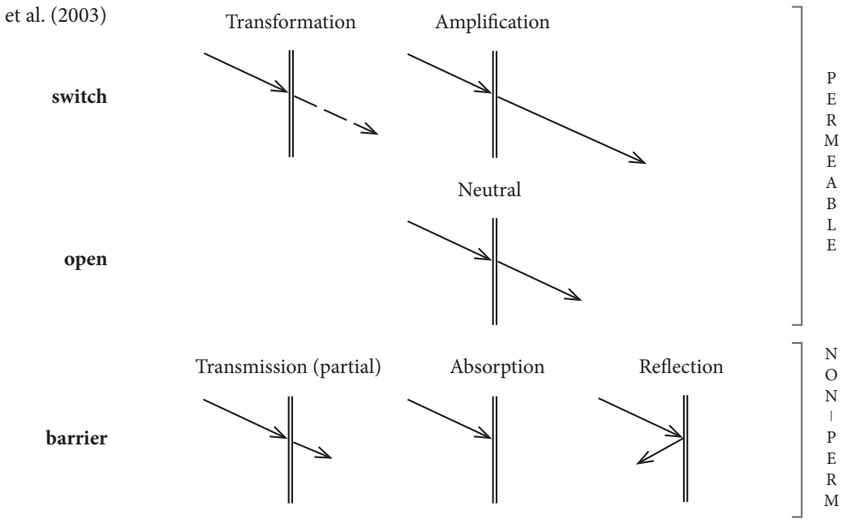


Ecotones & biodiversity
source: Neiman et al. (1989)





Boundary attributes I
source: Strayer et al. (2003)



fraction of materials, energy, or organisms to pass. Thus, wind speed falls as it moves from an open field into a forest, and many animals are reluctant to cross boundaries[14]. As an extreme case of impermeability, many ecological boundaries can become **absorptive**. For example, most of the mechanical energy contained in waves is absorbed in the surf zone boundary that separates land and water. In the case that this transmission exceeds 100%, it is said that the boundary amplifies the ecological phenomenon. Amplification by ecological boundaries is quite rare[15]. In many cases, boundaries are **reflective**: Organisms or materials that approach the boundary are returned to the patch from which they originated (highly reflective boundaries are sometimes called hard boundaries). Like transmissive boundaries, reflective boundaries may attenuate or amplify an ecological phenomenon and therefore might be said to have an albedo. Finally, the boundary itself may have no effect on the phenomenon under study - a **neutral** boundary. In these instances, either the flow has no net gain or loss as a result of traversing the boundary or the boundary does not interact with it. A distinction between these types is important for understanding how boundary function may change. If neutrality is caused by counteracting flux regulation, a subsequent change may lead to a shift in the net effect from neutral to positive or negative[16].

Since ecotones are constantly negotiating the interaction of two different habitats in tension, the two respective activities depend upon and sustain each other. This interdependence is achieved through the dynamics in action within the ecotone. Moreover the ecotone's resilience comes from its indivisibility and its capacity to incorporate even disruptive change, thanks to its species diversity and richness. As conditions in the environment changes new alliances are formed taking up the new challenges. These alliances form new practices with different inflection points where sometimes one entity is the driver and sometimes another. Work at the edge is unfettered and unencumbered by the inertia of core activity. It is more open to innovative forces that can reshape and transform the core, which the core will not do under its own constraints and conditions[17].

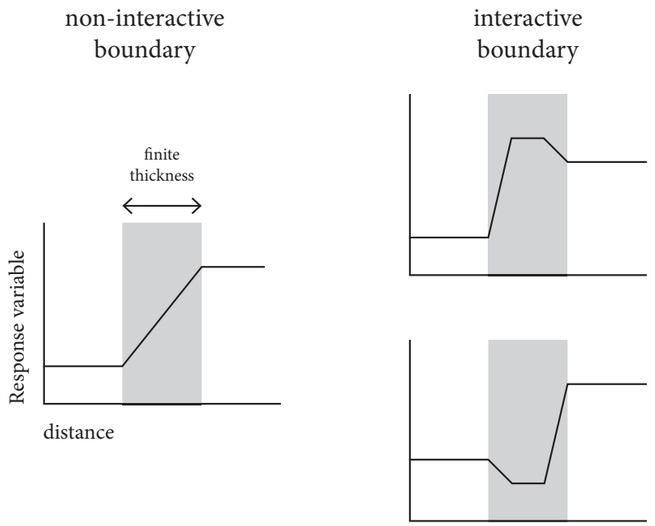
Conditions in the boundary may be a simple average of conditions in the patches on either side, or they may reflect interactions that occur along the boundary (see figures above). These ecotones are often referred to as interactive and non-interactive boundaries or as Lidicker called them ecotonal and matrix edges[18]. Many kinds of mechanisms can create interactive boundaries and indeed much of the literature on the positive / negative effects of boundaries has been focused on identifying, quantifying, and managing such interactions and processes[19]. Many biogeochemical reactions also take place in boundaries, resulting in the accumulation or depletion of materials in boundaries and finally boundary interactions may occur regardless of the geometry of adjacency; These different mechanisms may interact in complex ways to influence an individuals species' distribution and, ultimately a community´s structure at an edge. The flow of energy is one of the fundamental drivers of edge responses. Given that solar radiation is a major factor influencing the movement of energy, edges in different positions relative to the sun are likely to experience different rates, but not directions, of energetic flows[20].

Cadenasso describes the results of a multidisciplinary workshop aiming to describe the domain of a framework for ecological boundaries and ultimately understanding the regulation of flows across heterogeneous space in a hierarchical structure. The resulting definition was describes as *ecologically significant interactions among heterogeneous entities connected by flows of organisms, energy, materials, or information across a differentially permeable or reactive interface at any spatial and temporal scale*[21]. Therefore, in order to develop a holistic and inclusive framework, a researcher must precisely articulate the spatial and temporal scales to be addressed and at the same time define the point of the ecotonal hierarchy to intervene. Cadenasso in continuation also describes the three **components** of a typical boundary function[22]:

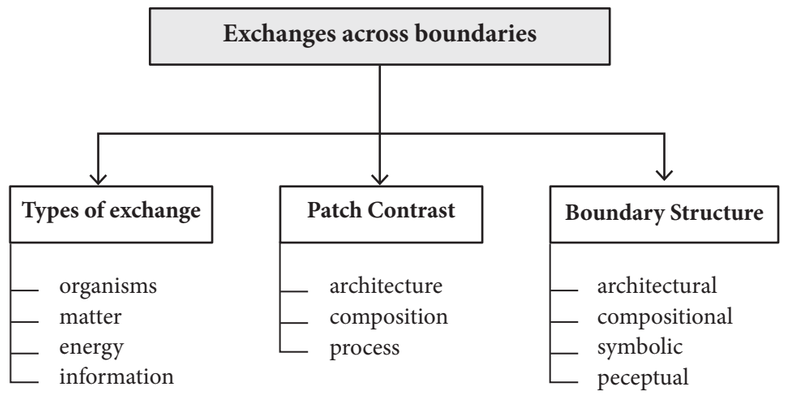
i) the type of flow, **ii)** the nature of the bounded systems, and **iii)** the nature of the boundary.

14. Fagan et al (2003), Lidicker W.Z. (1999), Wiens et al. (1985)
15. Strayer et al, (2003)
16. Cadenasso et al (2003)
17. Pendleton-Jullian A. (2009)
18. Lidicker W.Z. (1999)
19. Strayer et al, (2003)
20. Ries et al (2004)
21. Cadenasso et al (2003)
22. Ibid.

Boundary attributes II
source: Strayer el al. (2003)



Boundary Framework
source: Cadenasso et al. (2003)



i. Type of flow.
Four types of flow are relevant to ecological systems: **i)** materials, **ii)** energy, **iii)** organisms, and **iv)** information (see figure). This list is categorically comprehensive and represents multiple levels of ecological organization, but does not list/ enumerate all possible kinds of flow within each general category[23].

Flows of **materials** include nutrients, pollutants, dead organic matter, and clonal plant fragments. Materials move between patches through mechanisms such as diffusion, gravity, and transport by wet and dry deposition, groundwater and surface water, wind, or animals. The flow of materials, including type, amount, and delivery mechanism, varies across spatial and temporal scales.

Energy flow between patches can involve physical dissipation and transformation or movement of stored energy in biological forms. Energetic flows include light, heat, wind, and tides, the latter two of which serve as vectors of organisms and materials. Energy stored in biological forms may move across boundaries. For example, the energy in carbohydrates eaten by an animal in one patch can be dissipated as metabolic heat in a second patch.

The flow of **organisms** is a higher level of organization than either the flow of matter or energy. Organismal movement around the landscape may operate at broad spatial scales, as in the migration of surface or air species . Organisms may also move shorter distances but still traverse boundaries between patches, as in the daily movement of white-tailed deer between forests and open fields. On still finer spatial scales is the movement of microbes between soil horizons, as well as the vertical movement of algae. Plants move in landscapes through seed dispersal and clonal spread. The flow of organisms can occur on many time scales, for example, the use of more than one patch during a life cycle, seasonal or reproductive migration.

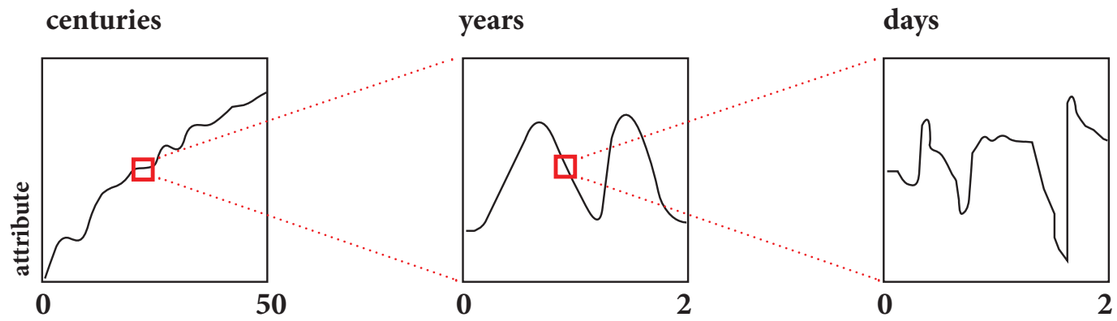
The flow of **information** encompasses genetic information as well as the visual, auditory, and chemical signals that affect pollination, host and mate finding, territoriality, predator avoidance, and so forth. Information is a distinct category from organisms and material, even though organisms and material may mediate in the flow of information. Indeed, for some biological concerns, information is the currency of interest, not the organism or material that carries it. In anthropized landscapes / mosaics the flow of information can also be related to the flow of data (oral/material/ digital) and the interactions with which it is ultimately connected to.

ii. Nature of the bounded systems: Patch contrast.
According to Cadanasso bounded systems can differ in architecture, composition, or process; the nature of the bounded system defines the characteristic or characteristics used to differentiate patches. For example, if patches are described as forest and nonforest, then the contrasting architecture of the plant community defines the patches[24]. Contrasting composition can also refer to chemical or bio-physical composition, such as the contrast between land and water. The contrasting composition of patches may support different / multiple processes[25]. An open question is how boundaries, defined by contrasts in architecture, composition, and process, are similar or different in structure and function[26].

iii. Nature of the boundary: Boundary structure.
The third component of the framework is the nature of the boundary, which encompasses features of the boundary that influence flows crossing it and, consequently, flows between contrasting patches as seen methodically in the previous section. A boundary influences flows because of differences in architecture, composition, or symbolic or perceptual features. The architecture of a boundary is its three-dimensional structure composed of biological or physical features. Physical features of boundaries can also modulate flows between adjacent patches. Thermoclines in the water columns of lakes act as boundaries between patches of water, affecting flows of organisms, nutrients, and particles. Organismal movement may be influenced by the gradient in water temperature across the boundary, and the flow of particles may be influenced by the gradient in water viscosity, density, and turbulence. Compositional differences such as those between patches of deciduous and coniferous forests may slow the spread of host-specific pests, or may be reflected in different nutrient cycling rates in the soil[27]. Perceptual and symbolic boundaries include signals (auditory, visual, or chemical) that may indicate to the different organisms that a predator warning or signal that they are entering enemy territory.

23. Ibid.
24. Ibid.
25. Ibid.
26. Ibid.
27. Ibid.

Time Scales (adapted by Turner et al, 2001)



Temporal dynamics.
Traditional cartography representation techniques have represented boundaries as snapshots of a boundary structure at a given time moment often creating the false impression that boundaries are static and do not change over time. As seen, in fact, ecological boundaries are dynamic entities. Both the properties as well as the location / position of a boundary may change over time, affecting respectively its spatial and structural properties. Strayer proposed two basic questions for investigating and analysing temporal dynamics of boundaries[28] which are :

1. The ***variations*** of position, structure, and function of the given boundary over time
2. The age and history of the boundary

The position of a landscape boundary may appear as ***stationary*** over shorter time periods, or it may as moving when observed at longer intervals. Movement may be ***directional*** (e,g. a forest expanding into a neighbouring field,), ***oscillating*** (an estuary limit moving with tidal and regular seasonal changes), or ***irregular*** (a climatically determined boundary between biomes moving in response to a fluctuating climate change). Further, a change in the location or properties of a boundary may be ***predictable*** or ***unpredictable***[29] based on the researcher´s point of view or capacity to successfully model it .

On another level the age and history of a boundary may also be key components in understanding its function and dynamics. Some boundaries are ***ephemeral*** (e.g. films around bubbles), while others are ***ancient*** in origins (continental margins, boundaries between biogeographic provinces or geologic formations). Because the effects of a boundary may be ***cumulative***, the age and history of a boundary may indirectly determine its functional properties as well as the local ecological conditions developing respectively around and along the boundary. Thus, both the function and the structure of a boundary can be considered as being directly dependent on the age and history of the boundary[30]. Understanding temporal effects on ecotonal areas can also help explain the observed variability in ecotonal responses[31]. As this variability increases, it becomes more complex to identify boundaries and more importantly apply physical models that are consistent and coherent. Nevertheless, the classification of boundary function should be expanded to include the formentioned variability factor, given that both boundary functional structure or distinct structural features can demonstrate temporal behaviour[32].

28. Strayer et al. (2003)
29. Ibid.
30. Ibid.
31. Ries et al, 2004
32. Cadenasso et al (2003)

The literature on ecosystem development and their self-organizing and emergent properties has largely viewed implicated systems as discrete entities with limited interaction with adjacent systems. However, coupling the formentioned hierarchy theory with the thermodynamic theory and concepts can lead / guide to conceptual advances in understanding ecological boundary development and dynamics[33]. On the other hand, boundary studies are often ***synchronic***, placing the most emphasis on contextual and spatial aspects of boundary systems[34]. In this context, the next section will briefly investigate potential implications arising from a combined outlook.

This section intended on a first level to collect and compile through the past research all the different terms and descriptors utilized for classifying ecotones, in their different manifestations and across the various spatial and temporal scales that they exist. As seen from the research of the current state of the art on ecotones, there already exists a terminology for describing the spatial and physical characteristics as well as the function and processes (biotic and abiotic) taking place within the ecotone influence zone. The use of these terms in past research although varied and often diverting (often resulting in terminological confusion), today with the systematic effort of diverse research efforts it has been consolidated and formulated into a more coherent methodological framework for analysing and ecotones, that at the same time permits describe the wide-scale of phenomena that the ecotone concept has come to encompass. On a second level it also aimed to develop and compile a descriptive vocabulary for describing ecotones and for posterior utilization in the analysis of the Thessaloniki case-study. Through the case study analysis, these concepts will be made explicit and allow solid hypotheses to be generated and tested. At the same time the use of research-standard vocabulary will help make the results *extrapolat-able* and transferable to other similar case studies or relative analyses. Resuming, a list of the general characteristics of the ecotones is provided in continuation. Thus ecotones :

- are characterized by three-dimensional spatial characteristics, including the space above and below the ground surface.
- are time and scale dependent.
- can host a vibrant edge activity (diversity & intensity of flows / species).
- can be unpredictable, incorporating improbability in their design.

33. Yarrow, M. M. & Salthe, S. N. (2008)
34. Ibid.

Ecotone structure and function - *summary table*

3D	Scale	Time	Pr	i	Inter
structure	size	dynamic	variable	indicator	interface

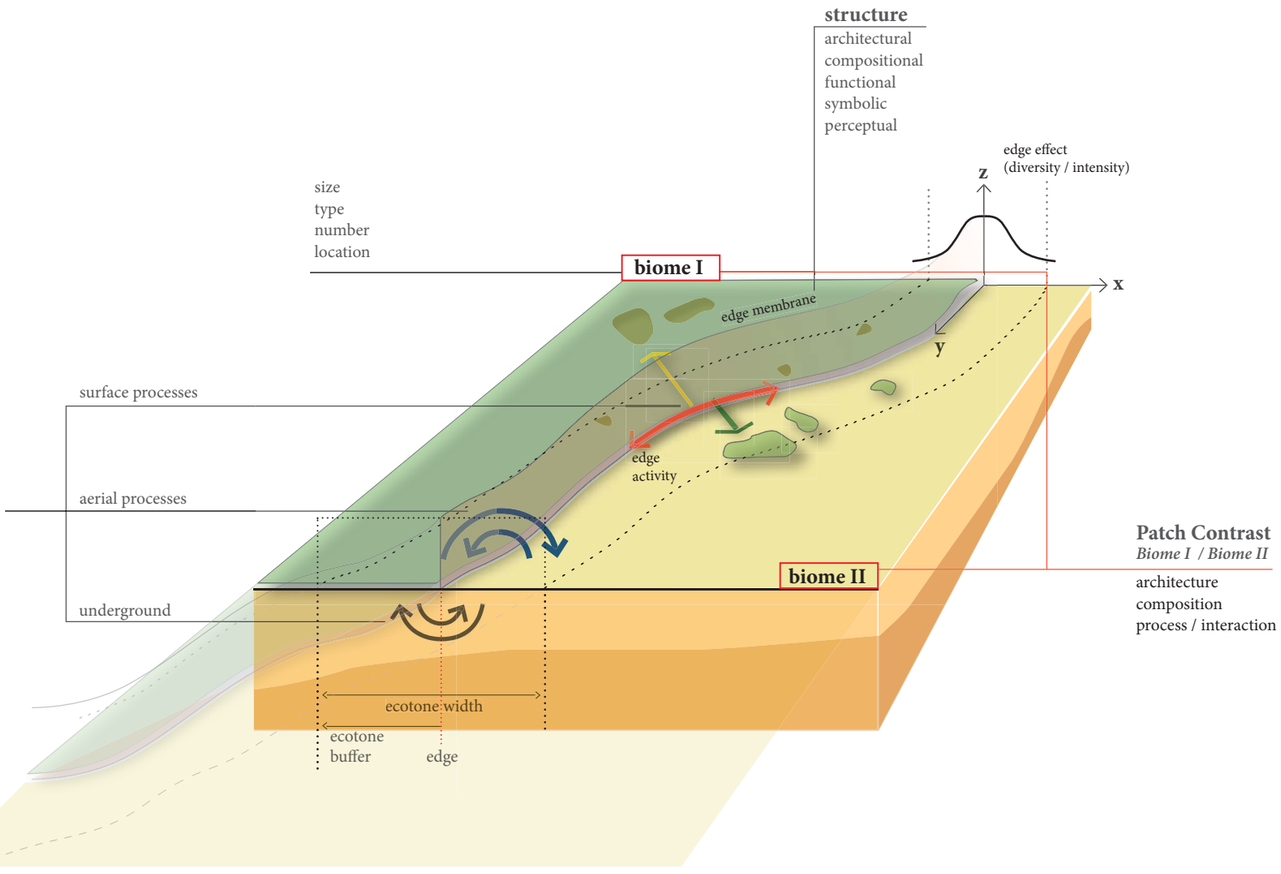
Causality in boundary systems

(adapted by Yarrow, M. M. & Salthe, S. N. (2008))

Synchronic		Diachronic		
Material	*Formal*	*Efficient*	*Final*	
Seed bank, genetic diversity of populations	Species interactions, patterns of landscape flows	Propagation from neighboring systems, key species' activity	Accumulation of genetic diversity, food-web complexity, tight nutrient cycles.	Infomation
Nutrients, substrate	Structural differences between neighboring systems, abiotic gradients	Physical disturbance patterns: floods, wind, landslide, human impact	Creation of dissipative structures	Material
Solar radiation, biomass	Differences in energy capture, flow rates, and entropy production between neighboring systems	Solar radiation changes and photoperiod, import of biomass	Creation of dissipative structures	Energy

Types of flow

organisms
matter
energy
information



- can have membrane like functions acting as interfaces of flows (organisms, material, energy & information) and having metabolic functions.
- can be zones of opportunity if interpreted and managed properly.
- can serve as indicators of spatial dynamics / change (climatic, metabolic etc.)
- are essential components of the landscape´s / mosaic´s resilience structure.

Future research should focus on how to take advantage of edge effect characteristic of ecotones to reprogramme them positively as territorial interfaces the development of ecosystems, surpassing the static definition of ecotones and advancing with the framework that incorporates temporal dynamics[35]. Although much progress has been made in describing how edges influence spatial distributions at local scales, there is a research need to be able to extrapolate ecotonal responses to larger scales that have been studied less. An additional knowledge on edge responses can contribute meaningfully to the management and conservation strategies, particularly in landscapes undergoing rapid and drastic change such as urban regions and their respective ecotonal areas.

One of the questions that are central to this paper, but also contemporary research focus is the one relating to the human impact on boundaries through activities that alter natural boundaries or create anthropogenic boundaries[36]. Such anthropogenic ecotonal areas can have unique characteristics, sometimes unparalleled in nature but nevertheless provide the opportunity to assess how the structure and function of anthropogenetic ecotones compare with those of natural boundaries. The urban region provides an opportune setting for investigating the interaction of human and natural factors in the creation and maintenance of boundaries, aiding in our further understanding of the functioning of cities as urban ecosystems of a larger territory.

35. Ting, Z. & Shaolin, P. (2008)

36. Cadenasso et al (2003)

V. Thermodynamic territorial processes.

There are two approaches to defining a concept. The first is to articulate a definition that attempts to be as inclusive as possible. From that definition, frameworks can be constructed to organize ideas and data and to provide a structure for operationalizing the definition in particular situations. The second approach is to ask how the concept can be quantified.

Researchers like Ulanowicz have claimed that the western narrative on and about nature had followed predominately monistic scripts, where entropy is maximized; efficiency is maximized; the Hamiltonian of a trajectory is maximized, costs are minimized and so on. But through his analysis he inferred that the universe is dualistic, rather than monistic in its dynamics[1]. Clinging on to this monism paradigm he said was likely to prove counterproductive and insisted that the appropriate metaphor for the course of nature was less the headlong drive towards an endpoint and more of *a nuanced interplay between agonistic tendencies*, evoking the Hegelian dialectic or the eastern Yin and Yang scheme[2]. It had been thought that the development of an ecosystem would traverse a wide range of states, culminating in a climax community characterized by a relatively higher value of order. Rather, it now appears that the various successional stages of any ecosystem maintain a narrow overall balance of concurrent ***organization/disorganization***. All living systems are poised near criticality and it is *impressive* how narrow is the range of complexity within which these living systems will thrive[3].

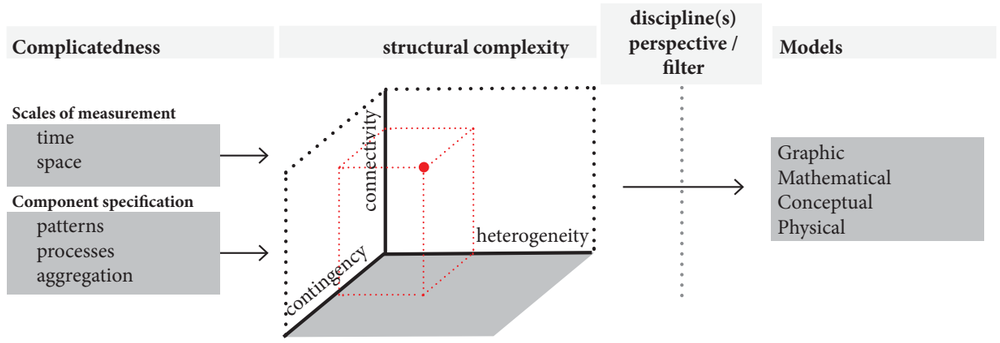
Living systems are capable of using metabolic energy in order to maintain or even to increase their levels of organization and this proper dynamic structure of living beings allows them to transfer energy while at the same time maintaining their organized complexity. Beyond the maintenance of a far-from-thermodynamic equilibrium organization, successful evolution also entails that living structures cast / project themselves into the future by means of reproduction and exchange of information. In this sense, a living being is a highly sustainable system in itself and by default. The thermodynamic model of an organism bears strong similarities with the functional structure of ecosystems, providing useful criteria to what may be understood as sustainability [4]. The use of energy parametrization to describe the process of self-organization of ecosystems and human societies was pioneered by H.T. Odum starting in the late 50's. Odum extensively analysed the use of embodied energy to define values for energy flows, studying the formation of hierarchical structures, the stabilizing effect of feed-back loops in dynamic systems and the emerging natural trends of self-organization of matter and the subsequent transformation of energy into information[5].

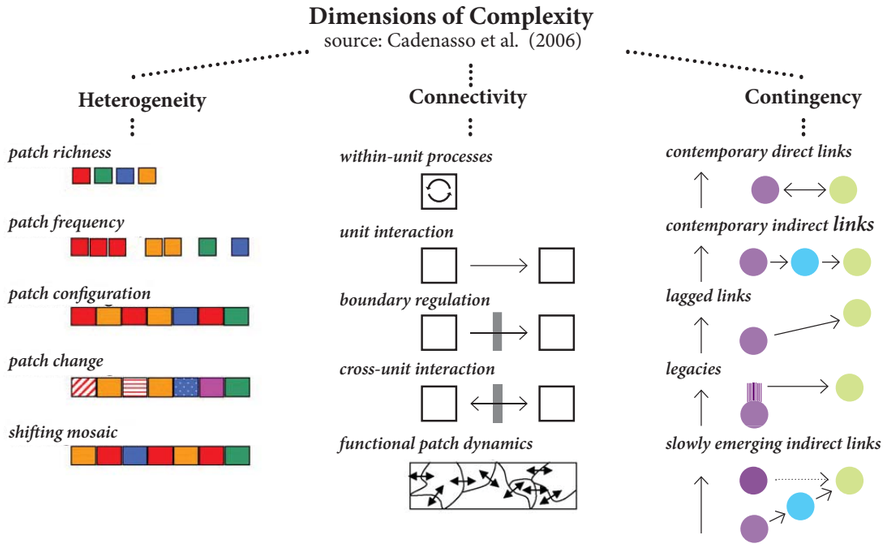
Accordingly considering the landscape as a system, the land matrix can defined as a space-time structure, (a chora) resulting from the physical environment, the biological component, its functional relationships and anthropogenic transformations which are expressed in specific land patterns[6]. Considering the land-use and land cover patterns as a single complex evolving system, an ecosystemic method can be chosen to study it in a historical perspective where the land matrix can be seen as a heterogeneous, dynamic and multi-scalar system organized in hierarchical levels of complexity depending on their space-time scale[7]. In order to understand the organization of this complexity, and its evolution, it is necessary to use a systemic approach that takes into account the main factors that typify landscape patterns in a global and at the same time integrated manner [8]. Recently, several studies are reassessing the role played by traditional knowledge and practices that ensured adequate strategies for the management and the conservation of territorial landscapes[9] . However, the role played by energy and material throughputs moved by social metabolism as a driving force of contemporary land-use changes is still not well understood[10], and will be looked in more detail in continuation.

Classically, the increase of entropy in a system implied an inevitable dissipation of energy and materials into what is known as *heat death*. The entropy of an isolated system never decreases, because isolated systems spontaneously evolve towards a state of thermodynamic equilibrium, which is the state of maximum entropy. Under non-equilibrium circumstances on the other hand the production of order becomes an inevitable feature of increasing entropy[11]. The dissipation of energy within an open system not in equilibrium, generates not only waste, but *also self-organization which in turn implies the maintenance of complexity in the system*[12]. A society that dissipates increased amounts energy than it earlier states while

1. Ulanowicz, R.E. (2009)
2. Ibid.
3. Ulanowicz, R.E. (2009)
4. Ulanowicz, R.E. (2003)
5. Odum H. T. (1988)
6. Margalef (1968) in Marull et al, (2010)
7. Marull et al, (2010)
8. Margalef R. (1991)
9. Farina A. (2000), Agnoletti M. (2006), Tello et al (2006)
10. Haberl, H (2001)
11. Ulanowicz, R.E. (2009)
12. Giampietro M. & Pimentel, D. (1991), Morowitz, H.J. (2002)

Biocomplexity framework, adapted by Cadenasso et al. (2006)





maintaining stability over time can be considered as maintaining a higher level of complexity in its structure/ function. This dynamic system of human society and natural environments can take on different configurations of dynamic equilibrium as well as dissipating different quantities of energy. For example, contrast a society of hunter-gatherers which has a low energy investment and a low energy return with an industrial society which makes a higher energy investment and receives a higher energy return[13].

The complexity theory is thus the precursor to more contemporary concepts such as ***bio-complexity***. The original complexity theory was driven primarily by approaches and inspiration from physics and mathematics and dealt with the task of assigning properties to complex systems or better yet to say to characterize complex behaviour rather than systems[14]. Simple systems, in many cases. can exhibit complex outcomes similar to complicated structures. And thus, the real issue / question is to assess / evaluate how simple systems can come to produce complex behaviours. The behaviours of interest include non-linear behaviours, self-organization, and emerging structures and properties. As a general and common conclusion it can be asserted that bio-complexity can be understood in three distinct and at the same time interrelated ways [15]:

A. As the structure of a system of interest;
B. As emergent, non-linear or self-organized outcomes;
C. As a highly connected explanation or model.

and comes to be defined as [16]:

> *Biocomplexity of a structure is the degree to which ecological systems comprising biological, social, and physical components incorporate spatially explicit structure, historical contingency, and organisational connectivity. In this definition, we use three axes of bio-complexity recognized by earlier authors spatial, temporal, and organisational. We further emphasize cross disciplinary integration, which will be particularly important in systems that are complex because of coupling natural and human components.*

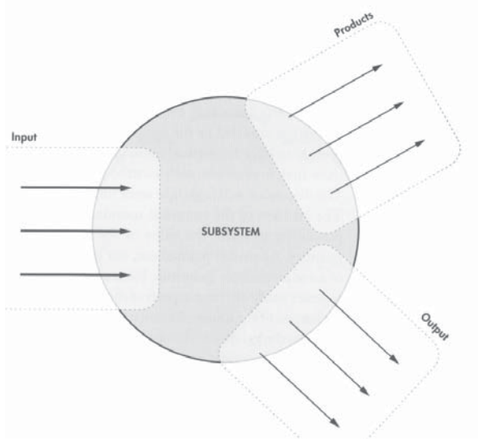
13. Giampietro M. & Pimentel, D. (1991)
14. Costanza et al., (1993); Cadenasso et al (2006)
15. Cadenasso et al (2006)
16. Ibid.

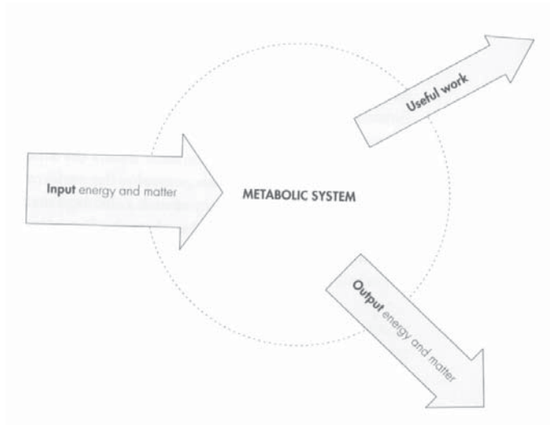
Landscape complexity is manifested in nature as an expression of the dissipation of energy in space which eventually leads to the formation of self-organized structures, and also to a historical successions[17]. But when humans increase the dissipated energy beyond an accepted level, the complexity of the system is reduced and environmental degradation becomes inevitable [18]. Ramon Margalef, the Catalan ecologist, contributed greatly to clarifying the theoretical basis for understanding the fact that the sustainability of ***human development is a direct function of its complexity, and an inverse function of its dissipation of energy***[19]. Today, the need to resort to external biophysical flows and the simultaneous abandonment of integrated land-use management has led to the loss of the ecological functionality and degradation of the traditional Mediterranean landscapes, as they were configured by agricultural and forest mosaics. The process of urban sprawl as experienced in many contemporary urban regions provides the extreme example, since it always seeks to increase its economic competitiveness by increasing the entropy spread to periphery environments [20].

In the biosphere an increase in entropy is associated with the acquisition of complexity, owing to the fact that living systems draw on solar radiation for their energetic needs. This supplemental and symbiotic mechanism thus supplements and absorbs what would otherwise be mere dissipation of energy while utilizing this energy to increase information and add complexity to the system. This is how, in nature, entropy combined with information increases diversity, creates heterogeneity, encouraging energy flows from the borders of simpler organisms to the more complex ones[21], where more information is accumulated. This suggests or gives hints of the importance of analysing the existing relationships between social metabolism and the functioning of the biophysical matrix in order to identify the mechanisms that link energy dissipation with the complexity of ecological systems. From a landscape ecology standpoint that complexity can be understood as the capacity of the land system to host different species and ecological processes[22]. Such a complexity evolves in the interplay between society and nature, and in order to highlight this societal link between energy or material throughputs and land-use changes it is deemed necessary to introduce the concept of landscape efficiency. *Work* is a concept related to the maintenance

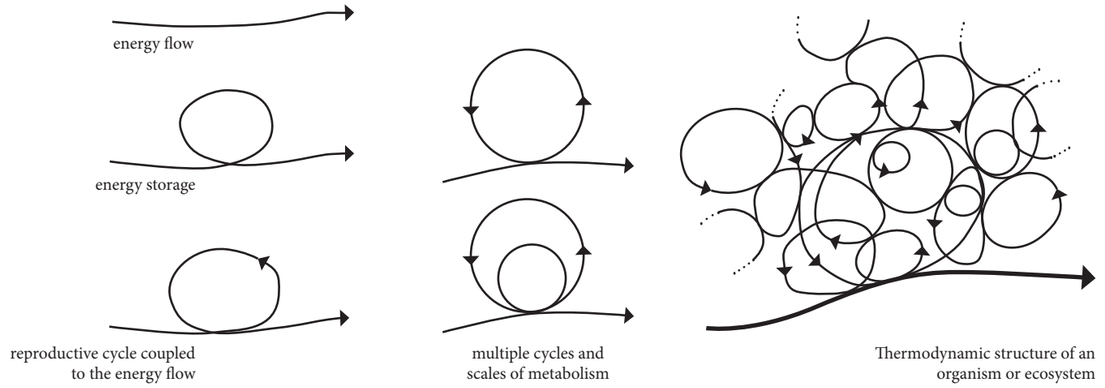
17. Morowitz, H.J. (2002)
18. Ulanowicz, R.E. (1997)
19. Margalef, R. (1991
20. Terradas, J., (2001)
21. Margalef, R. (1991)
22. Forman R.T.T. (1995)

General metabolic scheme (source: Acebillo, J., 2012)





Systems & functions (source: Marull, J. & Tello, E., 2010)



of an improbable state, and therefore cannot be assessed by measuring only the consumption of energy input and/or applied power flows. The use of thermodynamics of non-equilibrium provides a link between energy expenditures and information/ organization measurement[23]. Researchers have proposed / formulated models for describing the process of self-organization of a society by using four different steps controlled by four different parameters[24]:

1. ***Power generation cost***, referring to the ratio of conversion of the *energy input feeding the society per unit of applied power.*

2. Level of ***internal societal organization***, referring to the ratio between the applied power flow that is used in the direct interaction with the environment and the applied power flow that is used for the maintenance of the societal structure (e.g the weight of the service sector of a society).

3. Level of ***technological knowledge***, referring to the ratio between the power applied to the environment per unit of energy input harvested.

4. ***Space-time density*** of a unit of energy input, referring to the quantity of exploited space-time of environment required per capita to have a defined level of energy expenditure.

These four parameters are interdependent, linked by a feed-back loop, which means that they have to be adjusted together to able to reach a situation or condition of equilibrium. In the same manner the balance of energy flows between the environment and the society can be described as a similar dynamic process. The possible combinations between the parameters' values capable of guaranteeing an equilibrium define specific sets of values for the human population density and their levels of consumption per capita. This means that, depending on the energy chain and the technological knowledge used to feed societal needs, not all the combinations of population density and level of consumption per capita are possible. If we gain a better understanding of the relationship between the scope and efficiency of the energy flows driven by the economy, together with the complexity of the landscape structure and its ecological functioning, we may develop indicators, establish trends and recommend options so that land-use planning takes both economics and ecology into account[25].

23. Giampietro, M. & Pimentel, D. (1991)
24. Ibid.
25. Marull et al, (2010)

*Complexity in **structural heterogeneity** refers to increasingly subtle and comprehensive quantification of spatial mosaics[26]. Ecologists have described spatial heterogeneity using patches as discrete areas that differ in structure, composition, or function. The theory of patch dynamics has be en an important tool in understanding community organization, population dynamics, succession, disturbance, ecosystem function, and conservation but can also be used to evaluate complexity in ecological systems as an approach for exploring structure–function relationships[27].*

*The organisational axis of a system reflects the **increasing connectivity** of the basic units that eventually control the system´s dynamics. Within organisational hierarchies, causality can move upward or downward. Organisational complexity drives system resilience and the capacity to adjust to shifting external conditions or internal feedbacks (internal patch processes). As this interaction between patches is incorporated, complexity increases. Understanding at a first level how this interaction may be regulated by the boundary between patches constitutes in itself a higher level of complexity, which increases even more recognizing that patch interaction may be controlled by features of the patches themselves in addition those of the boundary. Finally, the highest level of structural complexity on the organisational axis is the **functional significance** of patch connectivity for patch dynamics, both of a single patch as well as of the entire mosaic.*

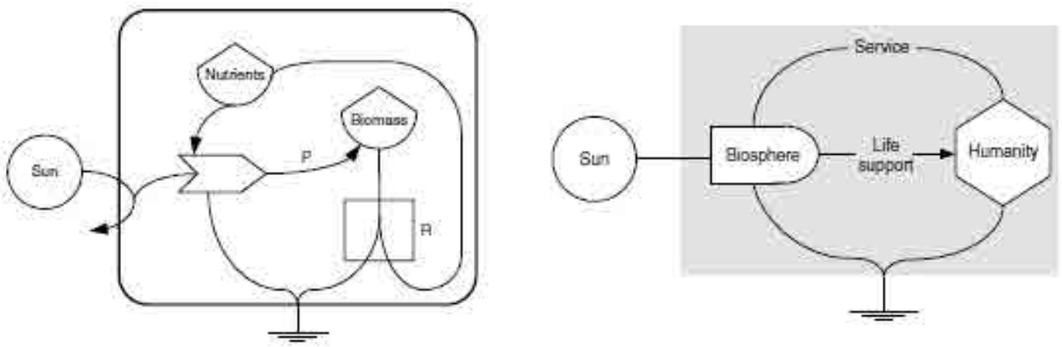
***Historical contingency**, the third axis, refers to these relationships that extend beyond direct, contemporary ones. Therefore, the influence of indirect effects, legacies or apparent memory of past states of the system, the existence of delayed or lagged effects, and the presence of slowly appearing indirect effects constitute an increasing **historical complexity**[28].*

with reference to landscape processes, a couple more considerations should be taken into account.

The ***integrity*** of the landscape units in a key factor where contact with anthropogenic habitats is primary source of disturbance for the fragmented natural and semi-natural habitats. Various studies have shown the significant and undeniable effects that urban areas and related infrastructure can cause on the structure of adjacent fragments and their inherent complexity[29].

26. Cadenasso, M.L. et al (2006)
27. Ibid.
28. Cadenasso, M.L. et al (2006)
29. Forman et al, (2003); Marull et al, (2006)

Ecosystem *(left)* & life support *(right)* models (source: Odum en Chapin et al, 2011)

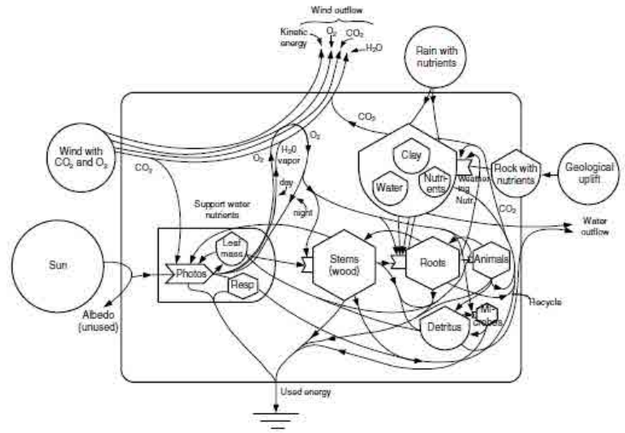


The ***vertical complexity*** of landscape units is another key factor understanding that the number of species that a landscape can host is not only result of its structural characteristics (number, abundance, biodomes´ configuration) but also consequence of the relative properties of the structural complexity of these units. In general, there is an increase in biodiversity associated with the increase in the complexity of vertical structures, from the simpler herbaceous level to those of the tree or canopy layer[30].

When it comes to describing human development, understood as a complex socio-ecological process, in energetic terms one has to additionally consider possible definitions that describe the notion of technological development, as the ultimate manifestation / expression of human ecosystem complexity. ***Technological capital*** is defined *as the product of the level of energy dissipated per kg of human in the society and by the density of humans in the ecosystem*[31]. The maintenance of humans at a high level of ***energy dissipation*** (W/kg) is assumed to be a direct measure of the complexity of the society. In this manner, the introduction of exo-somatic ways of using energy, such as fire, could be considered as the first jump in the technological evolution of mankind. The ***density*** of humans (kg human per area of ecosystem) is the second factor defining and conditioning the technological capital. With agriculture, humans were able to make a second technological jump, increasing their density in the ecosystem. Thus, the density of energy throughput per unit of area, is considered to be an indicator of the level of technological capital of a society (W/m^2). The level of technological capital of a society thus measures the relative improvement in the complexity of a society in absolute terms and without necessarily taking into account the stress on the environment[32]. The energy flows of a large city in a western context is a thousand times greater than the energy flows of traditional societies. Related analyses have confirmed that traditional societies that are dependent on biological flows of energy without the use of fossil energy nor technological capital, are severely limited in their future development, where the population and its level of consumption per capita cannot increase while exploiting a low density energy input. This means that the development of populated developing countries based solely on agriculture is limited: the density of energy dissipation within developed countries is higher than the density of energy input provided by the most productive agricultural crops[33].

30. Marull et al, (2006)
31. Giampietro, M. & Pimentel, D. (1991)
32. Ibid.
33. Ibid.

Terrestrial Systems (source: Odum en Chapin et al, 2011)



When considering the technological capital question in the urban context, it is necessary to additionally consider the information and knowledge society that is precisely articulated through the inherent urban complexity and is at the same time a direct indicator of its order. The increase in complexity attracts individuals, carriers of information that accordingly increase the diversity and density of information creating a determined critical mass. The physical and functional structure : buildings, technology and networks and related infrastructure supports and increases the interchange of information and knowledge[34]. The information flows, similar to metabolic flows, should be integrated in urban development policies, taking into consideration the compatibility of uses and functions that provide an increased mixicity and the spatial distribution of information in the diverse urban elements[35].

By comparing the technological capital or energy dissipated by human activities, with the density of the energy input that the society is exploiting, the relative ***technological efficiency*** of that society can be defined. There is no direct correlation between the level of technological development of a country and this assessment of technological efficiency[36]. In fact, the task of improving technological efficiency depends on the degree of availability of natural resources per capita and on the societal perception of the stability risk; always in relation with the time scale selected / adopted to analyse due processes. If huge stocks of exploitable resources are available, it may seem convenient to invest in harvesting the large flow of resources with parallel high losses, instead of investing in the improvement of harvesting techniques. Obviously, the low efficiency in harvesting would adversely affect the sustainability of the exploitation process by increasing the rate of stock depletion[37]. The existence of these two hierarchical levels and two time scales based on which the same process can be assessed (***ecological & economic levels***) induces a certain ambiguity in the judgement and respective decision-making process[38]. However, the parameter / concept of technological efficiency is predominantly related to the question of the overall stability of the system, highly-concerned with processes at the ecological level that maintain this territorial stability. Respectively it is looked in more detail in continuation.

34. Rueda, S. (2007)
35. Ibid.
36. Giampietro, M. & Pimentel, D. (1991)
37. Ibid.
38. Ibid.

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Social metabolism of the territory

Disturbance and fragmentation are two processes strongly related making it hard to distinguish the role and the rate of the interactions. These two processes are mainly responsible for heterogeneity in the (landscape) mosaic since these processes have effects and are related to many other abiotic and biotic processes in different hierarchical levels of functions and patterns[1]. Disturbance occupies a pre-eminent position in landscape functioning and is the main process responsible in shaping landscapes and their components[2]. Accordingly:

> *The term **disturbance ecology** is referring to any discrete natural or anthropogenic event in time and space that might alter the structure of populations, communities, and ecosystems, and/or change resources, substrate availability, or the physical environment [...] In order to maintain these 'culturally-frozen' landscape patterns and ecological processes, a society needs to spend certain amounts of human labour and/or physical work that can be accounted for as 'external' energy. The impact on biodiversity of this landscape 'disturbance ecology' may be either positive or negative depending on its intensity and territorial shape. Owing to the ecological hypothesis regarding the role of **intermediate disturbance** in ecosystems, cultural landscapes may increase environmental resilience*[3].

The historical human exploitation of the environment can thus be explained and understood in terms of and as ***disturbance ecology***. When the increase in dissipated energy reduces the complexity of the system, environmental degradation becomes its most tangible evidence / manifestation. By contrast, the human adaptations to the environment that have proven to be the most long lasting are those that have been able to reproduce the basic reticular pattern of ecosystems by means of exosomatic energy and appropriate technologies[4]. The impact on biodiversity of this landscape disturbance ecology may be either positive or negative depending on its intensity and territorial shape. According to the hypothesis of the 'intermediate disturbance' in ecosystems, cultural landscapes respectively may increase environmental resilience through their historic activity and that throughout the historical interaction between societies and nature there has always been a close link between the use of energy, land-use management, and the landscape ecology of humanized territories. From this socio-ecological point of view, landscape can be seen as ***the expression of the metabolism that any society maintains with natural systems***[5]. However, the role played by energy and material flows generated by social metabolism as a driving force of contemporary land-use changes is still not well understood. In the dynamic interaction between humans and their environment, the allocation of energy resources can be distorted by the existence of non-linearity in the processes that provide energetic returns for human activities. This suggests that relationships exist among thresholds of power, level of complexity of the system, and its size[6]. Clearly, the relationship among these parameters can affect the feasibility of technical solutions. As an example, a calorie invested as energy input in a small system, which has a lower level of power, has a lower effectiveness than a calorie invested in the industrialized system with a higher level of power[7].

Ecologists today consider the land matrix as a system consisting of discrete subsets; the physical environment, the biological component, its functional relationships and the anthropogenic transformations that manifest in particular tangible and intangible landscape in such a way that the energy and information flows, results of the metabolic exchange of the economy can be analysed in relation with the physical environment so that to understand the ways in which human intervention modifies landscape patterns and gives rise to different territorial / spatial phenomena[8]. In order to consider this multiplicity of criteria under a dynamic perspective, there is the vital task of linking energy flows with land-use dynamics and ecological functioning. In an organic-based economy, which depends on photosynthesis to grow almost everything, the larger the population density and volume of trade were, the more necessary it became to manage the local land matrix with the utmost socio-metabolic efficiency[9]. Thus any social metabolism based on solar energy is always area-dependent in a local or bio-regional sense (the well being of the population being directly dependent on land or energy management strategies)[10]. The substitution of that land-based solar energy system by the contemporary one based on burning underground fossil fuels on a large scale has enabled society to overcome the age-old energy dependency on bioconverters and as a result, efficient and integrated land-use management ceased to be a need at a local or regional scale[11]. Thus, one objective for the analysis of the energetic metabolism of societies is to understand the relationship between societies and their natural environment. Haberl H. described this transformation in the metabolic relationship between society and nature from the early hunters to contemporary industrial societies[12]:

1. Farina, A. (2006)
2. Farina, A. (2006)
3. Farina, A (2000), Marull et al, (2008)
4. Marull et al, (2008)
5. Ibid.
6. Giampetro et al (1991)
7. Ibid.
8. Marull et al, (2008), Costanza et al (1997)
9. Marull et al, (2010)
10. Marull et al (2008)
11. Krausmann et al, (2003)
12. Haberl, H. (2001)

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source:
1-4. greekscapes.gr
5. aiphotos.gr
6-7. buildnet.gr

The energy system of ***hunter-gatherers*** has been described as *an uncontrolled solar energy system*, because hunter-gatherers utilize suitable and accessible energy resources for nutrition and other purposes more or less in the form and rhythms in which the ecosystems delivered them and no significant systematic and intentional attempts are made to change and control ecosystem functions processes in order to render them more *productive* in socioeconomic terms.

Agriculture respectively lead to a fundamentally different type of relation between society and its natural environment. This type of society-nature interrelation is not only characterized by a considerably higher throughput of energy and materials than of hunter-gatherers, but also by a change of attitude pushing toward the intentional transformation / modification of parts of the natural environment so that to render them more productive / useful for societal needs. This has been termed as colonization of natural systems and is part of the succession phases of interactions between natural and anthropogenic ecosystems. This colonization includes diverse activities that alter and control important parameters of natural systems, often with the goal of producing materials (e.g. biomass) or harvesting / releasing energy.

The transition from the controlled solar energy system of agricultural societies to an ***energy-system powered by area-independent energy,*** fossil initially and later supported by large-scale hydropower and nuclear energy was a prerequisite for the industrial revolution. Although cause and effect may be debatable, we know for certain that this transition toward industrial society was associated with a fundamental change in the patterns of societal energy use. The result was an industrial energy system that was no longer linked to or constrained by the productivity of terrestrial ecosystems demonstrating that industrial energy metabolism is independent of ecological energy flows. The whole industrial revolution can be understood, in his view, as a dramatic increase in human ability of controlling energy flows[13]. These numerous environmental problems that arose were fundamentally different from those experienced by agricultural societies, and this difference depends, to a large extent, on the difference in size and pattern of the energetic metabolism between agricultural and industrial societies.

The empirical calculations presented by Haberl suggested that transformations between the different *modes of subsistence* (hunter-gatherers, agricultural societies, industrial society) are associated with qualitative and quantitative leaps in societal energy metabolism[14]. Analysed as per capita flows, these transformations are also associated with an increase in the amount of energy withdrawn by societies from their natural environments and an even higher increase in the amount of energy available. This increase in energy availability is parallely associated with a dramatic increases in the complexity of social organization[15]. Whereas discussion of the relation between societal energy flows and social organization has been in debate for some time, the usefulness of societal energetic metabolism for analysing the interactions between societies and their natural environments seems to have been less contemplated and contested. As empirical evidence have shown, changes in patterns and amounts of per capita energy throughput are intimately linked to subsidence problems of human societies and thus in this respect it is essential to be able to measure the total *amount of energy metabolized by society*[16] to be able to account for the different processes taking place. This means that societies based on machine power can maintain a structure able to provide high power levels, and are therefore able to face high power thresholds. The opposite is true for systems based on metabolic energy. Rural villagers will opt for a pattern of agricultural activities that minimize peaks of labour requirement and keep the number of animals used to power these activities to a minimum[17]. Analysing societies in this way suggests two factors that can be optimized for development [18]:

1. The level of rotation of energy investment understood as the final level of energy expenditure per capita in a society that has reached an energy equilibrium.

2. The stability of this equilibrium translated in the resilience of the society structure and function in occasions of internal or external perturbations. An equilibrium at a high level of energy investment will require more stability in its boundary conditions (a higher flow of negative entropy in order to maintain equilibrium).

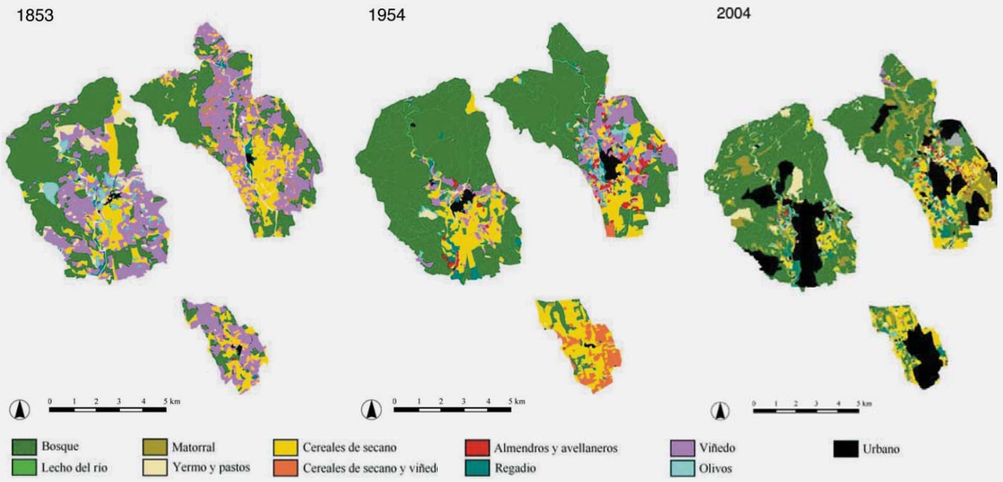
In particular, including these flows is essential for the understanding of the relation between land use and socio-economic metabolism processes, which have until recently been neglected in most land-use research. More specifically it can offer important cues with respect to phenomena related to the transition from agricultural subsistence economies to an industrial mode of subsistence, giving us cues for the successive succession phases that urban centres have or will be facing in the immediate future.

13. Conforti, P. & Giampietro, M. (1997)
14. Haberl, H. (2001)
15. Ibid.
16. Conforti P. & Giampietro M. (1997), Giampietro, M. (1996)
17. Giampietro, M. & Pimentel, D. (1991)
18. Ibid.

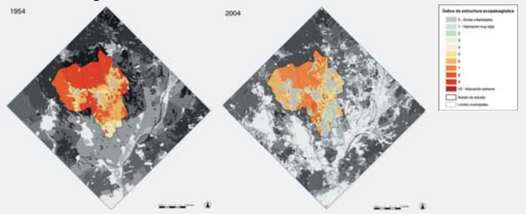
Reference research study by CREAF - UAB

Structural and functional analysis of the transformation of the agricultural landscape in the Vallès over the last 150 years (1853 to 2004)

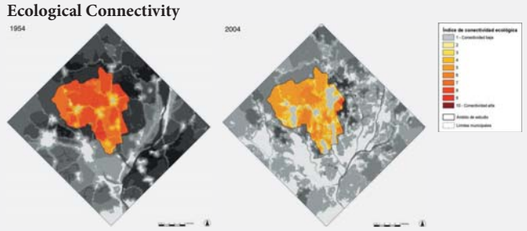
land-use patterns



Eco-landscape structure



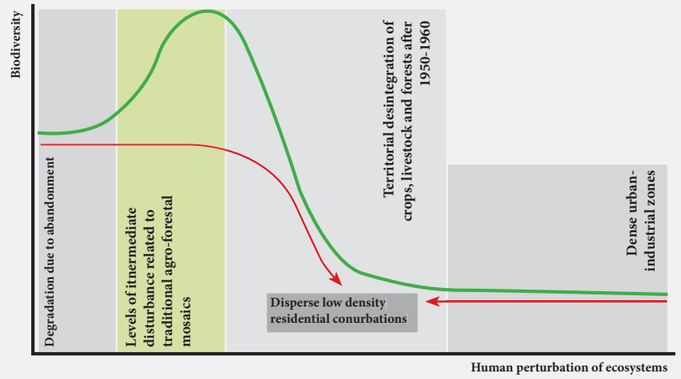
Ecological Connectivity



Social metabolism & biodiversity

The intermediate disturbance hypothesis

source: Tello, E. (2012)



Summary

When looking for specific studies that can serve as exemplary case-studies that have methodically analysed & quantified the concept of territorial / landscape efficiency is the one conducted by CREAF of the Universidad Autonoma de Barcelona. The key point that is of interest for the purpose of this paper as well is the intend to provide a serving definition / model for the relationship between societies and their environment establishing the spatial links between societal use of energy and corresponding land-uses, incorporating ideas from notable thinkers such as Ramon Margalef or Fernando González Bernáldez. The research departed with a clear interest in traditional agro-forestal mosaics, typical in the mediterranean context and thus the main empirical aim of this paper was to test the hypothesis that *what lies behind the deterioration in the energy yield of agro-forestry systems, together with the current crisis of a rural world that has lost its age-old capacity to manage the territory in an integrated manner, is a considerable loss of landscape efficiency associated with land-use changes in the structural patterns and ecological process of the landscape*[1].

The case study comprised of five Catalan municipalities in the Vallès county with a common extent of 13,488 hectares: Castellar del Vallès, Caldes de Montbui, Palau-Solità i Plegamans, Polinyà and Sentmenat, located in a small plain situated in a tectonic basin between Catalonia's littoral and pre-littoral mountain ranges[2]. The results obtained from the analysis of the five municipalities demonstrated that the drop in the energy efficiency has gone hand in hand with an important topological inversion of the traditional landscape patterns, where built-up areas and infrastructure sites go occupying an increasing space in the land matrix while the rest of the landscape and its functions tends to remain residual.

> *"The old agrarian mosaic has disappeared and a lot of the best agricultural soils have been built-up. The main energy flows of this unhinged social metabolism go across the territory as if it were only an inert base. Once again energy inefficiency is closely related to an inefficient and unsound land use that entails unsustainable ecological consequences... The end of this old Mediterranean agrarian mosaic has impoverished the ecological structure of landscape, and its biodiversity."*[3]

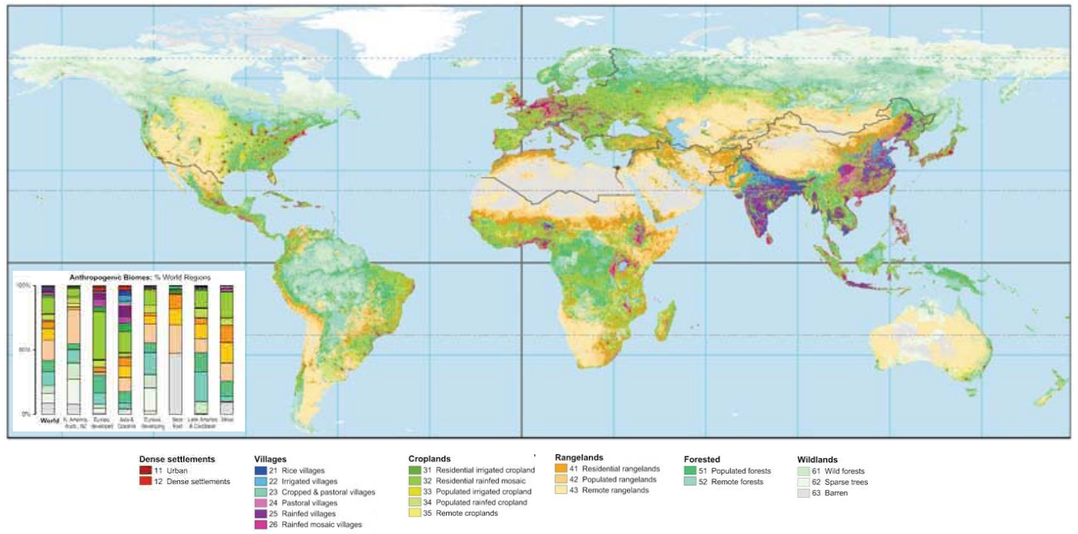
Thus it can be assumed that past organic agrarian systems were energy efficient largely because rural communities managed their land efficiently[4]. The key feature to attain such a high energy performance was the close integration between the three main agrarian spaces: *cultivated, pasture and wood lands*[5]. A healthy landscape ecology was therefore a corresponding side-effect of this land-use efficiency[6].

> *"The changes observed in the structure of the land matrix over the period under study, from the mid-19th century to the present, suggest that the possible cumulative effects on the ecological functioning of the landscape may be particularly sharp. The implementation of landscape metrics reinforces such a thesis: the potential relationship, the ecological ecotony and the territorial integrity indicate a loss of the functional capacity of the territory as a habitat during the period under study. Likewise, the connective capacity of the territory is also affected by those changes, as shown by the decrease in the number of functional ecological areas or the increase in the degree of affectation due to anthropogenic barriers. As a result a quantitative and qualitative simplification of ecosystems ensues. The loss of ecological functionality in landscapes whose structure of land mosaics has broken up becomes apparent in its lack of capacity to host and connect essential processes for conservation."*[7]

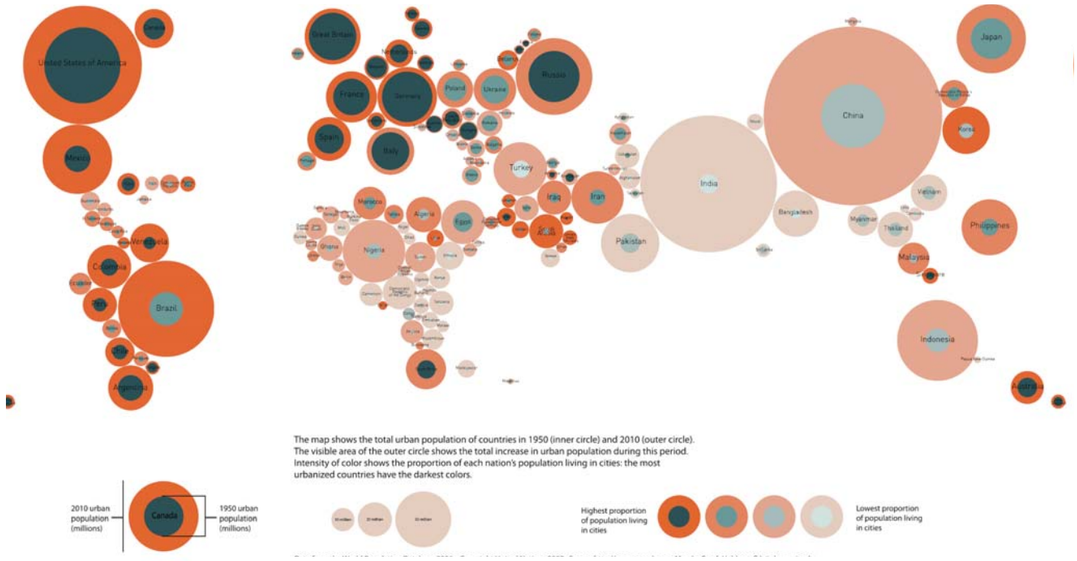
Summarizing, this study by CREAF serves as a key reference in its intend to tackle the need to use methods and concepts that allow the socioeconomic land development to be in synch with the landscape ecological functioning. In the same spirit it aims to establish guidelines for both land-use planning and strategic environmental assessment, bearing in mind a better historical perspective of the prevailing dynamic trends of the landscape integrated with the ecological economics through an accounting and consideration of socio-metabolic flows (historic & contemporary) in the territory[8]. It´s contibution in aiding towards a more meaningful and integrative definition / concept of territorial / landscape efficiency is undeniable and of great value.

1. Marull et al (2010)
2. Tello et al (2006)
3. Ibid.
4. Marull et al (2010)
5. Tello et al (2006)
6. Marull et al (2008)
7. Marull et al (2010)
8. Ibid.

Anthropogenic Biomes (source: Chapin et al, 2011)



Urban population 1950-2010 based on the UN World Population, 2006 (source: Frank Hebbert)



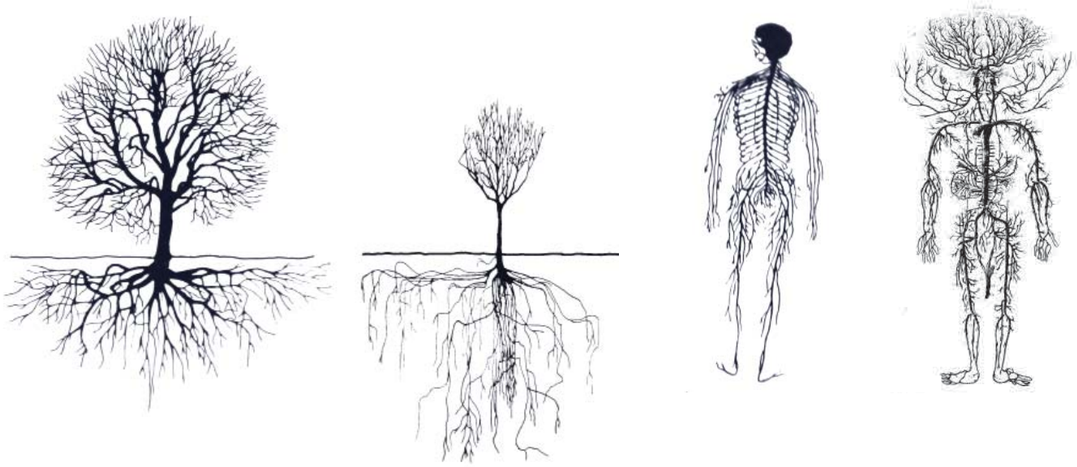
Given the current state of the art related to anthropized ecosystems, a critical point has been reached where it is possible to describe the relations between the ***biophysical structures of society*** and ecosystems in a similar way that system ecologists describe and define the distinct ecosystem components, offering the possibility of exploiting ecological concepts and methods while placing human activities in an ecological context. Heterogeneity is an inherent character of the land mosaic that can be defined *as the uneven, non-random distribution of objects* whose analysis is of fundamental importance to understanding most of the ecological processes and functioning of complex systems such as landscapes[19], natural or anthropogenic. This pattern exists at any scale of resolution and can be considered as the structural substrate on which the biological diversity can develop more easily. ***Heterogeneity*** and ***diversity*** are two related concepts in landscape ecology, but while diversity describes the different qualities of the patches, heterogeneity represents the spatial complexity of the mosaic[20]. Heterogeneity may be initiated or exaggerated by way of biological interactions with the environment. Local factors / conditioners determined by contemporary local characteristics as well as the past site-related history are relevant contributors to spatial heterogeneity. In the Mediterranean region, heterogeneity in general is positively correlated with biodiversity[21].

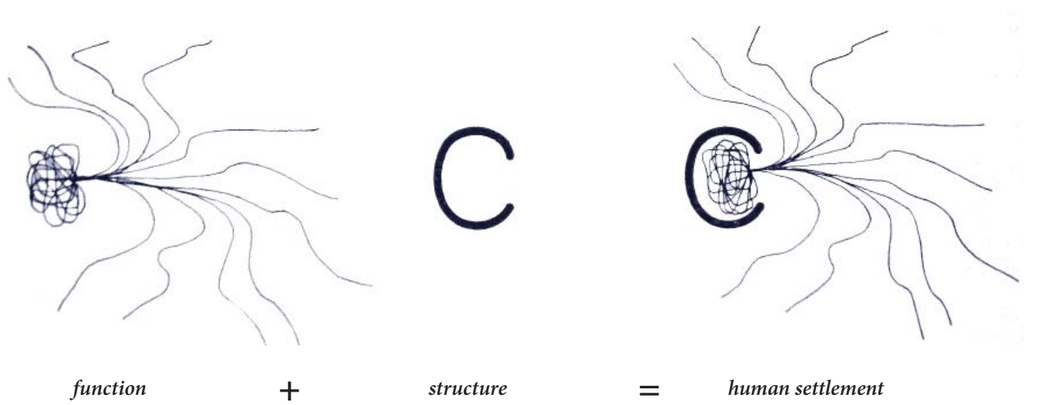
On the other hand, societal metabolism can also be related to social activities incorporating them in the spatial function of the territory. Therefore, the societal metabolism approach is both a theoretically appropriate and an *empirically promising strategy for analysing the relations between human societies and their natural environments a core field of inquiry in industrial ecology, ecological economics, and human ecology, especially in the context of sustainable development*[22].Recent research has concluded that the loss in energy yield goes hand in hand with significant anthropogenic modifications to the landscape structure and composition, and giving rise to phenomena such as increased land fragmentation ,reduction of grain size of patches or an increase in heterogeneity associated with a larger number of non-natural land-covers, such as urban and infrastructure[23]. Any socio-ecological assessment of this open historical link in energy and land uses must take into consideration the distinction between the driving forces that change and formulate the time-space context in which human act, and the different decision-making processes and agents present in the territory and their organisational potential[24].

Clearly, using either the thermodynamics of equilibrium or the thermodynamics of non-equilibrium, the current model of development of human society is a major concern. The increased pressure from human settlements reduce the stability of adjacent ecosystems, result in an increase of perturbations in the boundary conditions[25] and a decrease in the overall efficiency of the territorial functioning and putting at stake natural key components. Nevertheless thinking in the territory and the urban artefact in thermodynamic terms, of different spatial and time scales, enriches the current understanding of city functioning and merges the gap in integrating (even conceptually initially) the differentiated urban patches of the territory within the its biophysical matrix, both in structural and functional terms. Furthermore this applied thermodynamic perspective permits to expand discourse on metabolic processes of anthropized territories and more specifically urban regions.

19. Forman, R. T.T. (1995b)
20. Farina, A. (2006)
21. Farina, A. (2006)
22. Haberl, H. (2001)

23. Marull et al, (2008)
24. Marull et al, (2008)
25. Giampietro, M. & Pimentel, D. (1991)





source: Doxiadis, C. A (1969)

The urban region as a socio-ecosystem

The world's cities occupy about 2 per cent of global land surface, use 75 per cent of the world's resources and release about the same percentage of global wastes[1]. In addition to its widespread global reach, urbanization has important effect /impact on regional landscapes. For example, in industrialized nations, the succession of land from wild and agricultural uses to urban and suburban occupancy is growing at a faster rate than the actual population in urban areas[2]. Cities are no longer compact, isodiametric or concentric aggregations; but rather expand / sprawl in fractal or multi tentacular configurations, in surface and height and consequently coming in contact and interacting with natural lands, habitats and ecological systems. The resulting new forms/typologies of urban development interspersed within natural areas (forest, shrubland, cultivations) give rise to new urban habits, and new forms of living. As the UN-Habitat has noted repeatedly in its last reports the urban phenomenon of this century will be the megacities, high-density metropolises of more than 10 million inhabitants, functioning as hubs of trade, culture, information and industry, that eventually will be vested with such power that at many levels they will inevitably act as city-states, independent of national or regional mediation and with an added civic and governance responsibility. Today megacities are home to less than 10% of the global urban population and their recent pace of growth has been slower than that of smaller cities of 5-10 million people. However in the developing world, where megacities will be the hallmark of future urbanisation, there is an extraordinary spurts of growth in its largest cities[3].

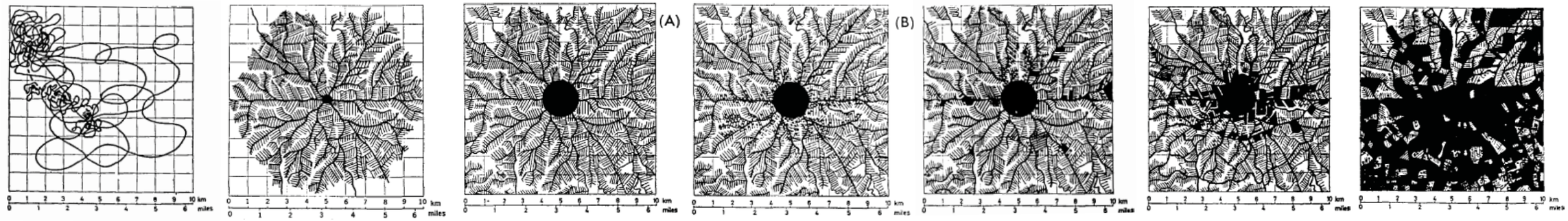
Urban ecosystems are precisely those in which people live at high densities, or where the built infrastructure covers a large proportion of the land surface or in an even broader sense, urban ecosystems are comprised by the *totality of suburban areas, consolidated fabrics, sparsely settled settlements, all connected by commuting corridors, utilities and hinterlands and directly managed or affected by the energy and material cycles of the urban core and suburban lands*[4]. As stated earlier as well, urban ecosystems can also be observed and examined as social-ecological systems. The proper essence of the city lies in the contact, the interchange, the communication between the diverse holders and carriers of information such as the individuals, the living organisms, the economic activity, institutions and associations that form the civil society[5]. Currently most conceptualizations of such systems are inherently interdisciplinary in nature and still tend to separate the structure and function of social and ecological components[6]. What is in need at the present historical moment is a more integrated conceptualization of cities as such social-ecological systems, where the structural component consideration includes both built and designed elements as well as natural features and the functional component the interaction between human actions/ decisions and the territorial ecological processes[7].

For much of the twentieth century, city planners and the plans they produced assumed that cities were in equilibrium and the focus was almost entirely on implementing some form of blueprint depicting a desired end state. The systems approach which emerged in the 1960s was entirely consistent with this notion of the city in equilibrium, notwithstanding the fact that contained early ideas of complexity sciences such as feedback, exponential growth, emergence, chaos and evolution[8]. In this sense, these theories bolstered the notion of master or blueprint planning by providing mechanisms describing and understanding how cities functioned in terms of their interacting parts, but there was little sense in which processes of evolution could be linked to such interactions. Much of what was developed from the 1960s by way of theories and the models used to implement them was based on the notion that the process of adjustment to a new state was relatively unproblematic, with no sense whatsoever that the elements composing cities might adapt, mutate, survive or disappear from processes that we knew little or nothing about[9].

Contemporary cities are open systems[10], that is to say they are not self-contained and are maintained by exchanges of materials, energy and information with areas beyond their region, respectively increasing their organization and complexity. In pragmatic terms no city is sustainable in the sense of being an autotrophic or even self-supporting ecosystem. Cities will always be heterotrophic[11] systems since resources and supporting processes must be supplied by ecosystems beyond the formal urban limits. The notion of sustainability should then be conceived as an ongoing process rather than an endpoint in itself. Pursuing

1. Williams D.E. (2007)
2. Pickett et al (2001)
3. UN Habitat (2006)
4. Pickett et al (2001)
5. Rueda, S. (2007)
6. Pickett et al (2013)
7. Childers et al. (2013), Pickett et al (2013)
8. Chadwick, G. F. (1971)
9. Batty, M. & Marshall, H., (2009)
10. Rueda, S. (2007)
11. Pickett et al (2013)

Evolutionary energy model of human settlements
source: Doxiadis, C. A (1969)



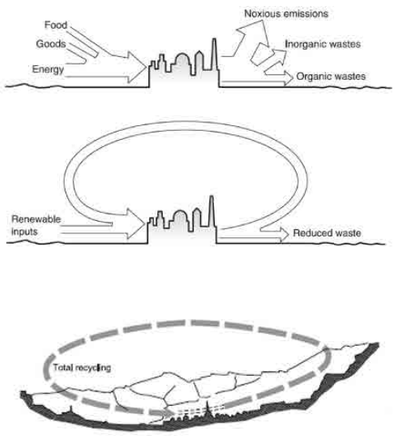
late hunters (3000 cal. day/capita) | Village (8000 cal. day/capita) | System of Villages (12000 cal. day/capita) | Central Settlement & System of Villages (early automobile era) | Central Settl. & System of Villages (late automobile)(25000 cal. day/capita) | Urban System (industry) (45000 cal. day/capita) | Dynapolis (100.000 cal. day/capita)

sustainability goals would require cities to better attend to human well-being, more effectively to encourage and to benefit from ecological processes and integrity, and promote social equity proportionally. The concept of urban metabolism, understood as an enhanced social metabolism, is useful in understanding this process. As applied to people, metabolism refers to the processes which we use in producing food and energy to conduct our daily living. Urban metabolism refers to the material and energy inputs needed to meet the living and nonliving components of urban systems and residents. While in natural ecosystems, the waste from one process becomes a resource input for another process in a circular manner, the wasteful process associated with city metabolism are respectively linear in form. That is, the city consumes goods, energy and food at high rates and pollutes the environment heavily with organic and inorganic wastes and dissipated energy.

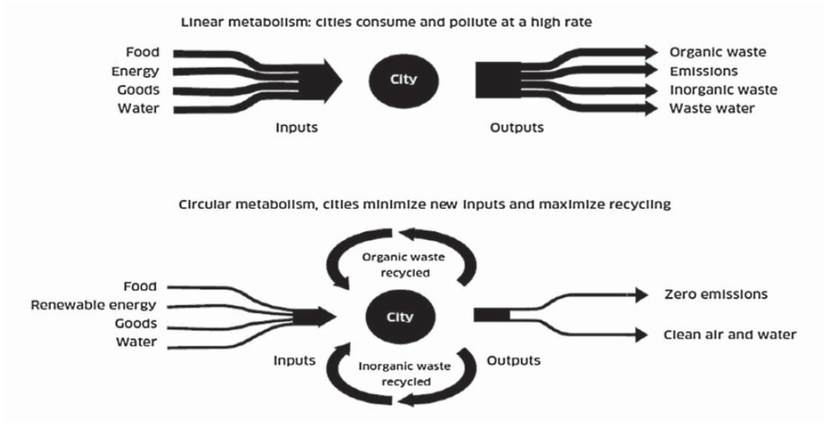
Urban sustainability is thus a relative concept that requires understanding the trajectories of change, the dynamics, and the contributions / impact these changes can have on ecological, social, and economic processes in urban areas. Existing natural ecosystems are examples of self-organized systems with long histories of adaptive capacity developed by evolution, selection, and migration, and thus provide a substantial and useful database of knowledge for sustainability studies[12]. It is becoming increasingly urgent the need to apply the principle of circular metabolism in urban ecosystems in an attempt to reduce the urban ecological footprint, in an adequate and efficient way, without disrupting key urban functions and parts. By applying the principle of circular metabolism to the city in relation to its regional context, and attempting to balance the ecological footprint at this scale, may also incidentally lead to a more balanced view of the relationship between the city and the countryside and between humans and their surrounding environment[13]. If we consider the land surface of the urban region, as the stage for all human and natural activity, past and present, as a source of sustenance and inspiration at the same time it serves as the capital and base investment for the future. Furthermore, nature depends on the land matrix for performing its basic function, and humans are consequently depended on nature for developing sociocultural activity. Thus, nature's flows and movements across the land are particularly important for the urban region, although buffeted by human activities. Surface and groundwater cycles support many human needs, (from clean drinking water to recreation, wastewater treatment, aesthetics criteria, underground reservoirs that support wells, irrigation agriculture, as well as diverse natural plant and animal communities). Wildlife disperses and migrates across the land demanding a minimum critical connectivity provision, a key value for ecological integrity as well human recreation and even human culture. In effect, important natural flows inexorably permeate the region. The local evergrowing population of the region, traditionally dependent on the local resources and immediate benefits of natural systems, is now encountered in a altered state, increasingly dependent on distant, and expensive resources. Concurrently the value of natural systems drops, as nature-dependent aesthetics, ethics, and resources for future generations erode. This disconnection between nature's fundamental patterns and processes and current development trends has led to multilevel crises, in need of prompt and costly actions. Irrespective, it calls for new thinking or vision, with the core objective to mesh nature and people within contemporary urban or metropolitan mosaics.

The diverse spatial mosaics of contemporary metropolitan areas present a variety of ecological and sociocultural situations, intrinsic to each place on one hand but characterized by common traits that permit research in comparing the socio-ecological structure and dynamics of anthropized systems. For example, the stranded riparian zones of urban sites, resulting from the downcutting of streams associated with impervious surfaces, can be used to examine altered environmental drivers of system function, such as nutrient cycling in the soil under altered moisture and temperature conditions or respectively examine human settlement patterns in relation with water in the city. Accordingly, examining succession in urban vacant lots may give practical information with regards to vegetation management or suggest potential strategies for changing/adopting land uses as the density of humans and buildings fluctuate in certain city parts[14]. The ecology of the entire city as a system can be conceived and represented by linking relative characteristics of the territory to the characteristics of cities. For instance, the number of plant species in urban areas correlates with the human population size. Species number increases with the increase in human inhabitants. The age of the city also affects the species richness; large, older cities have more plant species than large, younger cities[15]. If scientists, planners, and decision makers are to understand how the distinct social, economic, and ecological aspects of cities function and interact with and within the territory, the feedbacks and dynamics of the ecological linkages must be detected and assessed and therefore turn towards a review of system-oriented approaches to urban ecology.

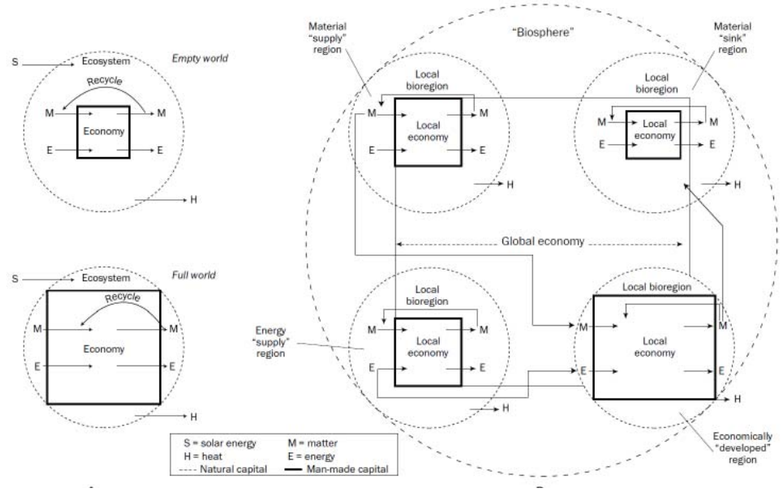
12. Pickett et al (2013)
13. Moughtin C. (2007)
14. Pickett et al (2001)
15. Pickett et al (2001)



(source: Moughtin, 2006)



(source: Meijer et al, 2011)



(source: Thayer, 2003)

This approach respectively represents a shift to the perspective of *ecology of cities*, as contrasted with the research literature which focused on *ecology in cities*. In basic ecological research the ecology of the city was first addressed by budgetary studies, based on the perspective of closed, homeostatic systems where the assumptions about spatial uniformity and the externity of social agents to the ecological processes can be questionable/debatable[16]. Picket et al (2001), discern two contemporary and concurrent stances with regards to the biogeophysical approach of urban ecological studies:

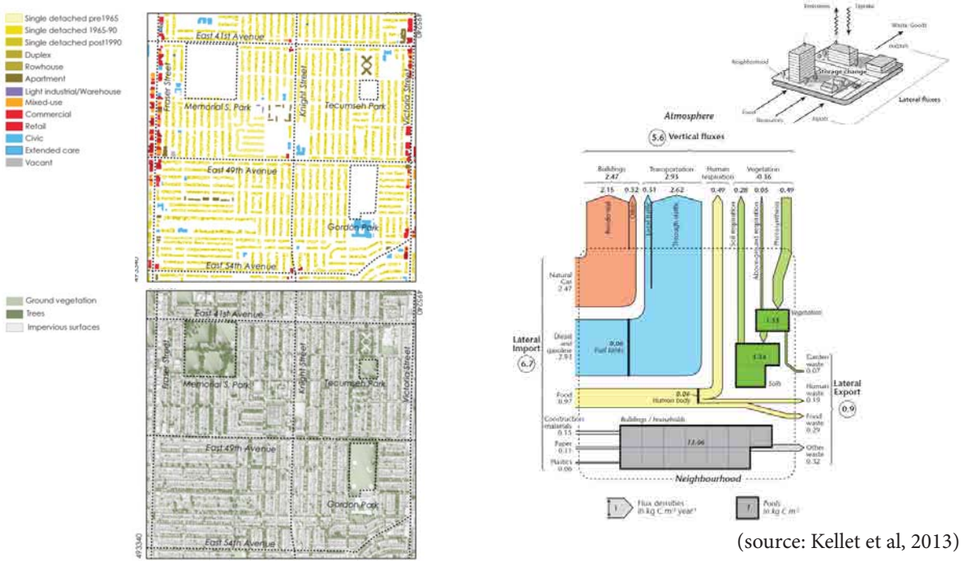
Ecology in the City
One, the pioneering and most common approach, examines ecological structure and function of habitats or organisms within cities. This approach is called ecology in cities. The study of ecology in the city has focused on the physical environment, soils, plants and vegetation, and animals and wildlife. These studies are the foundation for understanding urban ecosystems. The literature in this area has taken a case study approach, and unifying themes are still to emerge. We highlight key examples from among the many cases (Urban Physical Environment / Urban soils / Vegetation and Flora in Cities / Animals and Wildlife)

Ecology of the City
The second, more recent and still emerging approach, examines entire cities or metropolitan areas from an ecological perspective. The second approach is labelled ecology of cities. The knowledge of nature in cities is a firm foundation for understanding ecological processes in metropolitan areas. Yet it is not sufficient. If scientists, planners, and decision makers are to understand how the social, economic, and ecological aspects of cities interact, the feedbacks and dynamics of the ecological linkages must be assessed. We therefore turn to a review of systems-oriented approaches to urban ecology. These represent a shift to the perspective of ecology of cities, as contrasted with the literature we have reviewed so far, which focused on ecology in cities.

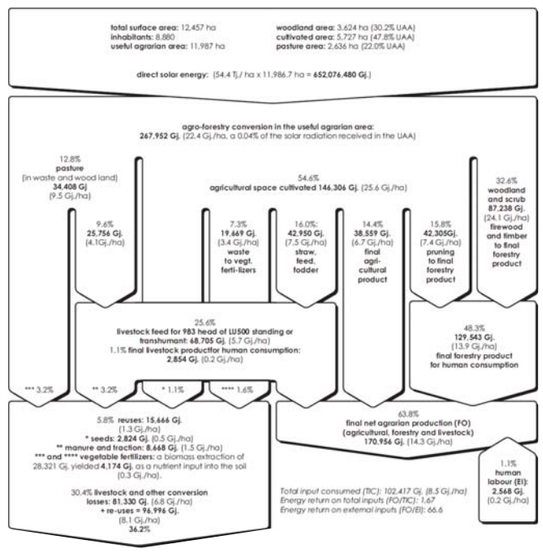
Although the differences in the prepositions in the description of the two contrasting approaches may appear subtle, as Pickett explains represent a significant turnpoint in understanding the history of urban ecology, as well as its future propositions[17]. This alternative approach to urban ecology is manifested in the fields of urban landscape architecture and urban / territorial planning theory and practices where intends have been made to incorporate / integrate ecological principles in the professional practice, decreasing in this manner the negative impacts of urban functioning on the environment, and thus adopting a more comprehensive approach closer to the formentioned ideals of the ecology of cities. Furthermore, the rapidly changing spatial forms and dynamics of urban growth, and the complex web of environmental factors that interact in and around cities, make simplistic environmental extrapolations / models risky if not pointless from a scientific viewpoint[18]. On the contrary all the distinct and converging ecological approaches classically and contemporarily applied to urban research and its respective planning practice, point to the need for the integration of the different disciplinary perspectives, an interdisciplinary and synergetic framework, integrating ecological and social sciences, and identifying key factors that govern the structure and function of biotic, abiotic, and socioeconomic processes within and around city regions. Furthermore, the spatial heterogeneity present in the biogeophysical and social components of urban systems can be interpreted utilizing the patch dynamics paradigm, structured accordingly along the multiple nested hierarchies / scales present in urban regions, from the household/ building to the regional scale[19]. This ecology in cities approach can be seen in the description of Salvador Rueda in his description of the ecological urbanism paradigm for the mediterranean city:

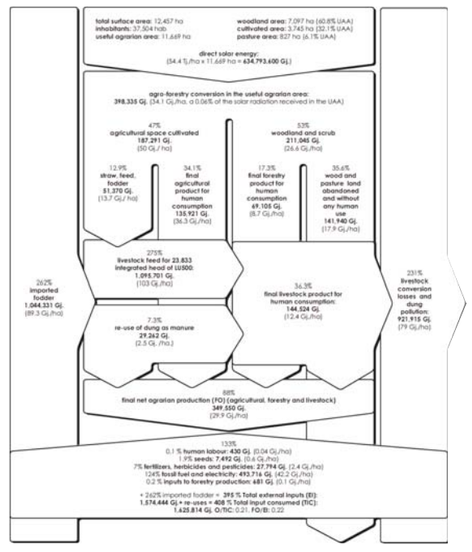
Ecological urbanism is well suited within the model of the mediterranean city, compact, complex, efficient and socially cohesive that conditions and makes possible the proximity between uses and functions while intentionally enhancing their mixture by multiplying organisational complexity [...] Urban planning should reserve spaces in the three management levels subsurface, surface and height to take maximum advantage of the local metabolic resources (and more specifically with respect to energy, water and waste management and environmental quality). Ecological urbanism activities are

16. Pickett et al (2001)
17. Picket et al (2001)
18. Ibid.
19. Ibid.



(source: Kellet et al, 2013)





(source: Tello et al. 2006)

accordingly located in three planes, favouring on the surface the most attractive activities and avoiding those that generate urban "deserts". Suitable mixture of diverse activity and residences permits an increased organisational complexity empowering the proliferation of activities of proximity linked to the residential use. Ecological urbanism seeks maximum metabolic and functional autosufficiency of urban ecosystems. The autonomy of metabolic fluxes for a given area involves the regression of the projected entropy in the system-environment derived from the mass consumption of materials, energy, water and food resources. The local metabolic sufficiency requires a definition of ecological mapping boundaries, ie the establishment of a basic cell coverage for the supply and deposition of resources[20].

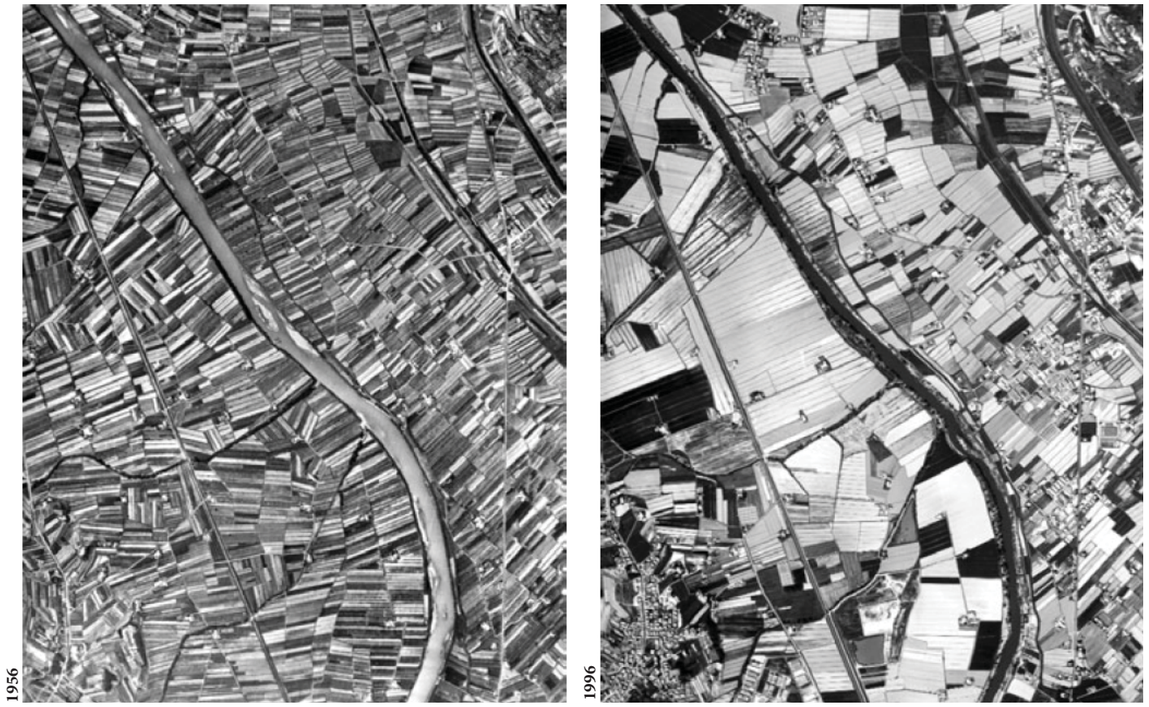
Traditionally, ecologists had based studies of urban areas on the assumptions that ecosystems were materially closed and homeostatic systems, following assumptions of ecosystem theory adopted by early geographers and ecologists, but these assumptions were replaced with the passing of time and with the notion of the ecosystem as a dynamic, connected, and open system, and as a conceptual platform that permits the diverse scientific disciplines to dialogue and to jointly form a more comprehensive theory (integrating ecological, social, and physical studies of urban systems)[21] through a rich and interdisciplinary discourse. Traditional ecological studies often proposed a systematic view of ecosystems that built upon a rigorous ***budgetary approach***. However, many contemporary studies of ecosystem budgets opt not to treat the distinct territorial systems as black boxes but rather try to pay special attention to the structural details and richness of the processes that take place within the boundaries of the system (exposing the roles and interactions between specific species, flows between patches as well as historical contingencies) as well with adjacent patches (highlighting mosaic dynamics and complexity) as key concerns of contemporary ecosystem analysis.

The study of social structures and their emergence are key social phenomena in the study of the ecology of urban systems where it is becoming increasingly difficult to determine the point where biological ecology ends and social ecology begins. With the emergence of the social sciences in the nineteenth century as self-conscious disciplines, the question of how much human behaviour should be attributed to our biological natura and how much to our social nature became a heated debate[22]. However the distinction between the two has gradually diminished through the convergence of related concepts, theories, and methods in the biological, behavioural, and social sciences field resulting in the appearance of term such as ***social differentiation.*** All social species are characterized by patterns and processes of social differentiation. and for that reason in the case of human eco-systems, *social differentiation or social morphology has been a central focus of sociology since its inception*[23]. Each human as societal unit is a carrier of information, occupying a specific place in the urban space. The density of information in an urban area will be determined to a great extend by a higher or lower presence of these information carriers[24]. The resulting diversity of the carriers in a specific area of a city can also serve as a measure of its urban complexity[25]. In particular, social scientists have used concepts of social identity (i.e., age, gender, class, caste, and social groups) and social hierarchies to study how and why human societies become differentiated[26]. Social differentiation is important for human ecological systems because it affects the allocation of critical resources, including natural, socioeconomic, and cultural resources and accordingly the modification of the physical space, giving rise to differentiated morphologies and situations. This territorial allocation of critical resources rarely being equitable, results in rank hierarchies and spatial differentiations.

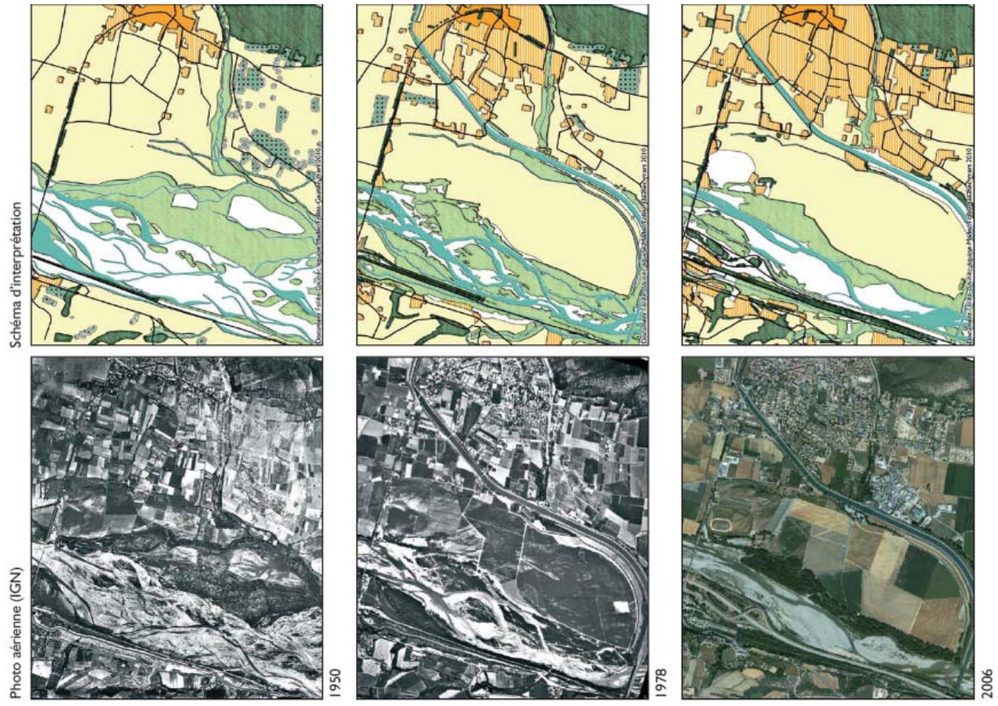
Human shelter usually appears in groups or as a consequence of collective action. The social nature of humans is affected by and is demonstrated through the explicit function of the constructed shelter. The interrelationships present in sociable animals are fundamental to their survival, and this is trait is clearly demonstrated in human social behaviour as well. When humans build, they reflect these social interrelationships in the form and disposition of their buildings (morphology), no matter how rudimentary

20. Rueda S. (2007)
21. Pickett et al (2001)
22. Machlis et al (1997)
23. van den Berghe P. L. (1975)
24. Rueda S. (2007)
25. Ibid
26. Pickett et al (2001)

Arno river (source: Agnoletti, 2006)



Val de Durance (source: CREPUDMED)



those structures may be[27]. This same resulting form is also representative of the relationship with the territory and the conditions present, that define and condition the vernacular element of local practices. Humans have been accustomed to the increasing exploitation of the environment, in habitually employing sequestered somatic energy found in the form of biomass, fossils or other resources to power the development of contemporary city regions. All human settlements, of all sizes, are the continuation of the ancient drive to modify the environment in a manner that helps to sustain the continued existence of the city organism as the highest manifestation of human development[28]. Although a sprawling megalopolis may not look much like a bird's nest, it is driven by the same evolutionary imperative. What is different though is the degree of social differentiation that their respective parts have experienced and most of all the implicated scales of consideration. It can be accepted then that the social differentiation of human ecological systems can manifest a spatial dimension characterized by specific patterns of territoriality and heterogeneity. As Burch (1988) noted,

> "*Intimate and distant social relations, high and low social classes, favoured and despised ethnic, occupational, and caste groupings all have assigned and clearly regulated measures as to when and where those relations should and should not occur*[29]".

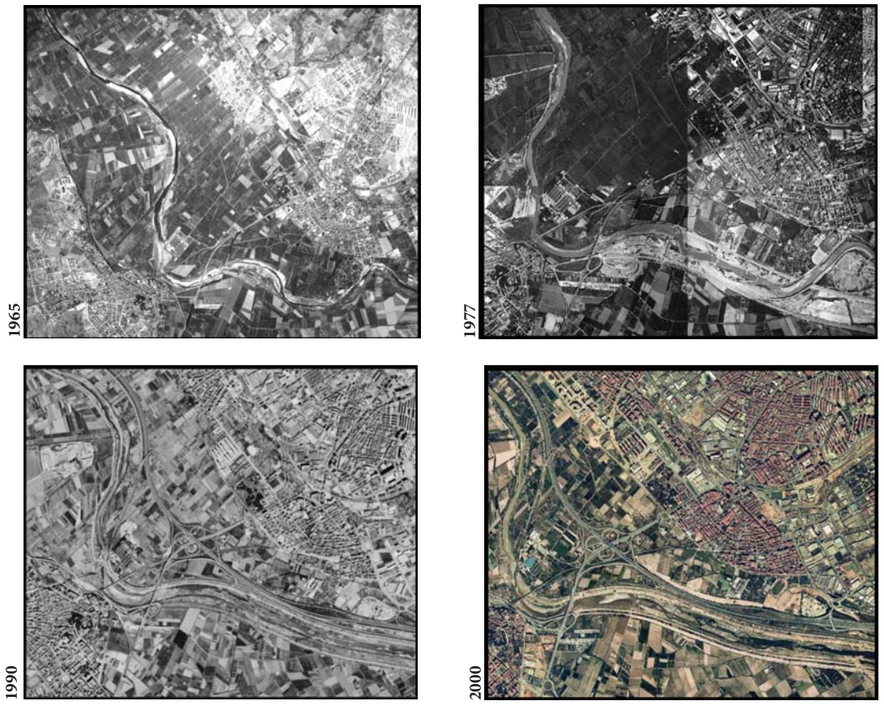
When ecosystem and landscape approaches are combined under a common spectre, the research questions change accordingly in order to incorporate the reciprocal relationships between spatial patterns, sociocultural and biophysical patterns and processes. The diverse processes of social differentiation, similar to most territorial processes, occur at different scales that have corresponding spatial patterns and biophysical effects[30]. A human modified landscape approach may be understood as the study of the reciprocal relationships between patterns of ***spatial heterogeneity*** and sociocultural and bio-physical processes[31]. Further, when human ecosystem and landscape approaches are combined, human ecosystem types are defined as homogeneous areas for a specified set of sociocultural and biophysical variables and as parts of the territorial landscape. The diversity in the possible scales and boundaries of ecosystems, and ways to relate the processes within them, is an indication that the ecosystem paradigm represents more of an open research approach rather than a fixed / closed methodology. Nevertheless territorial and regional analyses should always focus sufficiently on two key issues[32]:

1. The development and dynamics of spatial heterogeneity, (*morphogenesis*)
2. The influences of spatial patterns on cycles and fluxes of critical ecosystem resources (e.g., energy, materials, nutrients, genetic and non- genetic information, population, labor, capital, organizations, beliefs, or myths).

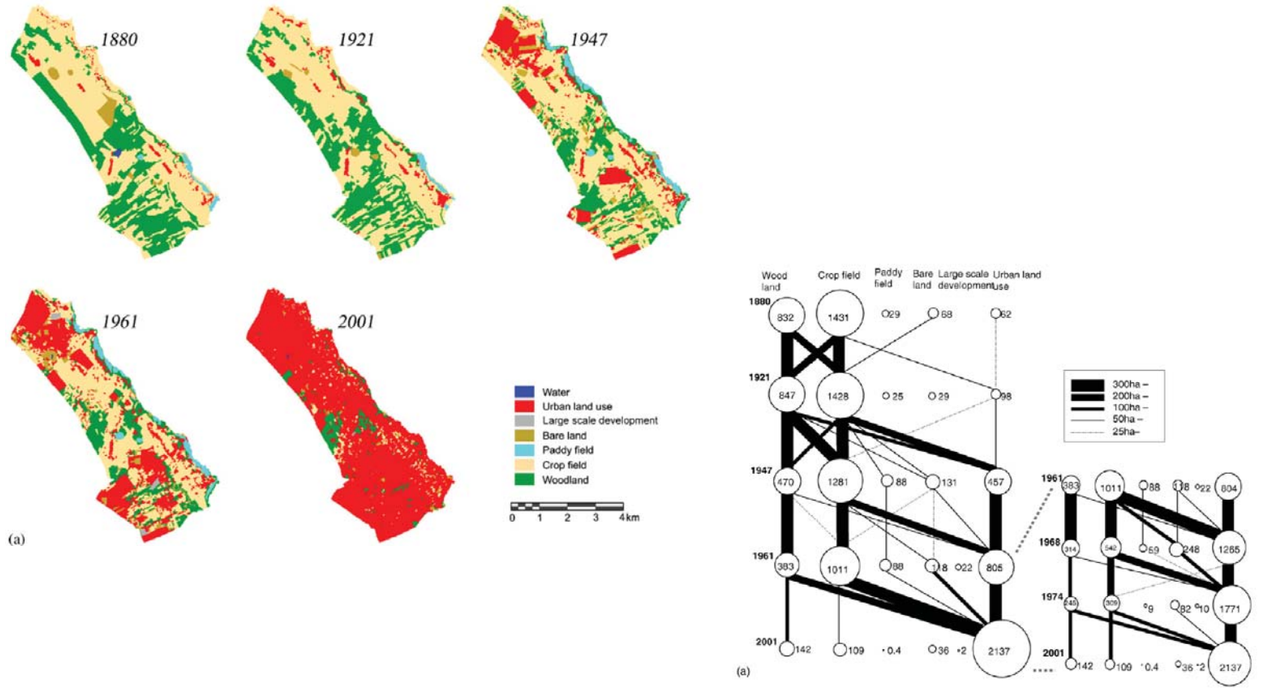
A few more elements are also critical for the successful application of this human ecosystem framework[33]: First, it is important to recognize that the primary drivers of human ecosystem dynamics are both biophysical and social. Second, there is no single determining driver for anthropogenic ecosystems. Third, the relative significance of such drivers may vary over time. Fourth, components of this framework need to be examined simultaneously in relationship to each other. Finally, researchers need to examine how dynamic biological and social allocation mechanisms such as ecological constraints, economic exchange, authority, tradition, and knowledge affect the distribution of critical resources including energy, materials, nutrients, population, genetic and non-genetic information, labour, capital, organizations, beliefs and collective narrative within any human ecosystem.

27. Downton P.F. (2008), p.407
28. Ibid.
29. Burch, W.R. Jr. (1988)
30. Pickett et al, (2001)
31. Pickett et al, (2001)
32. Pickett et al, (2001)
33. Machlis et al (1997)

Llobregat river (source: Carrasco, M. & ICC)



Ohno area (Tokyo) (source: Ichikawa et al. 2006)



Social and ecological differentiation of patches can accordingly give rise to new and distinct situations. In this context, a ***metacommunity*** is a dynamic set of patches of one community type differentially distributed and partially isolated in space[34]. These differentials include exposure to physical disturbances, persistence, succession, dispersal of species, and colonization of new species etc[35]. These differentials generate a shifting / changing mosaic of communities which is labelled using the prefix ***meta***. The term ***metacity*** concept was introduced by the United Nations to aid in the contemporary understanding as well as promote transformations in the sustainable city paradigm[36]. Thus, the definition of the metacity came to describe those cities that **1)** have more than 20 million residents, **2)** are larger than a megacity / megalopolis, **3)** are polycentric, and **4)** have a diffuse governance over the territory. Notwithstanding the UN definition the term metacity inherently links with other key concepts in ecology and especially process-oriented uses of the prefix, ***meta***. The functional and spatial prefix, *meta*, can be applied in urban theory as well as in biological ecology in ways that considerably expand beyond the UN's population-based definition mentioned earlier. A collective of human that form an urban community / urban biodome, can become isolated in space and over time from other instances of that same community, and thus become differentially affected by a number of socio-environmental processes. Metapopulations and metacommunities both involve *spatially dispersed units, each of which may be established, change, or disappear based on its own internal dynamics, relationships with the local environment, and migration from other units*[37]. The metacity paradigm could then be applied both to expanded metropolitan regions or could similarly refer to any other contemporary territory that is seen affected by the same socio economic pressures of the national or international context, giving rise to analogous effects. Processes and effects that can be linked to the concept of territorial heterogeneity, a concept ultimately related with the idea of complexity,

34. McGrath, B., & Pickett, S. T. A. (2011)
35. Ibid.
36. UN Habitat (2006)
37. McGrath, B., & Pickett, S. T. A. (2011)

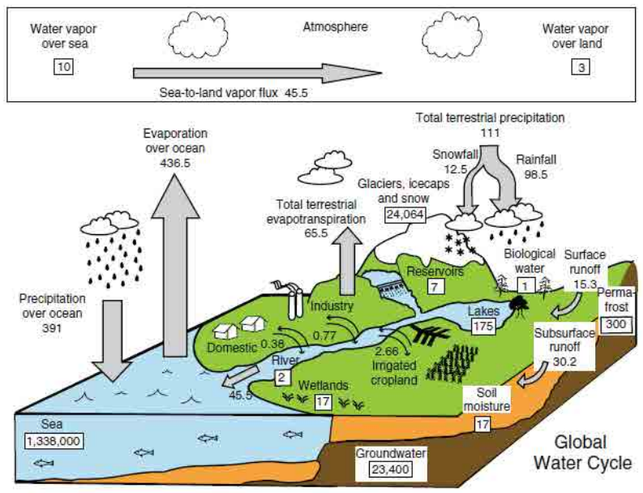
Heterogeneity creates borders, edges and a contrast between different patches[38]. This pattern again originates new processes, influencing, for example, movements of organisms, fluxes of material and energy. Plant and animal assemblages can react in a very short time to any change in mosaic heterogeneity and this can be easily detected by field and/or remote sensing investigations. Heterogeneity is also a sign of patchiness of the land. The level of heterogeneity can negatively affect some processes. Ultimately, three different types of heterogeneity have to be considered[39]:

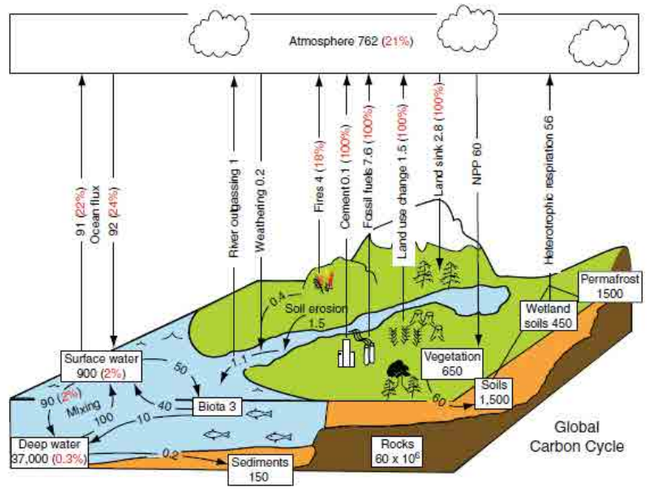
Spatial heterogeneity. This heterogeneity may be seen as a static or a dynamic pattern that consequently, effects many ecological processes like soil formation, weathering, plant distribution, animal distribution, abundance and movements, water and nutrient fluxes, energy storing and recycling, etc. Spatial heterogeneity may be further distinguished into horizontal and vertical components. Horizontal heterogeneity represents the uneven distribution of land cover that may due to anthropogenic reasons. Vertical heterogeneity represents the uneven distribution of vegetation above ground, and is more connected with natural landscapes.

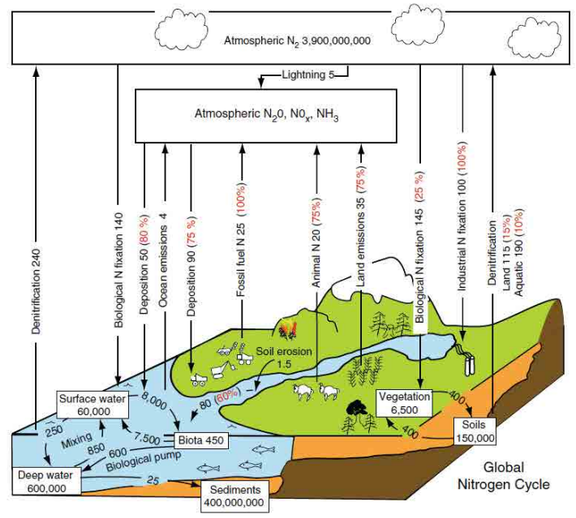
Temporal heterogeneity has a similar meaning to spatial heterogeneity but is measured as the variation from one point in the space at different times. Two locations may have an identical temporal pattern but be asynchronous in time, expressing here a temporal heterogeneity.

Functional heterogeneity represents the heterogeneity of ecological entities (distribution of individuals, populations, species, communities). This heterogeneity may appear linked to the life history of organisms at several scales.

38. Farina, A. (2006)
39. Ibid.







In the metacity context these heterogeneous - spatially differentiated units or patches might appear in the form of neighbourhood, districts or zones. Each neighbourhood eventually develops its own character over time, defined greatly by its social fabric and the related intensity and diversity of the activity present (commercial, manufacturing, industrial, residential, recreational etc.) The patches could furthermore be characterized by the specific land cover elements that they are comprised of, such as the multiple layers of vegetation type (*coverage and diversity*), the presence and condition of permeable or impermeable surfaces, built spatial configuration, height, density and voids[40] (*morphology*). The more detail is invested in this definition the richer and more precise the resulting mosaic impression produced. In some ways, metacities as a form of meta-theory, offer insight into the dynamic processes of urban transformation and reconsider the future potential of cities. The multiplicity of city scenarios present today worldwide, from newly planned cities to consolidated cities under revitalization processes, or metropolitan areas of extended and heterogeneous mosaics, there is the opportunity to act and incise in a diversity of scenarios never before present.

In absolute and theoretical terms, it could be argued that a higher integration of ecological processes could be successful in newly built cities, compared to existing ones, since it permits to pay greater attention in planning for environmental equity citizens early from the design phase[41]. Nevertheless, such benefits can also accrue to existing cities as result of revitalization / restoration efforts that reinvigorate ecological processes within the urban fabric in reciprocal ways that benefit both the citizens and the environment. Furthermore older cities also have great stocks of aging infrastructure that needs to be replaced with the passing of time. Thus, all cities scenarios have the potential to aim for an improved environmental management that benefits both social as well as ecological functioning of the territory, and increases overall resilience[42]. Through this enhanced human ecosystem framework the contemporary metropolis can be seen as an *integrated ecological & social infrastructural systems*[43]. The derived models do not put the human or anthropized artefact in contraposition to the natural, but instead combine human and ecological processes synergetically into a reciprocally interactive network[44].

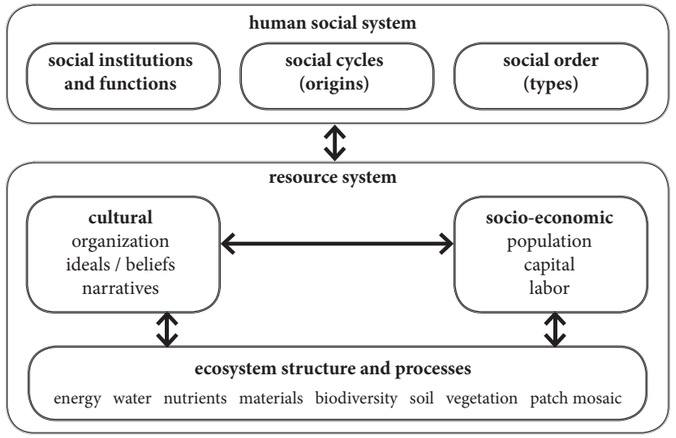
40. Cadenasso et al (2007)
41. Pickett et al (2013)
42. Ibid.
43. Picket et al (2004)
44. Ibid.

If sustainability is accepted as a socially negotiated set of goals for the human collective, then resilience could serve the underlying mechanism by which sustainability could operate. In biological systems, resilience is understood as a cycle that begins with a succession shifting from an initial rapid growth phase to one of increase in structural investment, or in the case of ecosystems shifting to a state of increased investment in maintenance. This cycle may be punctuated by periodic disturbances to its structured system, opening up new phases of succession as in the case of extensive forested regions, where the resulting complex mosaics of patches, forest gaps, canopy disruptions and local reorganizations are manifestations of such disturbance events, be it forest fires or invasion of exotic species[45]. Similarly in the urban context this differentiation as result of disturbance events can also be manifested in heterogeneous morphologies or diverse socio-economic conditions. Thus *resilience refers to the capacity of a social–ecological system to adjust to internal and external shocks, yet retain fundamental features of its structure and processes*[46].

One way of thinking about resilience is to focus on ecosystem dynamics where there are multiple (locally) stable equilibria, and where resilience in this sense is a measure of the magnitude of disturbances that can be absorbed before a system flips from a locally stable equilibrium to another[47]. Economic activities are sustainable only if the life-support ecosystems upon which they depend are resilient. Even though ecological resilience is difficult to measure and even though it varies from system to system and from one kind of disturbance to another, it may be possible to identify indicators and early-warning signals of environmental stress. For example, changes in the diversity of organisms or the heterogeneity of ecological functions have been suggested as signals of ecosystem resilience[48]. Ecotonal areas with their intrinsic characteristics can also be areas where fist symptoms may appear. In this ecological or evolutionary sense, resilience is different from the definition of engineers who are concerned with the capacity of a system to return to a pre-stressed state[49] almost in an elastic manner. A more ecological definition of resilience, acknowledges the fact that systems are not likely to have a fixed equilibrium point. This ability to evolve, adapt, and learn from the dynamic relations between a system and its surrounding environ-

45. Pickett et al (2011)
46. Peterson et al (1998)
47. Arrow et al (1995)
48. Ibid.
49. Peterson et al (1998)

Human Ecosystem framework
adapted from Pickett et al (2001)

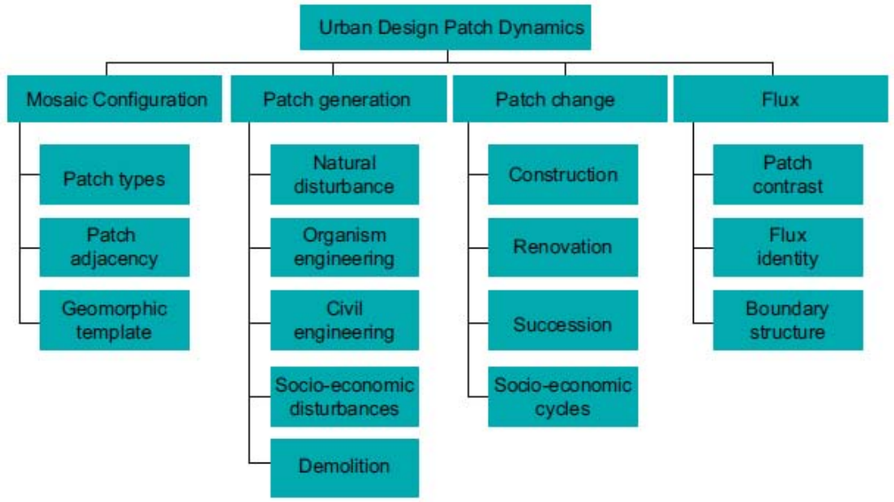


ment are most relevant to living systems with a social interaction component. Feedbacks, accumulation, genetic adaptations, natural selection, and cultural adjustment become the key features of each system[50]. Respectively, the loss of ecosystem resilience is important for at least three reasons[51]: First, the discontinuous change in ecosystem functions as the system flips from one equilibrium to another can result in a sudden loss of biological productivity, and consequently to a reduced capacity to support human activity. Second, it may imply an irreversible change in the set of options open both to present and future generations (e.g depletion of groundwater reservoirs and resources, desertification, loss of biodiversity etc.) Third, discontinuous and irreversible changes from familiar to unfamiliar states increase the uncertainties associated with the environmental effects of socio-economic activities. Incorporating resilience as the strategy and mechanism for establishing common sustainability goals simultaneously presupposes a need for a shift in our current urban and territorial functioning.

Cities can incorporate, by design or policy, more of these adaptive structures and processes that the resilience theory suggests, amassing the ecological, social, and built capital. This can effectively prepare them for future shocks whether due to socio-economic cycles and perturbations, or more environmentally related reasons[52]. During the early phases of urban settlement, there is little established structure and infrastructure but as the urban settlements grow, just as natural ecosystems, they tend to become more structurally complex, through a greater compartmentalization of redundant processes, and as well as greater investments in maintaining the overall structure. This high investment of energy in maintaining system stability as in physical structure or over-connected information flows, can be sensitive to disruption by external events / impulses. Severely disturbed complex systems may reorganize to simpler systems capable of rapid re-allocation of resources and rapid growth once the disturbance has passed. If no other severe disturbances occur soon after the event, the system can undergo further growth and develop in terms of complexity. In urban systems, this adaptive cycle may reflect sensitivity and reaction to economic or physical disturbances, and accordingly affect livelihood and overall well-being[53].

50. Ibid.
51. Arrow et al (1995)
52. Picket et al (2012)
53. Vale, L. J., & Campanella, T. J. (2005)

A framework for designed patch dynamics
(source: Picket & Cadenasso in McGrath et al 2007)



Carrying capacities in nature are not fixed, static, or simple relations but contingent on technology, societal preferences, the structure of production and consumption as well as the ever-changing state of interactions between the physical and biotic environment[54]. Nevertheless, a general index of the current scale or intensity of the human economy in relation to that of the entire biosphere can be useful or at least indicative. Such calculations in the past have shown that the total net terrestrial primary production of the biosphere currently being appropriated for human consumption is around 40%[55]. Bioproductive land area is one of the most important, and increasingly scarcer natural resources on Earth. In occupying or using this land, humans compete with other species for space as well as trophic energy[56]. In fact, an increased space-time of ecosystem activity is required by a society in order to be able to buffer the alterations / perturbations generated by the increase in technological capital. High levels of population density, coupled with high levels of energy dissipation can lead to a saturation of the available space-time of ecosystem activity per capita. The actual trend of human development is generating such a decrease in the available space (because of the increase of population on the fixed area of earth) and respectively of bioproductive land and an respective increase in space-time activity requirements for natural services of the biosphere (recycling pollutants, buffering the perturbation generated on biological, geological and chemical cycles, ect.)[57].

> ***Incorporation*** *is a useful concept when we observe the behaviour of a system facing a perturbation or disturbance. This is defined as the process by which the perturbation is adsorbed by a level of the system. Fire disturbance can be a good example of incorporating the disturbances of a forest. A fire generally destroys part of a forest but not the entire forest, and the forest survives the fire, incorporating the burned patches. In many cases, fires are necessary to assure high diversity of the forest and, in this case, fire is an incorporated disturbance. This may be the example of the coastal range of Mediterranean basin, in which human-induced fires occur so frequently that the system does not have the capacity to incorporate the novelty. In this case, the transformation from a forest to woodland and then to a scrubland represents progressive steps toward a simplification of the system. In this way, only some components of the system survive, but if the disturbance is severe, the system is completely replaced by another system*[58].

54. Arrow et al (1995)
55. Ibid.
56. Haberl et al (2004)
57. Giampietro, M. & Pimentel, D. (1991b)
58. Farina, A. (2006)

Cities accordingly need to generate and use all available energy and material resources efficiently, mimicking nature's capabilities of doing so but also consider their projected impact at larger scales, from regional to global. All urban development should seek to be energy self-sufficient and close the loops of resource and energy usage, while operating at optimum levels of energy and resource consumption, while eliminating dependency from risky or conflicting sources. Biomimicry offers a basis for optimal design in which all these techniques and technics evolve further to produce an even more effective design in different scales, from buildings to whole city-regions. The conscious and collectively intelligent organism that cities strive to be can not only invent processes from zero or borrow best practices from other cities, but also learn through the process of observation and investigation of nature, faculties that are by definition unavailable to organisms with no consciousness[59]. Again the advancements in the field of industrial ecology are representative of the potential of integrating regional flows within smaller proximity loops while increasing complexity of the territory, by applying decentralized and low maintenance solutions inspired by natural processes. Thus their effect is more ecologically as well as scale relevant in providing solutions efficiently.

The economic activity of a territory is another demonstration of its organisational complexity, that produces specialized activities and functions[60]. On the other hand, economic growth cannot be a panacea for environmental quality, nor monopolize territorial priorities. What is of importance is the content of growth, in qualitative terms, that is in the composition of flows: inputs (including environmental resources) and outputs (including waste products). This content is determined to a large extent by the economic institutions within which human activities are conducted and are conditioned by, institutions that need to be designed accordingly so that they are capable of providing respective incentives for protecting the resilience of ecological systems[61]. Such measures not only promote greater efficiency in the allocation of environmental resources at all income levels, but they would also assure a sustainable scale of economic activity within the ecological life-support system[62].

Nevertheless, as Richard Forman notes economic gains also can be expected from many solutions involving the integration of natural systems in urban functioning[63] such as: **a.** Maintaining diverse productive agricultural landscapes on the productive soils, **b.** Reduce infrastructure and servicing costs by densifying rather than disperse growth; **c.** Conserving key natural areas and nature-based tourism; **d.** Rethinking floodplain design to reduce flood-damage costs; **e.** Targeting a handful of pollution sources, **f.** Creating stormwater wetlands, to increase a scarce supply of costly clean water. Such investments in natural systems can eventually pay societal and economic dividends. Settlement patterns, in relation to natural systems, undeniably influence and define the future development of both. Special characteristics such as housing density, location and size of new developments can also have a varying impact on local natural systems. Such benefits emphasize the need to shift from a model overwhelmingly concentrating on the traditional socioeconomic aspects of public infrastructure and economic development, to a new one that seeks synergies, that is the optimum uses for the heterogeneous contemporary land mosaics as well as the finite and renewable land resources[64]. By focusing on land use specifications and suitability (aptitude), rather than the regulatory and legal approaches (that tend to have a provisional character and effect), such planning can provide a solid long-term base for the future of a region, a flexible but focused programme[65] addressing accordingly the plurality and diversity of its specific socioeconomic aspects.

In her seminal work Cities and the Wealth of Nations, Jane Jacobs presents four key concepts of direct or indirect implication to the economics of bio regions: import replacement, city regions, improvisation, and faulty currency. Together, these form the most sophisticated argument for a possible bioregional economics to date[66].

Import replacement

To be self-sufficient and vital, cities and their surrounding regions must replace imports with their own raw materials, goods, services, and expertise. Most cities, Jacobs contends, are not vitally import-replacing. Over dependence on export to other markets and regions or on administrative, tourist, or cultural services without the provision that a significant proportion of goods and services be consumed within the city itself makes for an inefficient (and incomplete) local economy.

City regions

Jacobs considered the city regional economy scale as the true, classical means of providing neces-

59. Downton P. F. (2008), p.407
60. Rueda S. (2007)
61. Arrow et al (1995)
62. Ibid.
63. Forman R.T.T.(2008)
64. Ibid.
65. Ibid.
66. Jacobs, J. (1984)

sities for people. When a city manages its immediate geographic surroundings in such a way as to provide a full supply of essential raw materials, services, and goods for local/regional consumption, it naturally becomes a city region; a complex economy with a high degree of self-sufficiency.

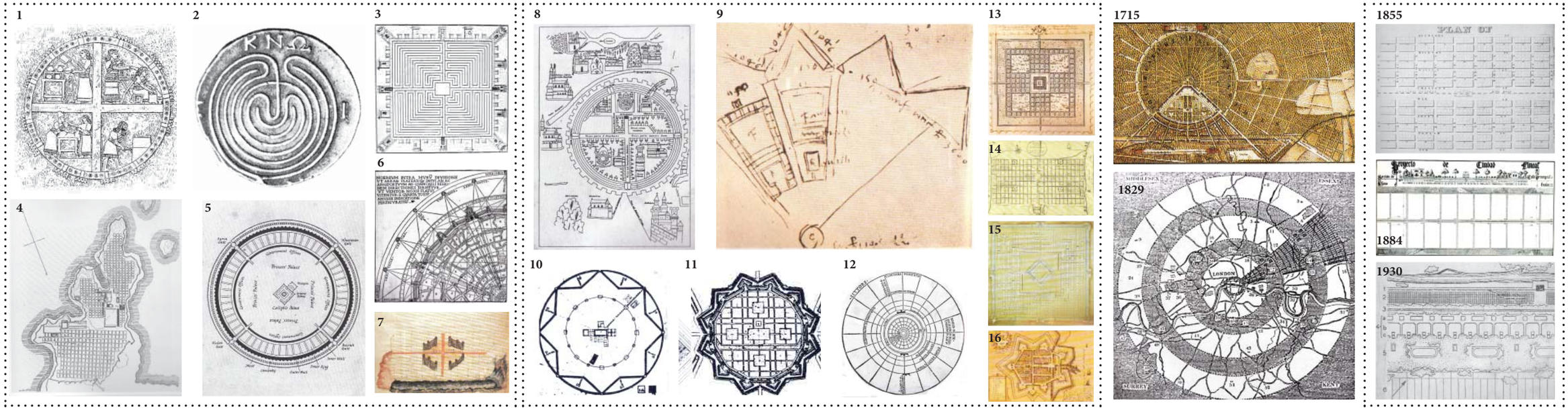
Improvisation
What allows cities to become import-replacing city regions, according to Jacobs, is improvisation. By investing local capital locally and by exercising a high degree of creativity in the provision of local goods and services, cities can emerge as economic powerhouses for their respective city region.

Faulty currency
Jacobs clearly criticized national and international currencies: "*National or imperial currencies give faulty and destructive feedback to city economies and ... this in turn leads to profound structural economic flaws, some of which cannot be overcome no matter how hard we try*." To Jacobs, it is like *one brain stem for many pairs of lungs*, each pair of which may be "respirating" at a different economic rate. This situation often causes a weaker or less-developed region to be unable to pay the high prices for goods and services from the dominant regions without losing its own economic improvisational ability and becoming a supply region to the stronger areas of the nation. Jacobs expressed the desire for the economies of scale to be visible and significant in their natural contexts. Seeking as an ultimate goal the territorial expression, of the existing complexity as expressed through economic terms, an early insinuation of the *real-cost economics* paradigm.

Notwithstanding the added complexity that the urban context entails, it can be asserted that urban systems do follow thermodynamic principles, thus they present metabolic functions in the strictest definition of the word; to transform energy. *This thermodynamic approach according to Josep Acebillo mirrors the essence of urban complexity, which is a consequence of the intermittent interaction between dissipative and homeostatic processes. The repeated cyclical tendency (* of social-ecosystems *) to break the equilibrium (dissipative processes) of the city and to re-establish its initial equilibrium (homeostatic processes) is at the heart of urban transformation as a dynamic process and, as consequence, it constitutes the key aspect of urban metabolism*[67]. The contemporary definition of metabolism has come to include an additional series of considerations with respect to social aspects (livability, mobility) of human settlements and their dynamics, identifying the simultaneity and multiplicity of layers present in the territory. A shared territory with its respective metabolism, converting energy and resources into useful products and waste, a thermodynamic system.

This overview of the diverse characteristics / considerations attached to the city concept when thought out as a socio-ecological system or a socio-ecosystem, has intended to describe this emerging complexity on our perspective of city processes and dynamics. In order to be able to properly describe certain phenomena it is necessary to have or invent the necessary vocabulary and theory to be able to describe them and understand them respectively. The next part will another overview of the consideration of the organic in the city concept, throughout the city history, through plans, diagrams and concepts that have been produced over the years. In an intend to trace the evolution of the projectual and analytical thinking from the early thinkers and planners to our contemporary state-of-the-art.

67. Acebillo, J (2012)



Historical examples - ***ancient / classical:*** **1.** *Mesopotamia* **2.** *The Cretan labyrinth (67 BC)* **3.** *The roman labyrinth (1st cent. BC)* **4.** *Militos by Hippodamos (5th cent. BC)* **5.** *Baghdad (8th cent. AD)* **6.** *Vitruvio - Ideal City (1st cent. AD)* **7.** *Roman ideal city (6th cent. AD)* ***medieval:*** **8.** *Jerusalem (7th cent. AD)* **9.** *Antonio da Sanglio - Citta ideale* **10.** *Filarete - Sforzinda (1460)* **11.** *Scamozzi - Citta ideale (1615)* **12.** *Francesco Colonna - Rennaisance garden city (1499)* **13.** *Rober Mounthomery_(1717)* **14.** *Willian Penn - Philladelphia* **15.** *Heinrich Schickhardt - New city (1599)* **16.** *Andriaan Antonisz - Willemstadt - New Dutch city (1647)* **1715.** *Karlsruhe* **1829.** *John Claudius Loudon - Breathing Places for the Metropolis (London)* *rail based:* **1855.** *Illinois Central Associates_ Standard Town Plan* **1884.** *Arturo Soria - Ciudad lineal* **1930.** *Nikolai Milyutin - Soviet Linear City.*

VI. The organic in city history

The review of the recent bibliography in the previous section has been suggesting that the linear metabolism functioning scheme of contemporary cities should evolution into a form of circular metabolism through the coordinated action of design and management. A circular metabolism, a system of nested loops, approximating the functioning of natural systems and the organicism of cities envisioned by different thinkers throughout history. There has always been a direct correlation between urban metabolism and urban form; from the contained and fortified ancient and medieval cities to the exploded cities of the postmodernity. The harnessing of the natural forces, the excessive dissipation of energy and the commercialization of space all led to respective forms, with distinct impacts and phases of succession. This relation was also reflected in the diverse conceptualizations of cities, real or utopic. In the face of the early overwhelming industrialism as in recent global corporate models of urban development, there have also appeared continuing attempts to conceptualize and realize an alternative type of city. Some times out of fear of the out-of-control growth of industrial back then and contemporary cities now but many times in an attempt to invocate a transcending practice and essence of city-building.

Organic analogies for cities have remained popular and implicit all through the last century and are present in the current theories of cities and city planning. Within this movement one can identify distinct tendencies, rising from different aspirations: a top-down approach to planning where the planner knew the intended optimal form and applied this like an act of design but with a biomorphic metaphor in mind, which could be the developmental paradigm of cities, as interpreted by Ebenezer Howard or Patrick Abercrombie. Contrasting this top-down developmental paradigm, however, there is a parallel evolutionary paradigm that also developed stemming from the ideas and practices of Patrick Geddes, according to which the city is not conceived of as a unified whole following a fixed developmental programme, but instead is seen as a collection of interdependent, co-evolving parts, forming a whole, the city. Representative though of the general organicist approach is the statement done the architect Jose Luis Sert, one of the key spokesmen for the in 1942, said:

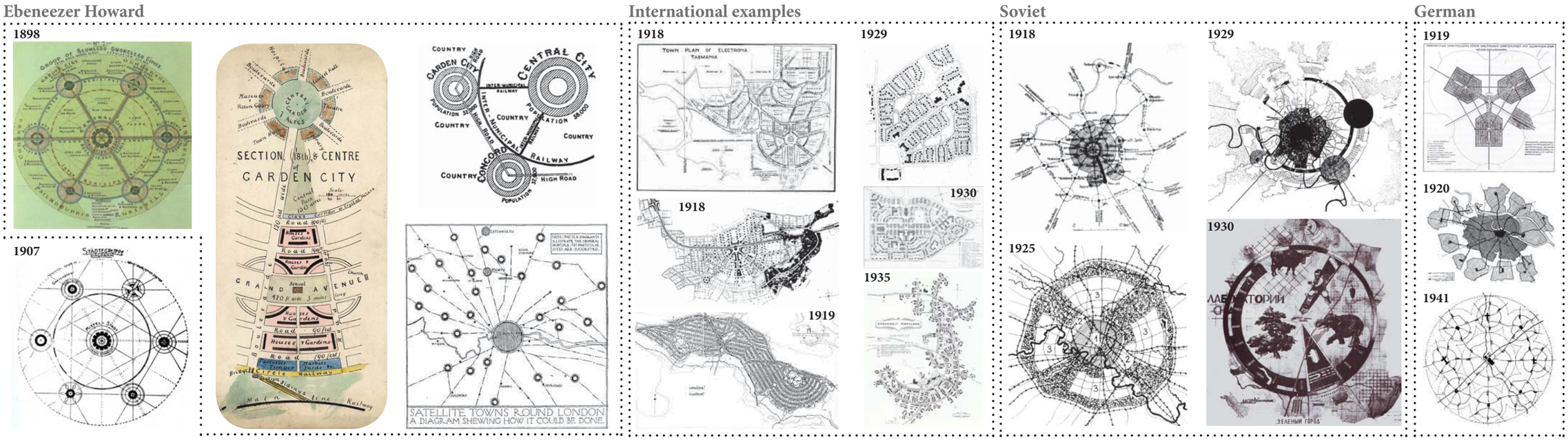
> 'Cities [are] living organisms; [they] are born and … develop, disintegrate and die … In its academic and traditional sense, city planning has become obsolete. In its place must be substituted urban biology[1]'

1. quoted in Time magazine, 30/11/1942 in Batty, M. & Marshall, H., (2009)

Ebenezer Howard (1850-1928) with the respective Garden City movement advocated the creation of carefully planned suburban communities, that contained no slums (slumless) and introduced large areas of green spaces located in-between multi-family housing complexes, conceived for the first time as superblocks. Howard was an original thinker, especially for his times given the fact that he saw the necessity for cities to absorb and re-use their own waste and under these terms he conceived Garden Cities on the basis of integrated land-use and a self-sufficient financial plan. One of the most intransigent problems of managing cities has to do with establishing and maintaining an optimum size to suit their function. Even if an ideal size can be ascertained, there remains the problem of how to maintain it despite pressures of growth. According to Mumford the first valid approach to this problem was not made until Ebeneezer Howard broached it at the end of the nineteenth century in his book *Garden Cities of Tomorrow*[2]. Howard considered city limits to be crucial to the definition of the city-region and this insistence on putting limits to urban growth is one of his key contributions to the development of planning theory. It set the stage for an early definition of the relation between city and countryside and for identifying and understanding the urban region spatially, although Howard did not enter directly or explicitly into the matter. Nevertheless his definition of the Garden City inspired diverse and differentiated versions on an international level with most notable among others the American, French, German, Soviet, Australian and Japanese versions that emerged over time. In pre-Nazi Germany, a number of urban theorists took inspiration from the Garden City movement and applied the schemes to fit the political / cultural agenda of the regime. One was Eduard von Berlepsh-Valendas', whose '*Stadtegruppe*' of 1907 re-represents Howard's Social Cities in a strict geometrical form – without any of the social reform overtones[3].

A contemporary of Howard, ***Patrick Geddes*** (1854 -1932) was a Scottish biologist and botanist known already in his times as an innovative thinker in the fields of urban planning and social education. The two first met in July 1904 and maintained contact for over 10 years sharing their approaches to planning theory. As mentioned earlier Howard represented more of a mechanistic mindset whereas Geddes being a biologist viewed the city in organic terms; its form was to be determined by the activities of its citizens, and their relation with the natural surrounding environment. Geddes gave us the first modern view of cities and can be regarded as the first to imprint the analogy

2. Downton P. F. (2008)
3. Ward, S. (1992)



The Garden City tradition 1920 (left). *Walter Determann - Bauhaus Colony* **1922.** *Le Corbusier - Plan de la ville de 3 millions d´habitants* **1925.** *Ernest Burgess - Co-centric zone model* **1930 (left).** *Frank Lloyd Wright - Broadacre city* **1930 (right).** *Le Corbusier - La ville radieuse* **1933.** *Walter Christaller - Central Place Theory*

of evolution in the study of cities[4]. Accordingly he developed his vision that the industry was going to be divided into two periods: the first one called paleotechnic and a subsequent called Neotecnics a synoptic view of nature, a constructive conservation of its order and beauty to health of cities[5]. The concept of regional design as we know it today has its roots in that precise realization of Geddes, that the cities in response to development pressures/ urbanization of the industrial revolution - could no longer be seen as units of confined limits.

Patrick Geddes believed passionately that, given reasonable social conditions, man is a cooperative animal. He also believed that, treated properly, the earth is fundamentally a co-operative planet on which to live. He aimed to find out how to achieve those reasonable social conditions and to teach people how their environment might be treated properly. He was the most comprehensive, if least acknowledged, father of civic renewal and bio-social ecology as we are beginning to understand them today 50. Geddes was one of the first to recognise that, with the rise of industrialism, urban centres were no longer cities as Plato might have understood them, and that the term needed redefinition. He put forward the term *city-region* to convey the idea of an expanded sphere of influence and held that humanity had the means to abandon the early industrialism and enter a *neotechnic* age with the promise of relief from drudgery and waste.

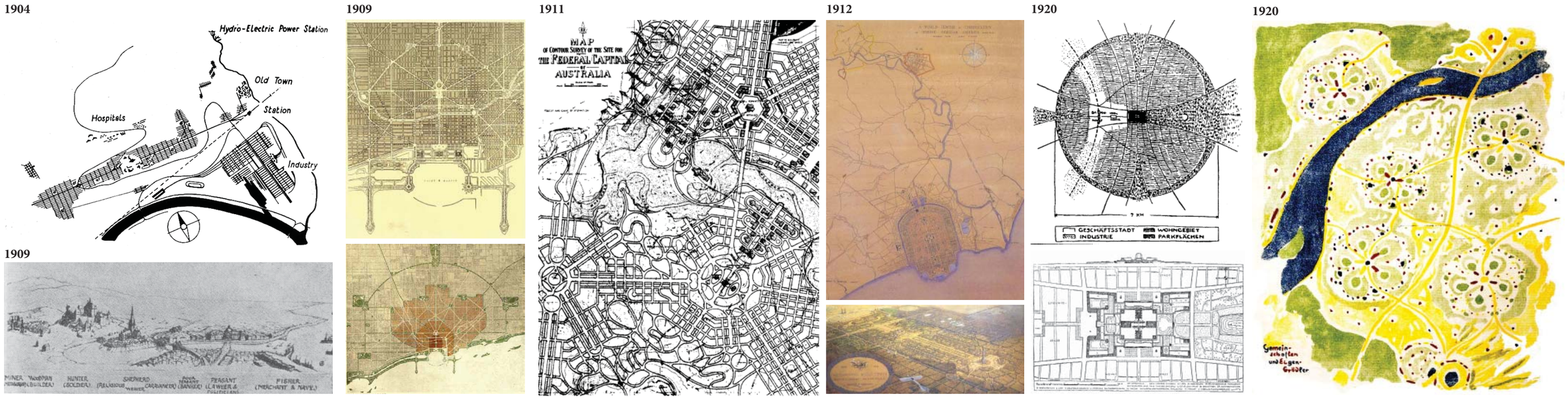
> (There is a). . .*better future now dawning – in which the applied physical sciences are advancing beyond their clumsy and noisy first apprenticeship, with its wasteful and dirty beginnings, towards a finer skill, a more subtle and more economic mastery of natural energies; and in which these, moreover, are increasingly supplemented by a corresponding advance of the organic sciences, with their new valuations of life, organic as well as human.*[6]

Geddes developed a deep fascination with the organization of human societies and their spatial manifestation in the forms of cities and the country. Geddes propagated a highly individualistic theory of societies and cities drawing from regional theories in biology and geography, philosophical ideas and political anarchist thought and especially what he called constructive anarchism. ***Elysée Reclus*** (1830-1905), geographer and prominent personality in the international anarchist movement, influenced Geddes with the stress he put on the organic relation of the city to the countryside and his predictions of their eventual integration. Reclus like ***Kropotkin*** (1842-1921), was an eminent geographer and both were well-known to Geddes and accordingly influenced his work as did ***Frederic Le Play*** (1806-82). From Le Play, Geddes developed the ideas of *folk, work and place* as tools of social geography, whilst Reclus inspired his Valley Section method of analysis and bioregionalist perspective. Gedde´s widespread interests were not the result of a pursuit of pure knowledge, but of an attempt to clarify, synthesize and emphasize the inter-relations between all branches of knowledge, and the importance of transdisciplinary flow. Through his work, Geddes was practicing the reclamation of science by citizenship, and, through his wide-ranging activities, was trying to bring together areas of thought that have become isolated and sterilized by modern thinking and its failure to begin and end with the unity that is life. Lewis Mumford was impressed that Geddes was able to couple thought to action, and action to life, and life itself to all the highest manifestations of sense, feeling, and experience[7]. In Geddes' view , life and the sundered fragments of the modern world were restored to unity, not by returning to their original simplicity, but by going forward to a more highly developed synthesis and to a more inclusive pattern of action: open to fresh ideas and ideals.

Geddes' inclusive and integrating approach to human knowledge and civilization was capable of bridging the cultures so that far from rejecting the primitive elements in our civilization (he) insisted that they were an integral part of man's inheritance[8]

Geddes rarely invoked Darwin when applying evolutionary ideas to the social and urban contexts, as Geddes saw Darwinian natural selection as being too mechanistic and too reliant on competitive struggle and claimed that the pathogenic social evolution of cities departed very radically from the notion of survival of the fittest[9]. Rather, Geddes had his own interpretation of evolution, being primarily driven from within the organism, rather than by external agency (as with natural selection), and emphasised the importance of cooperation, (a direct influence from Kropotkin), which ultimately triumphed over competition. According to this view, cities were the ultimate expression of social union and evolution[10]. Geddes' approach to cities was largely based on his historical classification of urban form, urban life even, into two distinct periods, which he defined as paleotechnic (early industrialisation), and the neotechnic (the condition into which he supposed industrial society to be heading).

4. Batty, M. & Marshall, H., (2009)
5. Lyle J. T. (1999)
6. Geddes, P. S. (1915)
7. Mumford, L. (1995)
8. Mumford, L. (1963)
9. Batty, M. & Marshall, H., (2009)
10. Ibid.



1904. *Tony Garnier - Une Cité Industrielle* **1909 (left).** *Patrick Geddes - Valley Section* **1909 (right).** *Daniel Burnham - Plan of Chicago* **1911.** *Walter Burley Griffin - Plan for Canberra* **1912.** *Hernest Hebrard & Hendrik Andersen - International World Center* **1920 (left).** *Bruno Taut - Die Stadtkrone* **1920 (right).** *Bruno Taut - The dissolution of the city*

It can been argued that it is possible to trace a line of descent from the morphological thinking of Goethe, through Humboldt, Reclus, and Haeckel all the way down to Geddes, all representatives of an alternative tradition in Western European thinking, deriving inspiration from the joint paradigm of geography and ecology[11]. This may well be true, but it now seems clear that Geddes should be seen as also a part of three further traditions: the utopian tradition from ***Charles Fourier*** (1772 – 1837) to Ernst Bloch; the Scottish tradition of generalism, and the organicist tradition from Aristotle to Hans Jonas and the late Murray Bookchin[12]. This generalist view gives insight into his approach to planning. For Geddes, planning risks losing touch with the communities, cities and regions that it sets out to serve, if it does not take a multiplicity of approaches into account. His philosophy of planning, is reflected in a phrase of a 1915 report[13]:

> "*Town-planning is not mere place-planning, nor even work-planning. If it is to be successful it must be folk-planning.*"

Mumford wrote that "*Geddes made an important contribution in restoring the Aristotelian concept of potentiality and purpose, as necessary categories in the interpretation of life-processes*[14]". For Geddes such potentiality and purpose were represented in man's capacity for insurgence. To which Mumford adds: "*Man for Geddes was not just an adaptive organism...but increasingly the shaper and moulder of his own world.*[15]"

Michael Batty and Stephen Marshal claimed that Geddes respectively employed two different kinds of organic analogy when it came to understanding cities as well as practising tow-planning: First, the city itself was conceived of as something *organic*, whether interpreted as a developing organism or 'evolving' in relation to its environment. In the context of his Ghent town planning exhibition, Geddes (1913, 80) claimed to detect

> *"...a beginning, perhaps the first clear and definite beginning, of the comparative study of cities in their life; each shown as arising like a living being, in a constant relation to its environment; ... Like the living being it is, a City also reacts upon its environment, and in ever-widening circles*[16]*"*

11. Wheeler, K. (1972)
12. Macdonald, M. (2009)
13. Ibid.
14. Mumford, L. (1995)
15. Ibid.
16. Geddes P. (1913) in Batty, M. & Marshall, H., (2009)

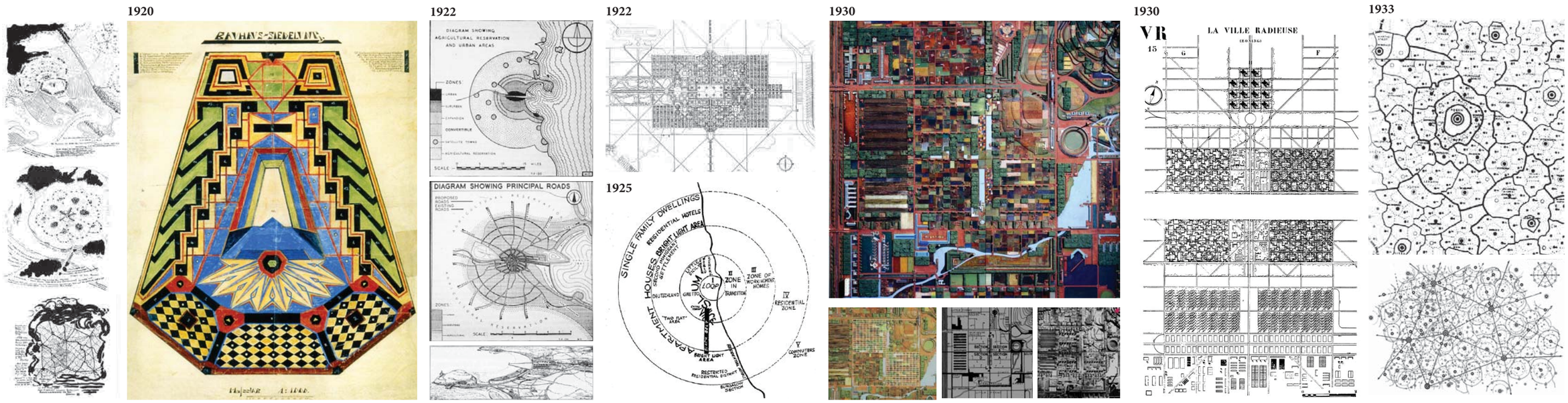
Geddes also introduced a second important evolutionary theme, in which the city was itself an *environment*: a built environment, whose design could influence positively the social organism it contained[17]. In this second sense, the role of the planner was to influence social evolution beneficially through physical design. Accommodate with his creations the needs and aspirations of the end users, the population. The teachings and vision of Geddes found a fertile ground in the face of Lewis Mumford that was to propagate his ideas even further.

Lewis Mumford (1895–1990) was one of the most consummate urban theorists whose enormous body of work on the history and theory of cities remains unsurpassed in its scope and depth nearly twenty years after his death. Mumford provided us with the most comprehensive view of the history of the city and its relationship with technology and culture. His work is notable, amongst other things, for its consistent emphasis on understanding the city in context with its region. He was an early proponent of an ecological worldview. His work on the evolution of cities built on the foundations laid by Geddes, was an advocate of regionalism, where city-regions determined the ecological parameters of civilization.

According to Mumford the maintenance/conservation of the regional setting, the green matrix, is an essential part of the culture of cities. Where this setting has been defaced, despoiled, or obliterated, the deterioration of the city would follow, for the relationship is symbiotic. The difficulty of maintaining this balance has been temporarily increased, not merely by the incontinent spread of low-grade urban tissue everywhere, but by the rapid industrialization of farming itself, which has turned it from a way of life into a mechanical processing business. What is vital he would argue is the preservation of the green matrix in which urban communities, big and small, are set. and above all, the necessity to prevent the uncontrolled growth of urban tissue from effacing this matrix and upsetting the entire ecological pattern of city and countryside [18]. He would conclude that the grasp of the region as a dynamic social reality is a first step toward a constructive policy of planning, housing, and urban renewal[19]. The vital and common elements in the regionalist movement lied in the recognition of the region as a basic configuration in human life; and as a permanent sphere of cultural influence and stage of economic activities[20].

In his 1931 address on Regional Planning, Lewis Mumford presented his theories on the past and future of regional planning. He put forward the idea that cities and towns should not be considered separately from the entire region

17. Batty, M. & Marshall, H., (2009)
18. Downton, P. F. (2008)
19. Mumford, L. (1938)
20. Ibid.



1920 (left). *Walter Determann - Bauhaus Colony* **1922.** *Le Corbusier - Plan de la ville de 3 millions d´habitants* **1925.** *Ernest Burgess - Co-centric zone model* **1930 (left).** *Frank Lloyd Wright - Broadacre city* **1930 (right).** *Le Corbusier - La ville radieuse* **1933.** *Walter Christaller - Central Place Theory*

and that the planned dimension of the region should be considered in its environmental and geological context as well as socio-economic and political culture. He argues, however that regions should be defined according to their natural geography and not political lines that have been merely drawn on maps for different motives. In defining regional planning, Mumford argues that the region '*includes cities, villages and permanent rural areas*' as opposed to metropolitan planning which '*viewed the surrounding countryside as doomed to be swallowed*' in the inevitable upcoming urban sprawl. Mumford stated that modern cities produced a level of degradation which "*mocked any pretensions to progress and enlightenment*"[21]. Health, happiness, culture, recreation, education and all other human preoccupation were by products of in this temporary / ephemeral environment that gave rise accordingly to an unstable and nomadic society[22]. Geddes´ classification of paleotechnic and neotechnic cultures as a kind of evolution was picked up actively by Lewis Mumford and exploited to its full extent in various of his books such as Technics and Civilization (1934) and The Culture of Cities (1938). Mumford foresaw the human prospect that technological progress could create, even though he did not get to see most recent advancements like the wide-spread use of internet, digital methods etc.

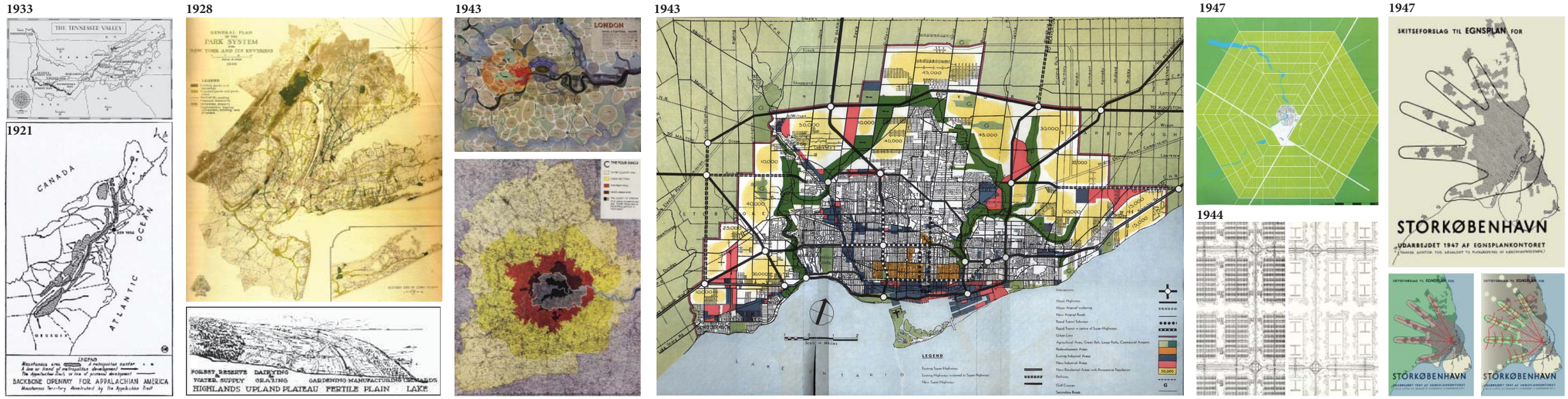
> We must now conceive the city. . .not primarily as a place of business or government, but as an essential organ for expressing and actualizing the new human personality. The old separation of man and nature, of townsman and countryman, of Greek and barbarian, of citizen and foreigner, can no longer be maintained: for communication, the entire planet is becoming a village; and as a result, the smallest neighbourhood or precinct must be planned as a working model of the larger world[23] 59.

Everything we build involves some kind of technology that alters flows of matter, energy and information. The term 'technology' is routinely used in everyday life without a clear sense of its meaning. Taking cues from Mumford, his understanding of technology is that it is not simply about things but it is also about how we use them.. This is a powerful little equation. The difference is in its use, and its use is informed by decisions based on value judgements. The generation of sets of values and their application is at the core of what we call culture[24]. Mumford suggested that modern regions would be more sustainable had the administrators of the past taken into account an area's natural affiliations. The topographical and geological conditions encouraged the development of certain industries and activities which subsequently influenced the respective socio-economic evolution of the region. For this reason, Mumford and his extended bibliography have re-entered in the focus of regional thinking and planning, being often more contemporary and pragmatic despite its age, than most theories that have recently emerged in the field.

The decade of 1930 was a productive period for regionalist ideas, and in the world of academia many of these ideas were accepted and developed in various disciplines and professions such as geographers, sociologists, ecologists, economists, anthropologists, architects or literary critics. Of these none was more diligent and Catholic in its outlook that ***Howard Washington Odum*** (1884-1954). Odum was a sociology professor whose professional interests were first been the public welfare and the role of blacks in Southern society. He taught at University of South Carolina in Chapel Hill where he also resided most of the Southern regionalists, such as T.J. Woofter, Katharine Jocher, Rubert B. Vance and Harry Estill More. But Odum, and his group did not have the high cultural aspirations of the RPAA and Mumford, instead the interest in regionalism was mainly political, in the sense that were trying to defend the attack of industrial interests of the North and its metropolitan culture on Southern values and rural lifestyle[25]. Most of them were rural-urban populist professional academics, and their theories dealt mainly with problems of underdevelopment, the marginal areas and the problems of poverty and racism that characterized them[26]. The Regionalists of the South developed an anti-metropolitan criticism, adapting a different point of view of the contemporary RPAA, criticizing what Odum called techno-methodology, the sum of science and social organization. This attitude ,they were claiming, was changing the traditional modes of human behaviour and replacing natural institutions with dehumanizing social relationships characteristic of urban industrialization[27].

For nearly two decades, Odum and his colleagues produced a series of books, dozens of research articles and theses, and hundreds of scholarly articles many of them in Howard´s Social Forces journal, all in the intend to promote the regional perspective as a mode of understanding the past and thinking in a fertile future development, and planning in practice, its new frontiers[28]. Odum's regionalism, less interested in physical planning, and more in social reconstruction and the formulation of social institutions that provide equal possibilities to the populace with respect its basic needs. Even though the works of Odum gave a great emphasis on real conditions and restrictions, other theorists speculated on more theoretical grounds.

21. Canizaro, V. B. (2007)
22. Ibid.
23. Downton, P. F. (2008)
24. Downton, P. F. (2008)
25. Sale, K. (1991)
26. Friedmann, J & Weaver C. (1981)
27. Ibid.
28. Sale, K. (1991)



1933. *Tennessee Valley Authority (TVA)* **1921.** *the Appalachina Trail by Benton MacKaye* **1928.** *New York Regional Plan & its environs* **1943.** *Sir Leslie Patrick - Abercrombie Greater London Plan (left), Toronto Plan (right)* **1944.** *Ludwig Hilberseimer - New City* **1947.** *Paul & Percival Goodman - Comunitas (left), Copenhagen Finger Plan (right)*

Frank Lloyd Wright's (1869–1959) architectural belief of organic processes and the idea that built form should exhibit a sensitive response to its environment contributed to the architectural ecological vision significantly. Wright was not an urbanist, and even more he was famously anti-city[29]. In his illustrated polemic *The Living City* he laid out his ideas for a city of organic architecture, of creative individuals, and self-sufficient communities, covering the landscape in a carefully designed and reticulated sprawl. His vision of Broadacre city was barely of a city in terms of urbanity. The city according to his theory was seen as a pancake, a superposition of activities and patterns.

> "*Garden and building may now be one. In any good organic structure it is difficult to say where the garden ends and where the house begins or the house ends and the garden begins and that is all as should be...*[30]" He was questioned about what this might mean for the countryside: *We are talking about the countryside itself developing into a kind of building [...] the building becoming part of the countryside, belonging there naturally with grace.*[31]"

Wright's concept of Broadacre City was prescient in many ways: He foresaw a landscape entirely altered or worked over by human activity and went even further by proposing that the human impact on the land should be a result of integrated design that serves the needs of both the landscape and its occupiers[32]. His ideas bore great resemblance to the ideas presented by his german contemporary ***Bruno Taut*** (1880-1938) and his vision of the dissolution of the cities in the landscape. Both thinkers naturally did not oppose urban culture or urbanity as form of social organization but instead could be understood as a reaction and critique against increased density and disorder taking place in cities, and not as an absence of a social vision or plan of the city[33].

Le Corbusier (1887-1965) although more known as a pioneer of modern architecture, in his book *Urbanisme* he also advocated the garden city and stressed the importance of an intermediary zone: "*Lying between these two organs (the central city and the peripheral garden city), we must require the legal establishment of that absolute necessity, a protective zone which allows of extension, a reserved zone of woods and fields, a fresh air reserve.*[34]". However oxymoron as it may seem his idealogy for the city of tomorrow brings great resemblance to Mumford's regional plan when he says that the basic principles to follow are the following[35]:

1. We must de-congest the centres of our cities.
2. We must augment their density.
3. We must increase the means for getting about.
4. We must increase parks and open spaces."

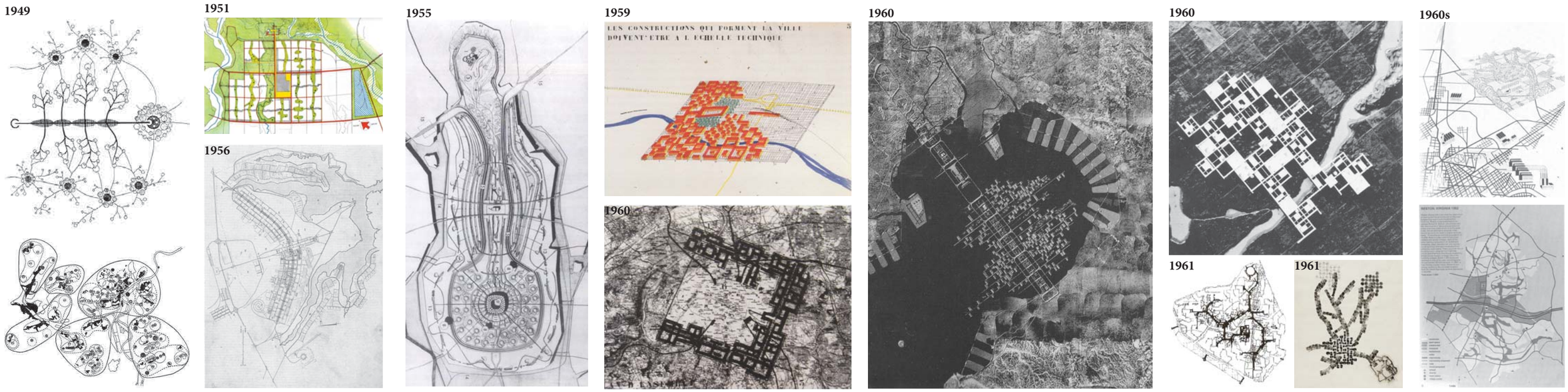
Konstantinos Doxiadis (1913-1975) was a Greek architect and town planner that held a key role in the reconstruction of Greece after WWII and author of many and diverse projects worlwide subsequently. Doxiadis studied meticulously the patterns and dynamics of human settlements in all their aspects and scales (spatial and time). For that reason he proposed the science of *Ekistics* as a science for the study and design of human settlements developing an extensive theoretical body outlining its scope, aims, intellectual framework and relevance. Ekistics aimed to encompass all scales of human habitation and learn from the historical patterns developed in the diverse human settlements on Earth. At the centre of his ideas lied the human being, the Anthropos, and all planning and design should be done to accommodate his well being and prosperity.

Doxiadis understood the dynamic nature of cities, their need to grow and evolve, for this he came up with the term *Dynapolis* to describe this precise phenomenon; the spatial-historical evolution of the city in the territory, that saw its centre expand or displaced due to the various dynamics present in the territory[36]. According to Doxiadis the cities worldwide were prone to involve into a continuous and interconnected urban conurbantion that would cover the entire globe, in what he called *Ecumenopolis*. His research project City of the future in 1960, that involved more than 100 scientists at some point was conceived as an on-going project re-examining and re-adjusting the assumptions and variables continuously and proceeded to foresee and propose future alternative plans and models for human settlements on a global scale, as one of its main tasks[37]. The findings and proposals were not to remain on the theoretical sphere, but were also to provide a frame and guidelines for proper planning. Doxiadis applied his theories in diverse studies and plans on a national and equally international level.

The ***metabolists*** respectively were an architectural movement by young Japanese architects theorizing, between 1958 and 1975, about the urban growth of megacities, introducing concepts and ideas that broke with the traditional forms. In their manifesto *Metabolism: The proposal for a new urbanism*, they tried to give answers to the questions / problems of urban density, population growth and increased flows through an original intersection of biology and computer science, fusioning the notions of efficiency and morphology . Their vision of the future-city

29. Downton, P. F. (2008)
30. Wright, F. L. (1963)
31. Wright, F. L. (1963)
32. Ibid.
33. Mantziaras, P. (2002)
34. Le Corbusier (1947)
35. Ibid

36. Doxiadis, C. A. (1968)
37. www.ekistics.org



1949. *Rudolf Schwarz - Milky way (top) & Thionville (bottom) diagrams* **1951.** *Le Corbusier - Chandigarh* **1955.** *Paolo Soleri - Mesa City* **1956.** *Lucio Costa & Oscar Niemeyer - Brazilia* **1959-1960.** *Yona Friedman - Ville Spatiale* **1960 (left).** *Ykenzo Tange- Plan for Tokyo bay* **1960 (right).** *Kisho Kurokawa - Agricultural City* **1961.** *Candilis Jossic & Woods - Toulouse-Mirail (left), Kisho Kurokawa - Helix City (right)* **60s.** *New Deal & decentralization projects, Reston Virginia (bottom)*

was characterized by large flexible and extensible structures for accommodating mass human population with an organic growth, producing models like the Ocean city, the Floating city or the Spiral city or the proposal for Tokyo bay among others. The movement was led by figures such as Fumihiko Maki and Kisho Kurokawa, Kiyonori Kikutake, Arata Isozaki or Kenzo Tange.

Given the different parallel movements in city planning it is essential to note "*that the systems approach as it emerged in the 1960s was a natural culmination of at least 50 years of top-down planning built on a synthesis of paternalist social philanthropy in concert with engineering and modifying the urban and natural environment and alien to the organic idea of evolution in relation to cities and the notion that most of what is created in cities is rather well adapted to purpose*[38]". The diverse attempts and examples of the City Beautiful Movement or the subsequent ***Walter Christaller*** (1893-1869) with his *Central place Theory* comes in mind as typical references and base models for subsequent related theories. While not directly inspired by the Garden City tradition, Walter Christaller's *Central Place Theory* had certain technical parallels with Howard's Social City diagrams. The spatial structuring, hierarchical ordering, polycentric layout and the connection between each of the centres bears resemblance however with a distinct socio-spatial agenda[39]. As Batty and Marshall comment "*the systems approach was devised to impress radically new forms on the city in the belief that the functioning system was far from efficient, and that new forms of top-down control were needed to establish environments more fit for purpose. The systems approaches of the 1960s were much more akin to management and control than to the notion that well functioning systems must adapt themselves by learning what works and what does not, slowly but surely with the only way to achieve such improvements being through the relentless pursuit of small changes*[40]."

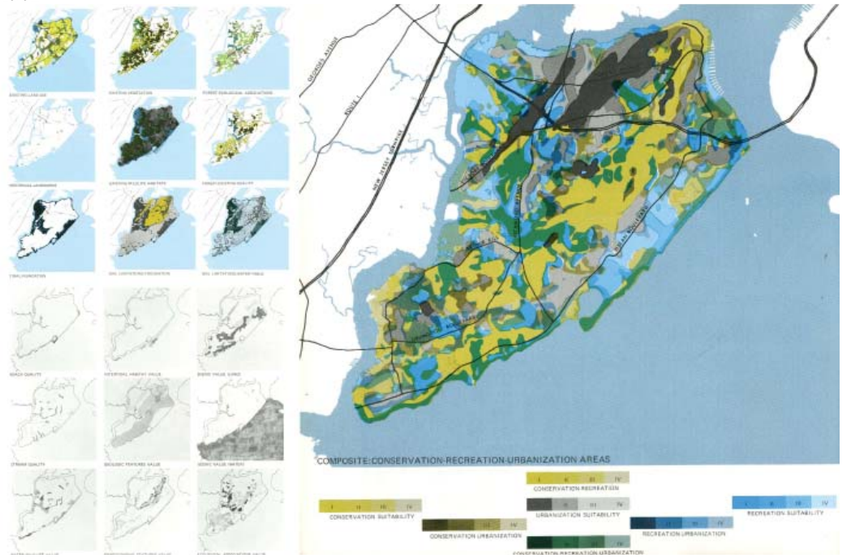
Grand visions of plans for future cities many times never materialized or have failed terribly in their implementation. The utopianism, and implicit authoritarianism, present in many of the city plans and city visions of the time generated both excitement and a foreboding of things to come. But even the exemplary, in many aspects, Regional Plan of New York gave rise and stage for the subsequent *Haussmannian* works of Robert Moses that left such a great impact on the city of New York. It has been the conditions and counter feelings that these situations have produced that favoured the re-emergence of the historical thread. There have always been those who saw an imperative to work with facts and real places rather than imaginary or utopian visions. Such was ***Jane Jacobs*** (1916–2006), a journalist and eventually an urban activist who led the movement against the corporate planning machine in many North American cities. Her analysis of the processes by which planners had destroyed cities and city life in general was quite in-depth and revealing for its time. She pointed towards the real nature of city stating that life and economy are the only civilised counters to *the doctrine of the super technologists, and the blind bureaucracy of planning orthodoxy*[41]. Jacobs' message was to revalue and regenerate what we have – the old streets with their contact and camaraderie, the economic use of old buildings, the necessity for diversity and the dangers of radical redevelopment. Above all, she stresses the possibility of regeneration through social and administrative means rather than through new construction[42] 75. Her pragmatic and critical point of view can be seen in phrases like the following:

> "*Automobiles are often conveniently tagged as the villains responsible for the ills of cities and the disappointments and futilities of city planning. But the destructive effects of automobiles are much less a cause than a symptom of our incompetence at city building.*[43]"

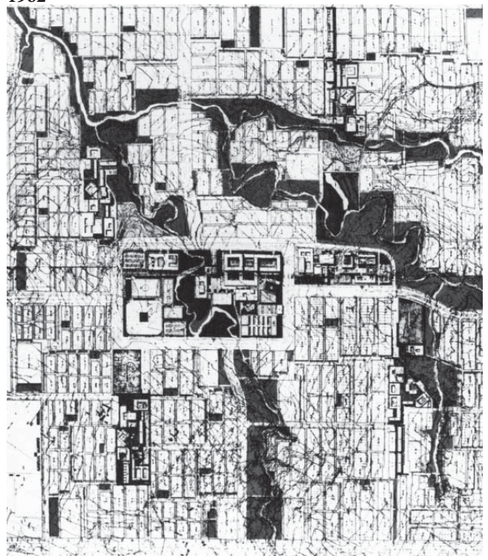
However, her real contribution to the idea to the debate was her argument that cities are complex systems. Her most famous work *The Death and Life of Great American Cities* published in 1961 drew on ideas found in the biological sciences to explain why cities need to be diverse, heterogeneous, messy, *disorganised*, as befits a complex system. Despite the heritage of Geddes, which did not lead to any widespread thinking of cities as evolving (or evolutionary), living systems, there were still lone voices such as Jacobs preaching the message that our understanding of cities and their planning should be from the bottom up. To an extent, the public participation movement embraced this message but it was Jane Jacobs (1916-2006) who, through her seminal text The Death and Life of Great American Cities, laid the groundwork. She argued that it was the diversity of cities that marked their quality and that this diversity was formed from countless individual decisions, generated from the bottom up. Her corollary was that top-down urban planning destroyed such qualities that made cities what they are. Jacobs drew her inspiration, of course, from observations of life in large cities, but she bolstered her ideas by reference to the way the biological sciences were developing. Drawing on Warren Weaver's (1948) address to the Rockefeller Foundation in which he argued that the greatest challenge was to deal with systems of organised complexity, systems that had the complexity of human organisms, not the dry sterility of statistical physical systems, she fashioned her argument around ideas that were entirely consistent with evolution[44]. Nevertheless, her message resonates down the ages and is a mantra for our times.

38. Batty, M. & Marshall, H., (2009)
39. Ward, S. (1992)
40. Ibid
41. Downton, P. F., (2008)
42. Jacobs, J. (1961)
43. Jacobs, J. (1961)
44. Batty, M. & Marshall, H., (2009)

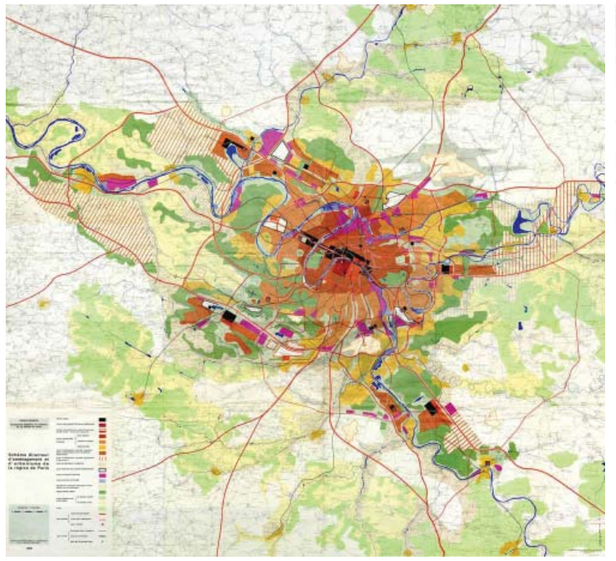
1962



1962



1965



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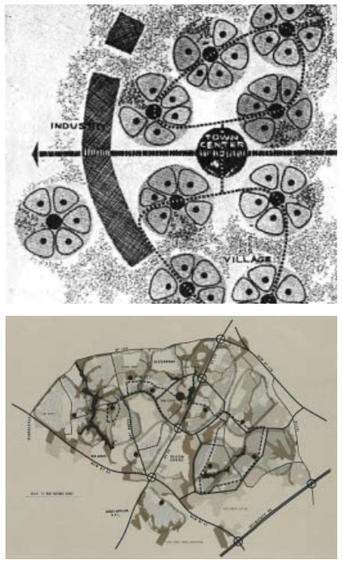


1962 (left). *Ian McHarg - Staten Island* **1962 (right).** *Konstantinos Doxiadis - Plan for Islamabad* **1965.** *SDAUR de Paris*

> '*cities happen to be problems in organised complexity, like the life sciences. They present situations in which half a dozen or several dozen quantities are all varying simultaneously and in subtly interconnected ways … The variables are many but they are not helter skelter; they are interrelated into an organic whole*'[45]

Christopher Alexander (1936-) illustrated the perils of codification and restrictive planning with the direct application of set theory and network topology to urban morphology. Trained in physics, mathematics, computer science, information science, and architecture, in his PhD thesis *Notes on the Synthesis of Form*, argued that good architecture, *was well adapted to context, the product of many decisions about form which were tried and tested as those who lived and used buildings sought to adapt them to their purpose*[46]. At the centre of his theory there is the idea that good design is not a matter of elements functioning properly in a mechanical system, but rather of spatial regions that amplify each other in a larger whole. The environment cannot thus be merely understood by breaking it down into small parts / components, but needs to be considered as a set of units, which support and enhance each other in a complex and interdependent whole.

In his 1965 article *The City is not a Tree,* he critiqued what he deemed to be the infrastructural or organisational template of many contemporary settlements and cities. According to Alexander a "tree" is a branching structure in which sets are either completely disconnected from one another or entirely contained within one set without any overlapping. The branches do not grow together but emanate separately from a single trunk[47]. Alexander demonstrated in his article that Greenbelt, Maryland, the Greater London Plan, Brasilia, Kenzo Tange's Tokyo Plan, Chandigarh, Hilberseimer's settlement patterns, and other well-known city plans followed this tree pattern[48]. He asserted that traditional settlements developed interconnections and overlaps that did not resemble an arborescent structure, primarily due to the proper activities of the inhabitants rather than the effect of authority and administration. Authority always generates a tree and therefore, in his terms, an artificial city[49]. In opposition to this deterministic diagram of *artificial* cities, Alexander proposed the model of the *natural* city. Such a city settles over time and is structured instead of a tree as a *semi-lattice*, an open structure, where the parts are connected to each other by several orders of relationships, in nested hierarchies, and the elements of a smaller scale may interact with others freely and without hierarchical restrictions[50]. This way multiple connections and informal levels of relationships between different orders of scale and significant interferences between the parts are facilitated and encouraged. This message of both Jacobs and Alexander calling for an approach to architecture and planning that diverged massively from the top-down corporatism of the state that kept increasing dramatically with passing of time, remained valid for the years to come and up till today. The discourse was enriched over time by additional inputs from distinct thinkers that added their piece in the complex vision that was being constructed.

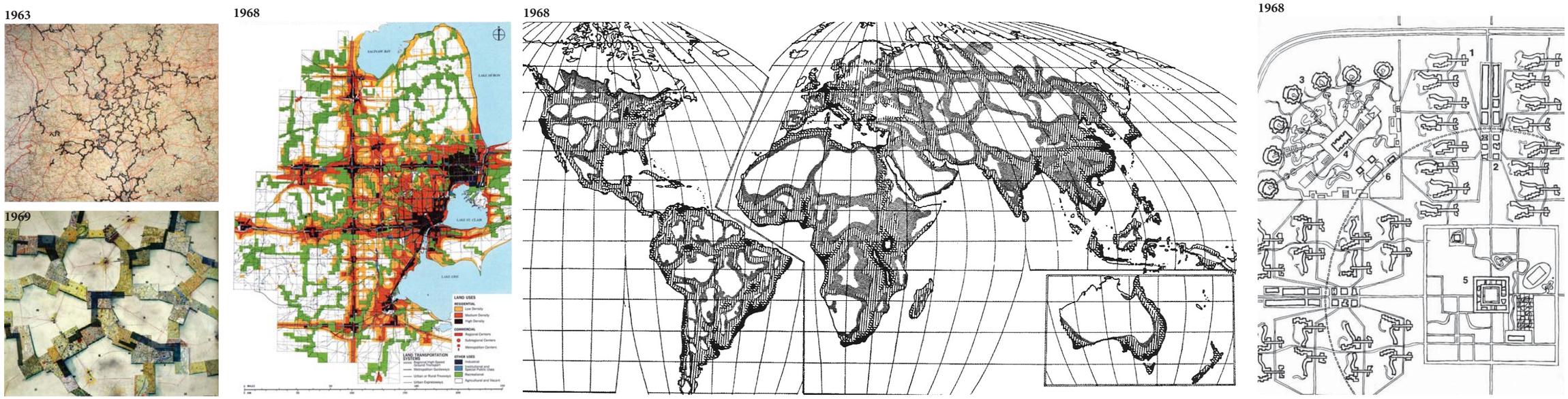
45. Jacobs, J. (1961)
46. Alexander, C. (1964)
47. Alexander, C. (1966)
48. Ibid.
49. Batty, M. & Marshall, H., (2009)

Christian Norberg-Schulz (1926-2000) was a Norwegian architect with a long practice in his home country and architectural historian and internationally as an architectural historian and theorist. In a later phase of his life though his theoretical work saw a shift from the analytical and psychological concerns of his initial writings towards the issue and question of the phenomenology of place, being one of the first architectural theorists to introduce the thinking of Martin Heidegger and Edmund Husserl to the field. With his book *Genius Loci: towards a phenomenology of architecture* (1980) he intended to give a phenomenological interpretation of architecture based on the concept of ***genius loci*** , a phenomenology of architecture and present a method for analysing and understanding architecture.

> "*Architecture means to visualize the 'genius loci', and the task of the architect is to create meaningful places, whereby he helps man to dwell.*[51]"

As Norberg-Schulz observed, natural settlements occurred only where nature (through the creation of favourable environmental conditions) invites man to settle[52]. He cites Hegel who defined place as the "*natural type of the locality, which is closely related to the type and character of the people born from this soil. This character is the way peoples appear and find their place in world history*[53]". To preserve the genius loci, means to actually respect these factors: "*the type of settlement and way of building ('massive', 'skeletal' etc.) as well as characteristic motifs […] If the primary structural properties are respected, the general atmosphere or 'Stimmung' will not get lost. It is this 'Stimmung' which first of all ties man to his place and strikes the visitor as a particular local quality*[54]". The genius loci of the human settlement sand cities represent microcosms, and cities at they differ in the distinct assemblies that they form and encompass. As Norberg-Schulz says to respect the genius loci does not solely mean to copy old models but through the work of architecture keep that essence alive:

50. Alexander, C. (1966)
51. Norberg-Schulz, C. (1980)
52. Ibid.
53. Ibid.
54. Ibid.



1963. *Columbia, Maryland - Scheme & Plan* **1969-1963.** *Constant - New Babylon* **1968.** *Doxiadis Plan for Detroit (left), Ecumenopolis diagram by Konstantinos Doxiadis (middle), Alexei Guntnov - Ideal Communist Cities*

> "*To protect and conserve the 'genius loci' in fact means to concretize its essence in ever new historical contexts [...] It means to determine the identity of the place and to interpret it in ever new ways*[55]"

Although encountering the essence of a place was a key concept it also soon became evident the need to preserve the biophysical attributes of this places that serve as the stage of human activity. The rise of ecology in social and intellectual terms also brought significant advances in ecological planning and management. ***Ian L. McHarg*** (1920 - 2001) was born in Scotland and became a landscape architect and a renowned writer on regional planning using natural systems. He was the founder of the department of landscape architecture at the University of Pennsylvania in the United States. His 1969 book Design with Nature pioneered the concept of ecological planning. It continues to be one of the most widely celebrated books on landscape architecture and land-use planning. laying the foundations of what is now know as GIS technology.

> "It is not a choice of either the city or the countryside: both are essential, but today it is nature, beleaguered in the country, too scarce in the city which has become precious[56]" 66

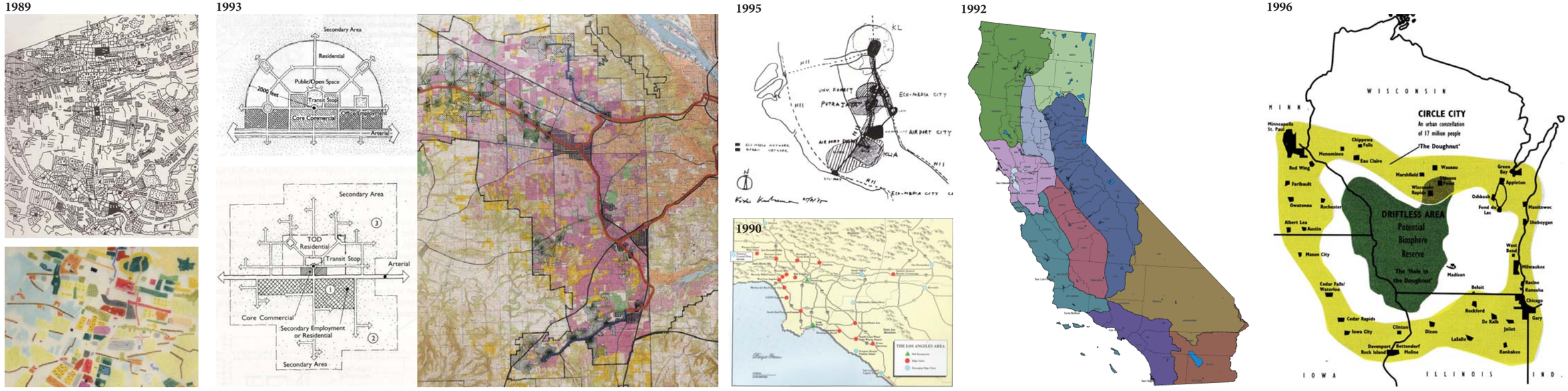
> "Let us accept the proposition that nature is process, that it is interacting, that it responds to laws, representing values and opportunities for human use with certain limitations and even prohibitions to certain of these.[57]"67

Ian McHarg took the intellectual baton from Mumford and applied ecological thinking to the problems of planning human settlement. In the Introduction to McHarg's seminal work *Design with Nature* Mumford called him an inspired ecologist. McHarg applied his perceptions of nature and propositions of process to the task of designing a system for designing with nature. His resulting approach, developed over many years, was tested through practical application in difficult environments, typically where urban development pressures threatened nature[58] 68. With case studies undertaken in places like the Potomac basin that cradles Washington DC, the Baltimore region and metropolitan regions in the USA, McHarg used the technique of layering various analytical maps of a region one on top of the other so that the patterns of the place could be revealed. Thus hydrology, geology, soils, drainage, historical landmarks, vegetation, wildlife habitats, slope, and scenic values might all be layered to decide the places most likely to be suitable for recreation, residential development, and so on. This powerful technique was employed at his times without the aid of computers and set the foundations for what are now the essentials of environmental planning. The legacy of McHarg can be seen across the planning world. McHarg's methodology of analysis by layers of patterning in the natural and human landscape was a revelation when it first appeared and it has long since continued to influence and advance the environmental and landscape theory and practice, inspiring subsequent followers like Richard T. T. Forman with his patch mosaic theory that has helped explain and systematize heterogeneous landscapes using a common vocabulary. Understanding natural ecosystems was one challenge but understanding the deeper links with human activity development was a pending challenge and one that has yet to be fully comprehended.

Both Geddes and Mumford had expectations above and beyond mere policy and planning, and were stretching towards a concept of a rounded-self, a citizen, aspiring to their anarchists ideals and way of thinking. An element which demands a mention, connecting, as it appears to do the ideas of Geddes with those of the organicist Murray Bookchin. Critical of the modern metropolis, ***Murray Bookchin*** (1921-2006) distinguished it from the idea of the city, which he thought of as a liberating human invention that deserves careful analysis and passionate support as the essential home and cradle of human civilization. The city according to Bookchin is more than a mere assemblage of space, and in evolving to its present state, wherever its geographical location, it has brought together strands of cultural development from across the globe. City history has been uneven and does not reflect a simple increase in civic virtue by any means but, the city can only be understood by seeing it in terms of its history, and that history has been a cumulative one in which traditions of rationalism, morality and law have persisted even as the physical frameworks of cities have come and gone[59].

Bookchin's view of the city is that of an ethical union of citizens, as the basis for the continuing improvement of the life of citizens and as the basis for collective human action in the world. It sees the city as the primary location for effecting social change. Taking this idea forward to look at how governance would work without the apparatus of the central state, Bookchin proposed a libertarian municipalism in opposition to statism in all its derivatives. A pioneer in the ecology movement, Bookchin was also the founder of the social ecology movement. He was a staunch critic of biocentric philosophies such as deep ecology and the biologically deterministic beliefs of sociobiology. He was the author of two dozen books on politics, philosophy, history, and urban affairs as well as ecology. His definition of Social Ecology is the following [60]:

55. Ibid.
56. McHarg, Ian L. (1967)
57. McHarg, Ian L. (1967)
58. Downton P.F (2008)
59. Ibid.
60. Ibid.



1989. *WJ Neutelings - Randstad Patchwork Metropolis* **1990.** *Joel Garreau - Edge Cites / Los Angeles* **1992.** *INACC, Working Bioregions, California* **1993.** *Peter Calthorpe - Transport Oriented Development (TOD)* **1995.** *Kisho Kurokawa - Ecomedia City* **1996.** *Philip Lewis - Circle City*

"*Social ecology is based on the conviction that nearly all of our present ecological problems originate in deep-seated social problems. It follows, from this view, that these ecological problems cannot be understood, let alone solved, without a careful understanding of our existing society and the irrationalities that dominate it. To make this point more concrete: economic, ethnic, cultural, and gender conflicts, among many others, lie at the core of the most serious ecological dislocations we face today—apart, to be sure, from those that are produced by natural catastrophes*"

Although Bookchin talked of bioregions it was ***Peter Berg*** and ecologist ***Raymond Dasmann*** brought the term ***bioregion*** into the vocabulary of environmentalism in the mid-1970s. It defined the bioregion by its life forms, its topography and its biota, and the human perception[61]:

"*A bioregion can be determined initially by use of climatology, physiography, animal and plant geography, natural history and other descriptive natural sciences. The final boundaries of a bioregion are best described by the people who have long lived within it, through human recognition of the realities of living-in-place.*"

A feel for the concept of the region can be gained by knowing the land, learning the regional traditions and recognizing that every place has a history: a record of how both the human and natural possibilities of the region have been explored, a record that may be embodied in local myths and legends. Developing the potential to see what can best be realized within the boundaries of the region, using all the biotic and geological resources to their fullest, constrained only by the logic of necessity and the principles of ecology [62]. Knowing, learning, developing, liberating are some of the processes most central to the bioregional idea. The specificity of place is pivotally important. Sale writes of the interaction between city and country as a social symbiosis which, in a bioregional world, would bring the benefits of the country to the city, and vice versa [63]. Bioregionalism developed as a movement, fuelled and informed by the ideas of Berg, which deliberately set out to link politics with place, yet at the same time it sought to avoid reactionary approaches to politics. With regard to its implementation, Sale observes that bioregionalism has the virtue of being possible only via a gradual process: low, steady, continuous, and methodical, not revolutionary and cataclysmic[64].

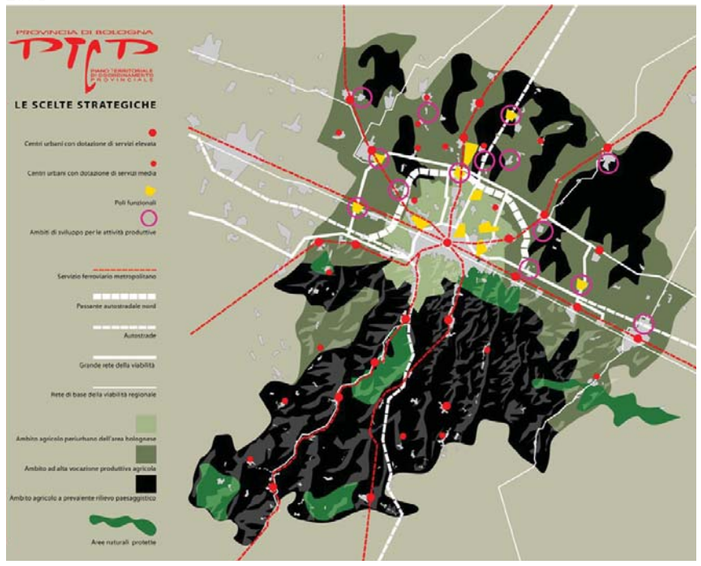
61. Berg, P. and Dasmann R., (1977)
62. Downton P.F (2008)
63. Sale, K. (1991)
64. Sale, K. (1991)

Kisho Kurokawa (1934-2007) called for a philosophy of symbiosis – a new age where man, the man-made and the natural can dwell in a place in peaceful unison. Kurokawa saw a physical manifestation of this symbiosis in the ambiguity of intermediate spaces present in traditional Japanese architecture and related this ambiguity to the 'fuzzy boundaries' of Mumford's bioregions where all exists in symbiosis. A more sustainable and encouraging form of regional development has been proposed by Kisho Kurokawa through the decentralisation of some industries in Kuala Lumpar in Malasia. His proposal for the Eco-Media City 2020 consisted of 5 small cities of equal density and weight, where Kurokawa's vision, fuelled by his philosophy of symbiosis, preserved the natural environment, uniting man and nature[65]. Berg speaks of reinhabiting landscapes, by which meaning that a modern landscape can, and should, be conceptually revisited so as to understand better how to live in it[66]. This involves becoming aware of its natural boundaries, conscious of its landforms, climate, fauna and flora, and seeking to understand the indigenous human history of the place. Instead of accepting the damaged places of modern urbanism and planning as a reality to respond to, Berg suggests that places should be lived the way they were in their predeveloped, usually pre-industrial, state.

Bioregionalism built on the illustrious history well rooted in the organicism of traditional, pre-industrial urbanism, and in the works and writings of Geddes, Mumford and their philosophical contemporaries. This bioregional tendency gained energy and impetus in the european context in different manifestations as in the work of Alberto Magnaghi and the Italian Territorialist School at the turn of this last century. Avoiding the purely technical approaches to sustainability, the *territorialists* emphasised the need to balance and combine three objectives as the strategic keys for the sustainable development[67]: **1)** Development directed towards fundamental human requirements (which cannot be reduced to material needs alone); **2)** Self-reliance and the development of self-government by local society; **3)** Enhancing environmental quality. This vision of self-sustaining regional planning was explicit about adopting clear sets of rules to enable and support that development within the context of a defined territory. This type of approach stressed the increasingly role of the territory in itself when tackling problems of sustainability and consequently assumed the production of ***territorial quality*** as an important indicator of lasting well-being[68]. Alberto Magnaghi with his definition of the urban bioregion conveys well this message:

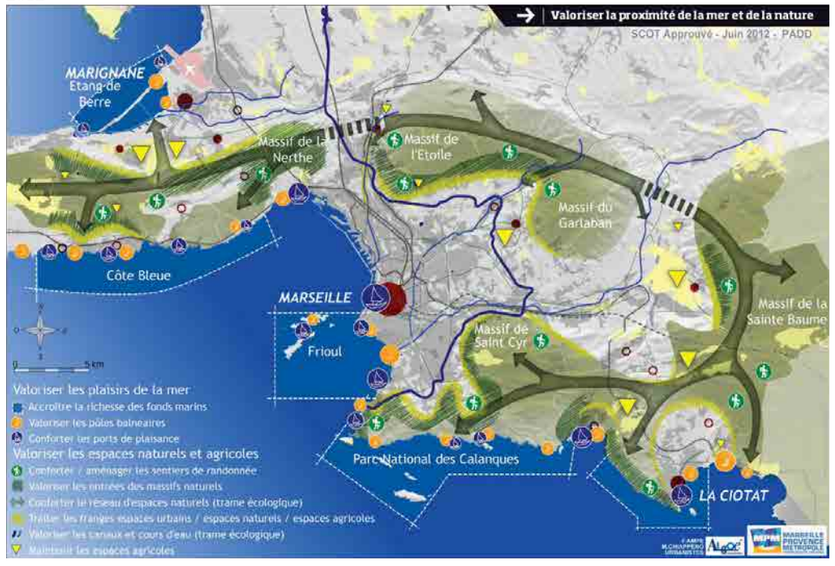
65. Kurokawa, K. (1994)
66. Downton P.F (2008)
67. Ibid.
68. Magnaghi, A. (2005)

2004

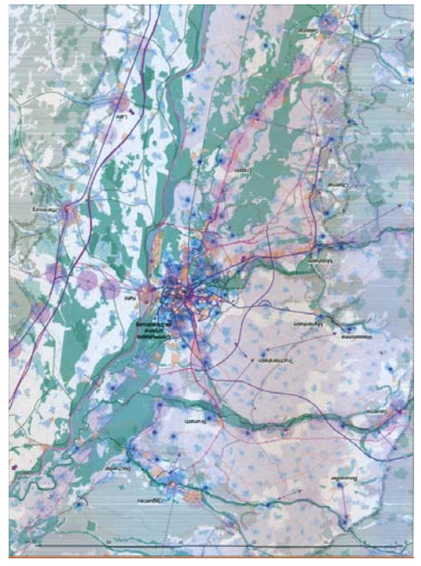


2008

2012



2013



2004. *PTCP Bologna* **2008.** *PTCP Prato - Alberto Magnaghi* **2012.** *SCOT Marseille Provence Metropole* **2013.** *SCOT Region de Strasbourg*

"The urban bioregion is a large network city studded with small centres connected up in dense constellations [...] The urban region of is not a 'garden city', it is a compact city with gardens [...] The urban bioregion is as 'large and powerful' as a metropolis. [...] Respecting the supply capacity of a territory means setting quantitative, typological and morphological limits according to the capacity of a place to sustain transformations without destroying its capacity to reproduce its own identity and without reducing its value. The quest for renewal of the regional is a search for ecological limits [69]"

This has been a short presentation of recent influential thinkers that have on one side influenced this particular research and one another level have had their respective impact in contemporary planning and in the advancement of theoretical thinking. With the respect to the second question this is by no means an exhaustive list, something that would be outside the scope of this paper. The ideas and ideals described previously, serve as the theoretical guidelines in combination with contemporary research for reaching conclusions analysing the case study. The urban region, as a specialized type of region in itself is a notion that has gained increased attention and importance in the recent debates. Building upon the ideas of regionalism, the urban region is presented as an emerging concept for controlling and adjusting urban growth and degradation. The urban region concept re-emerges as a special form of a bioregion, ***the urban bioregion***, making an implicit reference to urbanity as a quality, and the natural as the relevant context of all activity and development.

The seeds of this kind of thinking are being sown in developments in systems biology, allometry and related areas – which in one sense go back to Geddes – in the new economic geography, in growth theory, in a new appreciation of scaling and size in cities, and in new ways of thinking about mobility and access to resources. These concerns blend economics with physics in a manifestly evolutionary framework which takes as its essence, the notion that cities are as seen earlier by default dissipative systems following non-equilibrium logics. and that a multitude of bottom-up decisions, while realising coordinated and ordered patterns, produce shocks and abrupt changes in ways that are intrinsically unpredictable. The effects of climate change, for example, force us into this kind of thinking, and as part of this quest we are beginning to generate new ways of thinking about the future and the role of prediction and predictability in such systems and especially how ecotonal areas can serve towards such a direction.

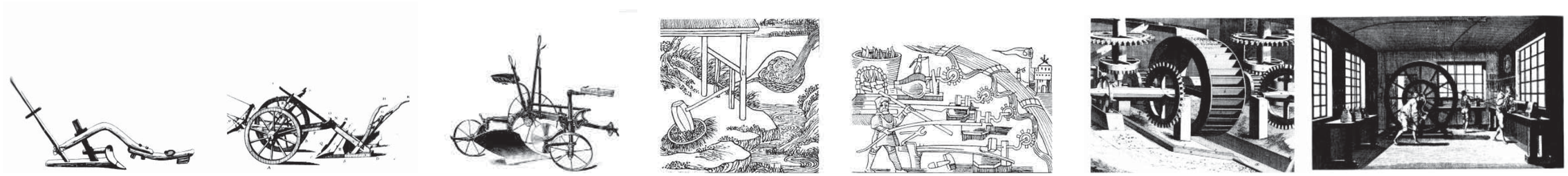
Essentially thinking of cities as complex systems takes us back to Jane Jacobs and the notion that cities are vehicles of enormous heterogeneity, which maximise rather than minimise economic and social opportunities. Although Geddes blazed the trail of local renewal with a philosophy of life that was tolerant of personal and individual differences, he and his successors in the town planning movement were almost forced by the times in which they lived to adhere to a model of uniformity that considered good planning to be the imposition of an homogeneous order, quite counter to their visions and aspirations. For many years, there has been a debate about the disconnection between cities and their planning to the point that in the 1970s it became legitimised through the idea of theories of planning contrasted with theories in planning. In that the professional and scientific mind sets that led to each were often dramatically different, theories of planning took a different form and logic from theories in planning; and because of this separation, planning was often regarded as part of the problem rather than part of the solution.

Taking all the previously mentioned into consideration a theory of cities must start from the premise that the city is composed of complexly-ordered nested systems, an organization that offers a certain degree of resilience and capacity for adaption in the sense that independently of external and internal pressures / perturbations the city has the capacity for readjustment while maintaining key functioning and integrity. The collective project that the city , and respectively the city-region has come to be considered should also be the outcome of collective and multi level decision-making. In a way that planning and governance should adopt to feasibility as a starting point for, finding ways for steering these decisions into ways in which collective outcomes are optimised and expressed.

If we are able to understand how collective outcomes are formed through the repeated actions of bottom-up decisions that adapt, mutate and innovate with respect to an individual's action space, then making small changes at small scale is likely to have far greater consequences for the collective outcomes that we observe in physical changes usually associated with city-planning. To make sense of all this, a new theory of cities is required, one that builds on evolutionary thinking, linking to the complexity sciences in the ways we have indicated here[70].

69. Magnaghi cuoted in Downton P.F. (2008)

70. Batty, M. & Marshall, H. (2009)



VII. Towards a concept of a territorial efficiency

*The **structural efficiency** was one of the paths followed by the process of rationalization of architecture. Another one was that of **functional efficiency**. While structural efficiency has relation with the constructive system of the building, without considering the operations and processes that take place in its interior, the functional efficiency refers to the building´s capacity to contribute positively to the development of the activities that it hosts [...] For the rationalist tradition in architecture, the structural efficiency was the first principle that had to be defined and promoted. It was much later that the respective one of the functional efficiency appeared in a systematic form. Why wasn´t the question of functional efficiency proposed earlier in the development of the rationalization discourse in architecture? One of the arguments utilized to explain this deed was the affirmation that people can only improve the realization of their activities, in a rational sense, when they are capable to measure them. It was also maintained that not all types of efficiency can be measured with the same ease. In this sense the objective of structural efficiency was developed first because it presented less difficulties in its measurement [...] The functional efficiency presented great difficulties in being captured and registered, given that it is related with processes that take place in time and that enter in consideration diverse human factors. This delay of the functionalism can, therefore, be explained due to its higher degree of complexity.*

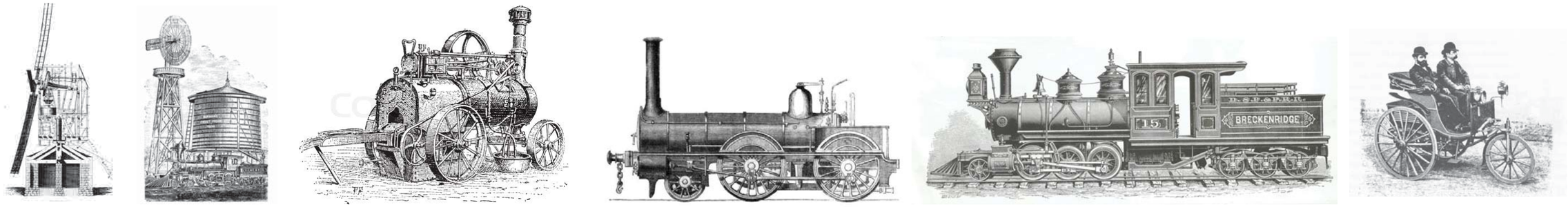
Tzonis, Alexander. *La belleza navegante*[1]

Every organism, individually and in concert with others, benefits from the persistence of the conditions / circumstances that maintain its own existence. Natural and co-evolutionary processes have ensured that the relative impact on the environment by any species within a given ecosystem would tend towards a dynamic balance within that system[2]. Living organisms, whether in nature or the city, are carriers of information and accordingly develop diverse and complex relations with each other[3]. Prior to urbanization and industrialization, humans could be seen to fit to patterns similar to other animals. Their nomadic, opportunistic exploitation of the environment was contained by the evident limitations posed by that environment whilst the other organisms in that shared environment coopted human activities and co-evolved with them simultaneously to work in seamless cycles. All organisms capture energy from their environment, using it to do the work necessary to maintain their function as organisms, and also preserve or enhance the environmental conditions that surround them. Accordingly all organisms act upon their environment in some degree and unconsciously or consciously manipulate it to either directly fuel its metabolism or improve the efficiency of those parts of its physiology. All with the mere intention of improving the living conditions directly experienced by its users whether its by the creation of new spaces or the modification of existing ones[4] (creation of micro-climates, creation of landscape and acoustic barriers, defensive purposes etc.). Thus virtually all energy that directly or indirectly powers living processes on Earth comes from the sun. The energy that is burned within an organism pertains to the body and is thus called *somatic* energy while any other type of energy burned outside this body is thus considered as *extra-somatic* energy.

A particularly surprising feature of contemporary urban theory is the complete lack of any focus on questions of energy its relation to urban morphology. Moreover, the use of energy and the way it is distributed in most biological systems has an intimate relation to morphology is easy to ascertain by metabolism distribution and function. Ever since Geddes there has been a mild flirtation with ideas of biological energetics with urban planning, but the debate has never been elevated to dealing with complex spatial systems until quite recently with the advancements in ecological systems and complexity studies. Updated research will need to find links between urban morphology, metabolical use of energy and the emerging complexity, understood as an appreciation of bottom-up procedures, networks and interactions. Coupled with a concern for climate change, resource depletion and pollution issues all of which are highly localised and location-specific, there is now a real chance to explore how all these factors interrelate[5]. The contemporary context of urbanity with its increased needs in mobility and information exchange creates an augmented complexity and complicatedness of implicated systems. There is an increasingly urgent need for an integrated theory of cities that can on one hand link and interrelate the physical form to the multitude of metabolic processes of energy and informatation, socioeconomic patterns and behaviours and on the other have the capacity to efficiently manage this multi scalar and multi layered mosaic in unison.

Energy efficiency can easily be associated with the question of optimization, often related to technological development issues. However, this concept is difficult to apply when dealing with specific situations since an assessment of the energetic efficiency of a system implies a previous definition of the ratio of energy output/ input of the system. In practical terms, the definition and the assessment of such a ratio proves to be very insidious because it requires a clear confinement / definition in space and time of the processes and flows under analysis[6]. An approach based on the thermodynamics of non-equilibrium is proposed to describe the dynamic interaction between human society and the ecosystem's natural processes. The society considered as a dissipative complex structure taking energy from the environment and investing energy back into the

1. Tzonis, A. (1977)
2. Downton P.F. (2008)
3. Rueda, S. (2007)
4. Ibid.
5. Batty, M. & Marshall, H. (2009)
6. Giampetro et al (1991)



source: Smil, V. (2008)

environment in an iterative loop[7]. Accordingly the activity of self-organizing biological systems results in the generation of new distribution of probabilities for the possible states that comprise it, or borrowing Margalef's words: *any cybernetic system, through the interactions of its parts, restricts the immensely large numbers of a priori possible states and, in consequence, carries information*[8]. Assuming this approach, it can be stated that the energy used by a dissipative structure is spent generating information related to its organization (the ability of keeping a defined structure/function)[9]. Also taking into consideration the advancements in the theory of social metabolism, we can now accept the hypothesis that there is indeed a complex and dynamic relationship between the degree of efficiency in the societal use of energy, the efficiency in land-uses and the environmental quality of ecosystem present in the territorial / land matrix.[10]

The structure of any ecosystem does not serve only for the distribution and management of energy flows, but also for maintaining the stability of boundary conditions. Even assuming that the evergrowing societal energy needs can eventually be matched by rapid advancements in technological innovation, there is the everpresent question of environmental stability, given the currently used techniques of ecosystem management,principally based on resource exploitation and associated with a loss of biological diversity that is seriously affecting the existing biophysical capital on a local and global scale. Many of these practices have been used and justified with the pragmatic objective of temporarily increasing the technological capital of human societies while at the same time ignoring the problems that arise in parallel with the loss of environmental structural stability at different levels[11].

As already noted, the pattern of development experienced recently by western cultures was possible because of the use of fossil energy, and because of the transformation of country-states into open systems based on trade; the industrial revolution in Europe was based on coal mining as well as colonial imports[12]. When dealing with open systems stabilized by the interaction with their environment, a simple linear output/input balance of energy flows referring to a single component, does not provide a meaningful way of assessing its energy efficiency. In fact, the measurement of a ratio output/ input able to assess its energy efficiency can be obtained only by assessing embodied values of the associated energy flows[13]. However, a more integrated approach for the assessment of the embodied energy values would necessarily have to re-evaluate and probably scale up the boundaries chosen for the assessment of the hierarchical structure, considering levels different form the one that the original component belonged to. Following Margalef's indication that by "*looking at energy subsidies we can gain a better understanding of the role that external energy plays in ecosystems*", we seek to understand the historical relationship between the transformation undergone by a cultural landscape, its driving forces, and the loss of this landscape's ecological functionality[14]. In this case, differences in time and space scale assessment may indicate and demonstrate the fact that the goals and values at one level may not necessarily coincide with the goals and values of a different level[15]. At least three hierarchical levels can be identified and used to optimise the energetic efficiency of a society. Despite the possibility of having independently formulated policies for each level it should be noted that similar to earlier scale questions these hierarchical levels are far from independent. A decision made on one level invariably affects the fulfilment of objectives on the other levels. Therefore, any proposed analysis should try to take into consideration the interaction between humans and environment at all three hierarchical levels[16]:

- ***Biosphere level***. The society viewed as a part of the whole biosphere at an ecological level at which efficiency basically refers to the entire relation of the human specie with natural ecosystems at time and space scales that are very large (eg. planetary scale). Research at this level is focused at studying the compatibility between human levels of energy dissipation and biophysical levels of energy dissipation, as well as impact of human activity.

- ***Societal level*** where the society is viewed as interacting with an environment composed of natural ecosystems and other societies. Research at this level focuses at studying the energetic efficiency of a society and its multifaceted metabolic functions, where the constraints provided by the availability of natural resources are conditioned by two factors:

  (a) the ***short time scale of economic processes*** that can prevent or overlook a full assessment of the stock depletion of natural resources; due to or justified by a difference in time scale in relation with the biospheric processes, making the calculation of the economic discounting of natural stocks of resources impossible.

7. Giampetro et al (1991)
8. Margalef, R. (1968)
9. Giampietro et al (1992)
10. Marull et al (2008)
11. Giampietro, M. & Pimentel, D. (1991)
12. Ibid.
13. Ibid.
14. Marull et al (2008)
15. Ibid.
16. d'Arge, R.C. & Spash, C.R., (1990)

(b) the ***small space scale of economic assessment*** that considers imported commodities as coming from an infinite environment outside its finite boundary. In this way it is permitted for particular areas and countries a level of consumption of natural resources that is not consistent with their local productivity as well as overall availability at a world level.

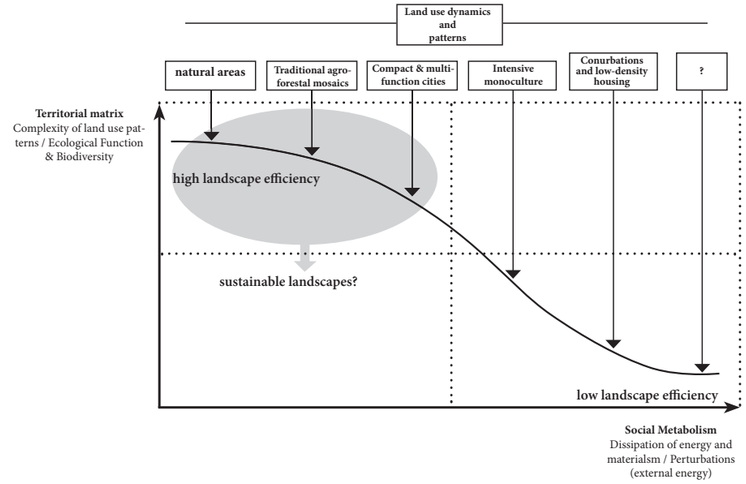
- Lastly the ***Individual level*** at which level a new set of values should be introduced involving criteria and considerations directly related to ethical as well as existential issues related to the human activity. The space and time scale of this hierarchical level (hundreds of km, years) is smaller than the societal level but can still sized in the same order of magnitude. Research at this level looks at the mechanisms through which the consequences of changes in the parameters describing and conditioning the standard of living at the individual level (i.e. population characteristics, level of expenditure per capita, pattern of human time use, etc.) can be transferred and interpolated to the other two levels efficiently.

The simple measure of energy input does not necessarily define a value for the respective flow of energy. An energy resource can exist but if it is dispersed, like eg. gold reserves in the ocean, it can become inaccessible. On the other hand, the use of an energy input with a very low density (e.g. biomass in a semiarid ecosystem) would require the exploitation of huge areas of ecosystem per capita and consequently high expenditure of energy to make it functionable and imply a low return of energetic investment and a low level of societal development. Space-time density of an energy input is thus considered to be a fundamental factor in defining its quality[17]. Clearly, other factors can also affect the value of an energy input, for example its predictability or its compatibility with the system that will utilize it. The ability of delivering power can be considered as another indicator related to the complexity of the system's structure given that a *defined level of power requires a device capable of converting an accessible energy input into applied power at the required rate*[18]. The assessment of the quantity of energy needed to perform a particular operation cannot detect the existence of power thresholds, when the time scale used to calculate it is too large or small for the question in hand. Finally, energy also drives complexity through the transformation of work into raising the system into higher hierarchies of complexity and order / organization, while reinforcing production through the maximization of available energy acquisition[19].

As early as 1922, Alfred J. Lotka stated that *natural systems tend to operate at an efficiency that produces the*

17. Odum, H.T., (1971)
18. Giampietro, M. & Pimentel, D. (1991)
19. Odum H. T. (1971)

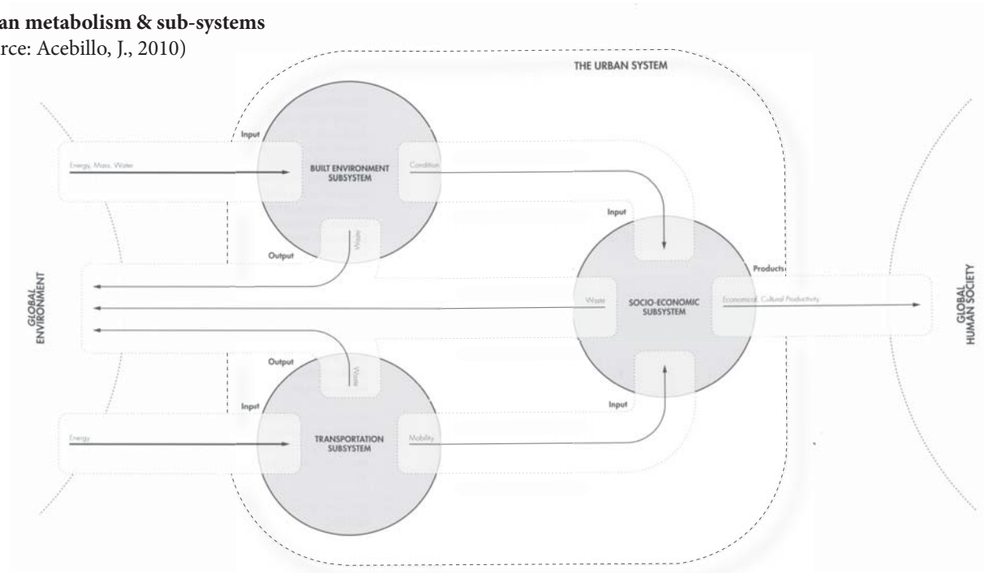
Landscape efficiency and sustainability of the territorial matrix
(source: Marull, J. , 2010)

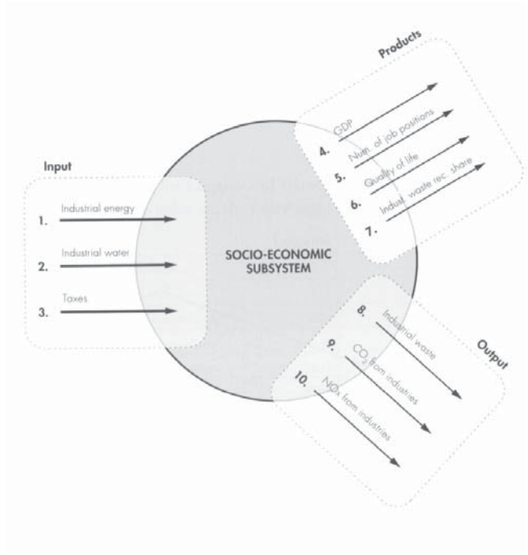


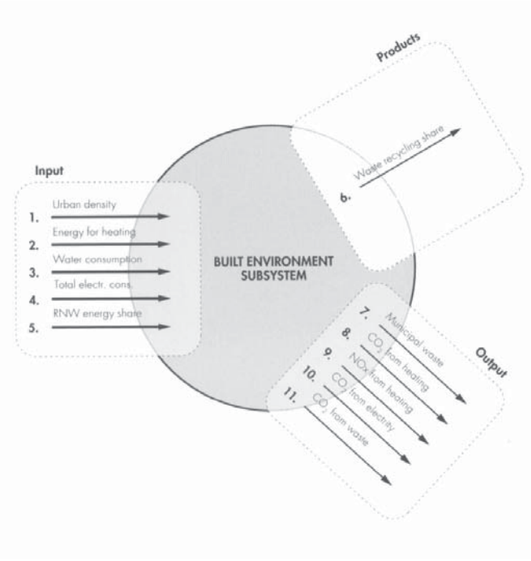
maximum power output rather than the maximum efficiency[20] offering the first definition of what came be to be know as the Maximum Power theory. *Self-organization systems optimise efficiency to maximize power, seeking to maximize the efficiency that is consistent with the maximum power loading of the system*[21], was the updated definition given by Odum and coined as the maximum (*em)power theorem*. It stated that *in the competition among self-organizing processes, network designs that maximize empower will prevail*[22] and tried to explain why social systems such as cities or civilizations can self-organize outside the universal tendency towards an increased entropy. Odum clearly differentiated between energy efficiency (the ratio of useful outputs over total inputs) and power (the rate of doing useful work) in systems and related these two concepts; at zero efficiency, power is zero because no work is being done, but at maximum efficiency, power again is zero because to achieve maximum efficiency one has to run processes reversibly, which for thermodynamic systems means infinitely slowly and therefore the rate of doing work (power) again goes to zero[23]. Thus a calorie invested as energy input into a small system, which has a lower level of power, has a lower effectiveness than a calorie invested in an industrialized system with a higher level of power. Interestingly, a similar analogy exists with the economic phenomenon of scale economies[24]. It is at some intermediate efficiency that power is maximized. The significance of this is that in systems (including both ecological and economic systems), the configurations that will tend to have a selective advantage are those configurations that maximize power, not efficiency[25]. Entropy dissipation being a requirement for the survival of living systems also sets theoretical limits to the efficiency at which this can go on, especially in the case of dynamic adaptive systems[26]. Because designs with greater performance prevail, self-organization selects network connections that feed back transformed energy to increase inflow of resources or use them more efficiently[27]. In a later reformulation of the theory of Maximum (Em)Power, Odum describes the maximum rate of energy acquisition: *In time, through the process of trial and error, complex patterns of structure and processes have evolved…the successful ones surviving because they use materials and energies well in their own maintenance, and compete well with other patterns that chance interposes*[28].

20. Odum H. T. (1971)
21. Odum H. T. (1971)
22. Ibid.
23. Ibid.
24. Giampietro, M. & Pimentel, D. (1991)
25. Costanza et al (1997)
26. Ibid.
27. Odum H. T & Odum E. C. (2000)
28. Ibid.

Urban metabolism & sub-systems
(source: Acebillo, J., 2010)







Either accepting the maximum power principle as formulated by H.T. Odum or just observing the historical trends it seems that the quantity of energy dissipated by human activity tends to increase with the advancements in technological development[29]. The dynamic interaction between human society and its environment involves humans invest applied power in modifying their environment in order to be able to harvest energy from it and at the same time considering the return of human investment including the energy input needed to sustain the society and its critical infrastructures. On the other hand, since the energy produced by societal activity, is equal to the initial energy input required by society activity, we can face the paradox reported by Georgescu-Roegen when he said that: "*a technical evolution leads to an increase in the rate at which a society wastes resources yet this economic process is actually more efficient than automatic shuffling in producing higher entropy, i.e. waste.*[30]" setting the ultimate question as "*what is the final goal of technological development*"?

In a subsistence type society, the flow of nutrients produced and consumed coincide in time and space. This means that the structure of a subsistence society, based on biological energy flows, is found in a state of equilibrium that works specifically for a low density of energy throughput (low density of population & low level of consumption per capita). But if a switch is made to a more specialized configuration, a sudden increase in the level of energy expenditure would occur. This would imply that the steady increase in population withing the given space, after initially saturating the resilience of the rural equilibrium, could only be further absorbed by its transformation into an urban system type configuration of the society (switching the parameters of the societal system and thus passing into a new equilibrium state). However, this transformation requires an additional amount of energy input and at a high density of flows. The preservation of the bio-activity of the natural biota during this process is essential not only for means of biomass production (e.g. agriculture) but also for the all around equilibrium of the territorial biophysical matrix[31] that subsequently results in an improved overall territorial efficiency. Thus humans cannot expect maintaining their current sustenance of human ecosystems only with the management of anthropized elements of the territory (crops, livestock and machines) but need to consider the further integration of natural and urban systems. In this manner a more significant definition of the term of territorial efficiency can be reached.

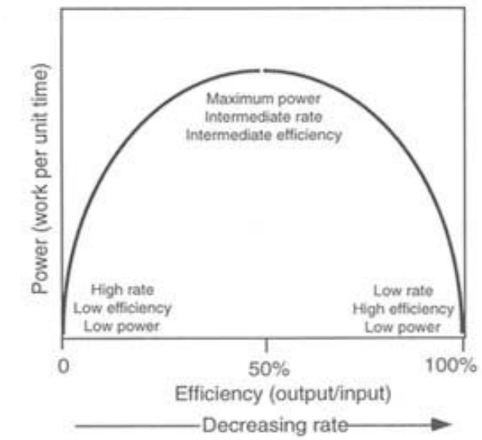
A key factor in determining whether human development can be achieved while at the same time preserving, improving, or degrading the ecological systems are the land-use management choices made by the respective societies[32]. Distinct land-uses can give rise to diverse cultural landscapes of outstanding aesthetic, economic and ecological value or result in land degradation, soil loss and impoverished ecosystems[33]. By trying to correlate socio-economic processes to landscape-ecological patterns, it can contribute to the development of integrated land use policies that might eventually succeed in integrating economic, social, and ecological aims and thus, foster sustainability[34]. It is for this reason that we have chosen the term "landscape efficiency", a necessary condition for sustainable development. The comparison between current practices of energy and land-use management with those of 1860 in the Valles County of Catalonia, revealed that the dramatic increase in external inputs and significant losses in energy transformations in the agrarian system were closely connected to major processes of land-use change and the growing functional segregation between crops, livestock and woodland. In other words, the agrarian system became energetically inefficient during the fossil fuel era principally because of its land-use inefficiency. Moreover, this inefficiency combined with urban, industrial and infrastructural development pattern became a major driving force towards an overall landscape degradation[35].

In order to highlight this societal link between energy or material throughputs and land-use change, the concept of ***landscape efficiency*** was coined, to describe *the historical relationship between societal land-use patterns and the ecological processes that may be at work in the territory and at the same time as a way / paradigm for improving the socio-economic satisfaction of human needs while maintaining the healthiest landscape ecological patterns and processes, so as to guarantee that the natural resources and environmental services offered by the existing land matrix*[36]. In this context the term efficiency is not used in its strict sense, as in economic geography or engineering terms, but rather in a wider socio-ecological sense, closer in this respect to the idea of ***eco-efficiency***, defined as the process achieving those forms of economic land-use that meet human needs while enhancing ecological complexity and function[37]. This eco-efficiency can be assessed by analysing three relationships [38]:

1. between socio-metabolic energy-use and land-use efficiency,
2. between landscape patterns and ecological processes, and
3. between the disturbance exerted by external energy flows moved by social metabolism and the ecological functioning of the whole land matrix.

29. Giampietro, M. & Pimentel, D. (1991)
30. Georgescu-Roegen. N. (1971)
31. Odum, H.T., (1971)
32. Marull et al (2010)
33. Haberl et al (2004)
34. Ibid.
35. Marull et al (2010)
36. Marull et al, (2008)
37. Ibid.
38. Marull et al (2010)

The Maximum power principle
(source: Constanza et al, 1997)



If an updated theoretical framework is to be adopted for analysing territories there also needs to be a respective switch from the classical thermodynamics paradigm of equilibrium, where every transformation implies and corresponds to an increase in entropy, to the thermodynamics of non-equilibrium, where the stability of open systems is based on the exchanges of negative entropy flows[39]. The essence of biological and societal systems, given their intrinsic dissipative nature, implies the existence of a state of non-equilibrium[40]. Cities and urban regions as open and dissipative systems, base the stability of their respective structures and functions on the interactions (and corresponding flows) among the different components.

Changes in the levels of energy dissipated by societies seem to imply *jumps* in the levels of energy expenditure as well as *jumps* in the size of the system. The fact that evolution in societies is based on such disruptions rather than on smooth transitions means that linear projections of society's demands and supply can be quite inaccurate. Such a non-linear behaviour implies that organizative patterns are changed when large differences in the density of flows occur. Clearly, these 'jumps' also imply a non-linear increase in the stress on the existing boundary conditions. Increasing the density of humans implies not only the requirement for an increased food production, but also an increase in the ability of fine-tuning the flow of nutrients from the areas of production to the respective areas of consumption[41].

The concept of efficiency is the cornerstone of urban metabolism, when considering the multiplicity of flows of materials, water, energy or information that constitute the backbone of any urban system for maintaining organization. The natural resource management should achieve a maximum efficiency with regards to the minimal disturbance inflicted upon ecosystems[42]. In the field of urban metabolism future urbanistic studies ought to integrate the diverse metabolic fluxes, minimizing dissipation and contamination and thus the overall impact on both the building and the public space realm[43]:

- Hydrological management: collection and storage of rain-water, aquifer management, combined with technology and management techniques for selective filtration / treatment and reutilization or urban runoff and sewage.

- Energy management: Depletion of finite energy sources, demand and uptake of renewable energy sources (solar, wind, geothermal, etc.). Energy storage and passive systems for savings and increasing energy efficiency through architectural design and provisions.

- Auto-sufficiency in material terms: selective waste management, recycling of materials, promoting the use of local materials and the hierarchy of waste management under the 3Rs - Reduce - Reuse - Recycle paradigm considering the entire cycle of urban materials, a cradle to grave approach.

- Information management: setting up an adequate infrastructure for handling the ever increasing amounts of data & information available. Guarantee and accessibility to information and encourage further mixicity and interaction between agents and elements of the territory.

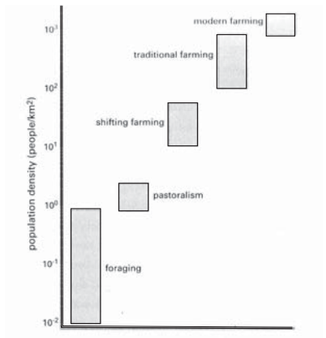
Taking all these factors under consideration a multiplicity of possible hierarchical levels of analysis open up. Nevertheless a more meaningful description of human development can be reached if adequate indicators referring to the base hierarchical level are utilized - e.g. individual level (changes in individual life span, level of expenditure per capita, hours of labour per capita/year etc.), instead of only focusing at the societal hierarchical level when performing the overall efficiency assessment[44].

Efficiency, from a traditional economic point of view focuses on the society's ability to exchange goods and services with other societies principally via a price mechanism, in order to promote continuing consumption. Policies of development based solely on this level of reference mechanism tend to generate non-sustainable patterns of growth as those experienced by contemporary regions; on the other hand. the adoption of such a point of view (with space and time scales adapted to social structures time scales instead of planetary / territorial time scales) proves to be the most effective in rapidly stimulating technological progress and increasing the average standard of living[45] even if its short-termed progress. We must stress that the alternative to the current unsustainable economic development has to be the implementation of a strategy of enhancing complexity without increasing the dissipative system. Undoubtedly, landscape efficiency becomes a necessary condition for sustainable development[46]. ***Ecological Economics*** deals with all the different hierarchical levels at which analyses can be carried out (biosphere level, societal-economic level, individual level). Each hierarchical level has its own goals and values but choices and changes adopted at one level are inevitably transferred to the others. Thus, before deciding goals and performances on one level (i.e. according to ecological,

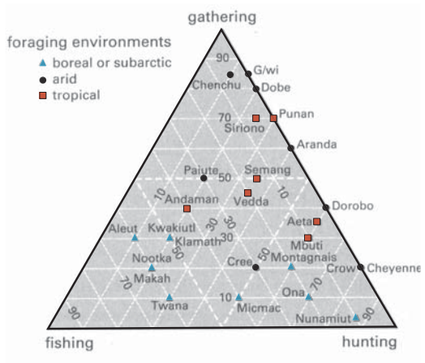
39. Giampietro, M. & Pimentel, D. (1991)
40. Ibid.
41. Ibid.
42. Rueda, S. (2007)
43. Ibid.

44. Giampietro, M. & Pimentel, D. (1991)
45. Ibid.
46. Marull et al (2010)

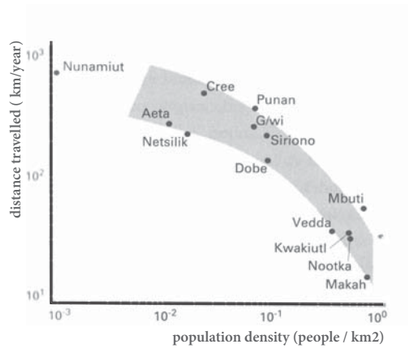
Ranges of population densities supported by intensifying modes of food provision



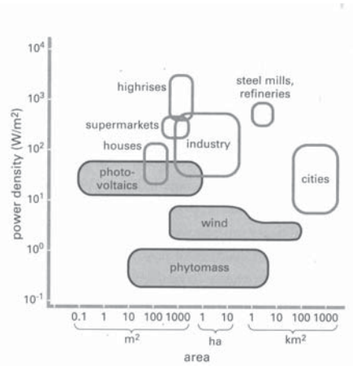
Approximate contributions of gathering, hunting and fishing to the diets of foraging societies that survived into the 20th century.



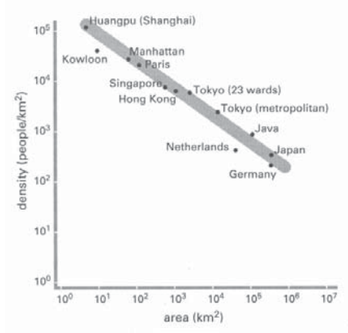
Annual mobility and population density of foraging societies that survived into the 20th century.



Mismatch of typical power densities of renewable conversions and common societal energy uses.



Maximum population density of cities as the function of area



source: Smil, V. (2008)

economic, individual optimizing factors) we must assess the effect and the compatibility of these goals on the other levels. Energy analysis seems able to provide common indicators which can be used to describe changes at all three hierarchical levels. Equilibria related to different degrees of societal complexity imply jumps in the size of the system, following the typical non-linear behaviour of dynamical systems. These jumps in size as well as in the level of energy expenditure imply jumps in the stress on the boundary conditions that sustain a human society. This suggests that a large dose of caution should be used when dealing with projections of human development and its sustainability[47].

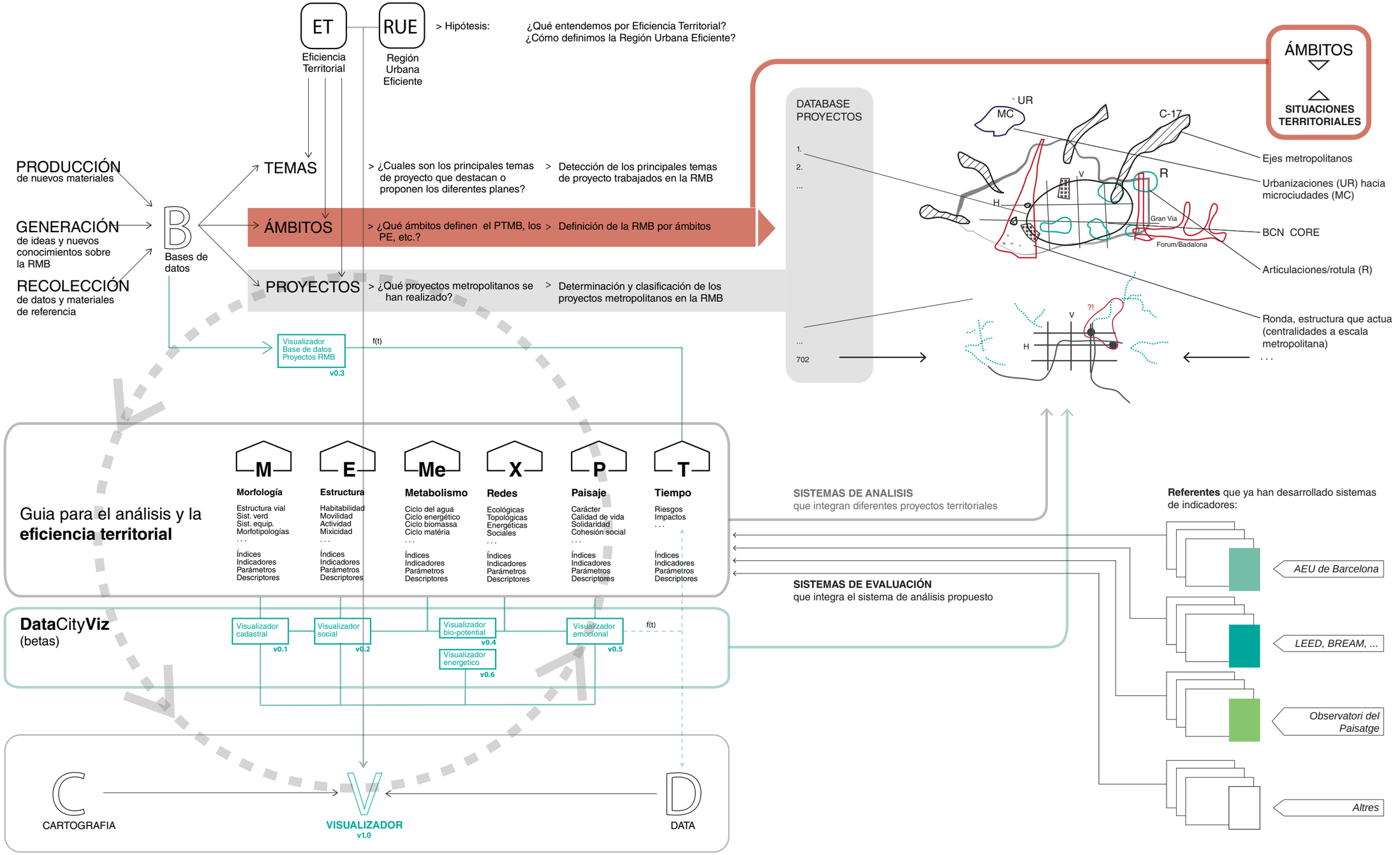
Since a correlation exists between the economic value produced and consumed by the society and the societal level of energy consumption[48] the level of rotation of the energetic investment can be assumed to be proportional to the level of satisfaction of human needs and wants, expressed in economic terms[49]. Costanza studied the possibility of using embodied energy as an indicator of the economic concept of value and found that the correlation between the monetary value and the embodied energy value in the U.S. economy would be way different if the entire economic cycle was to be considered[50], approaching closer to a concept of ***true cost economics***. An economic model that explicity includes the cost of negative externalities associated with goods and services enjoyed and consumed by society, in the final market price. In practical terms this means that the boundary chosen to calculate embodied energy should consider not only the production sectors but also the consumption and service sectors, that is enclosing within the circuit of energy and matter flows of all societal procedures of the society[51]. In fact any system analysis should include two different steps; first, the definition of possible equilibria for the system; and secondly a study of the conditions of stability of these equilibria. From this point of view, the difference in development strategies proposed by economists and ecologists is better understood. The economic approach, which screens among possible equilibria, looks for the most convenient configuration for humans: maximization of human activity within the system; that is maximization of the rotation of energy investment. The ecological approach is more concerned with the stability of the final equilibrium of the whole dynamic system, including and integrating both anthropized and natural ecosystem activity[52].

Different techniques have been or are being utilized to assess this human impact on a global and local scale, such as the calculations of the Ecological Footprint or *human appropriation of net primary production (HAANP)* seen earlier. Comparing the *Ecological Footprint* to a second aggregate measure like the HANPP, while both methods relate socio-economic metabolism to land use and aim at providing insights about the sustainability of society-nature interaction there are important differences between the two and distinct research questions driving each of them. The Ecological Footprint evaluates the aggregate amount of bioproductive area needed exclusively for resource extraction, waste assimilation and infrastructure of a defined population and is especially useful to compare the resource consumption profiles of different human populations, while at the same time providing indicators of possible overuse of resources (*overshoot*)[53]. It also assesses whether the regenerative capacity of the biosphere in a given year with the given technology suffices to regenerate the diverse resources people have used in this year. In contrast, methods focusing on net primary consumptions identify and measure the intensity with which humans use the land on and within a defined territory. Thus related studies can show which percentage of the yearly energy flow in ecosystems is appropriated by humans and therefore unavailable for most other species and natural processes. The advantage of such methods is that they can map the intensity of socio-economic use of ecosystems in a spatially explicit manner, relating it with landscape structure and local biodiversity[54].

Our understanding of cities as for many other complex systems appears to be getting less, but there is also a slow realisation that changing the physical form of cities to meet social goals is a somewhat more effective way than broaching social change directly: that controls and instruments to engender physical change are somewhat less intrusive than the more direct forms of action. There is also a growing belief that in complex adaptive systems, identifying pressure points and engendering small but local change can be as effective, if not more so, than the kinds of grandiose plans that have dominated past practice: once again echoes of Geddes' *conservative surgery*[55].

Two key contemporary concerns – energy use and climate change, which cut across one another in diverse ways – will only be interrelated if we move to a theory of cities that links their morphology to the processes and their functioning, phenomenically explaining their morphogenesis. In order to predict how changes in the demand and supply of different resources enable individuals and flows and powers the economy to function in different scales, we need a theory that explains how cities link such movements to locational, transport behaviours and trade in different scales. This requires a theory of urban dynamics that is far beyond anything we have at present[56], an undoubtedly an objective for current research to seek.

47. Ibid.
48. Costanza, R. (1980), Costanza et al (1997)
49. Giampietro, M. & Pimentel, D. (1991)
50. Costanza, R. (1980)
51. Giampietro, M. & Pimentel, D. (1991)
52. Ibid.
53. Haberl et al (2004)
54. Ibid.
55. Batty, M. & Marshall, H., (2009)
56. Ibid.



Esquema de trabajo y metodología # 2

Febrero 2014 [Evolución de "Esquema_de_trabajo_metodologico_1.jpg"]

CIUDADES, TERRITORIOS METROPOLITANOS Y REGIONES URBANAS EFICIENTES.
ESTRATEGIAS Y PROPUESTAS DE PROYECTO PARA LA REGENERACIÓN DE LA CIUDAD_MOSAICO_TERRITORIAL DESPUÉS DE LA EXPLOSIÓN DE LA CIUDAD
Proyecto de Investigación Fundamental No Orientada. Plan Nacional 2013-2016. Código BIA2012-35306

Miembros del equipo:

Antonio FONT, Carles LLOP (directores de equipo), Josep Maria CARRERA, Albert CUCHÍ, Salvador RUEDA
Arturo CALDERON, Marta CARRASCO, Simona CERRI, Konstantinos KOURKOUTAS, Lorena MARISTANY, Sílvia MAS

Case-study / National Research Plan (BIA2012-35306)

Cities, metropolitan territories and efficient urban regions:
project strategies and proposals for the regeneration of the territorial mosaic city

The latest research program that the author participated as a member of the research team, initiated in 2013 and was directed by Dr. Carles Llop & Dr. Antonio Font (and counting with the participation of Dr. Albert Cuchi of the UPC, Dr. Salvador Rueda of the Agencia de Ecologia Urbana de Barcelona, and Josep Maria Carrera of Institute de Estudis Territorials de la Generalitat de Catalunya) tried to tackle the question of territorial efficiency as manifested / demonstrated in case of the Metropolitan Region of Barcelona (*RMB*). The research task in hand was an analytical presentation of the phenomenology of forms and structures of the territorial transformations that derive from the respective city and territorial activity, during the recent time-period of the explosion of the city. The main objective is to contribute, from a multidisciplinary standpoint, an updated interdisciplinary knowledge in order to able to determine specific and measurable actions, for the regeneration of cities, metropolitan areas and urban regions, and their efficiency in economic, social and environmental terms, all through a renewed concept of the territorial project. The study - area is constituted on a first level, by the metropolitan region of Barcelona, and on a second level by a series of reference cases of sixteen European urban regions, that the group has been investigating corroboratively in past research projects. The proposed methodology by the project considers six systems of analysis:

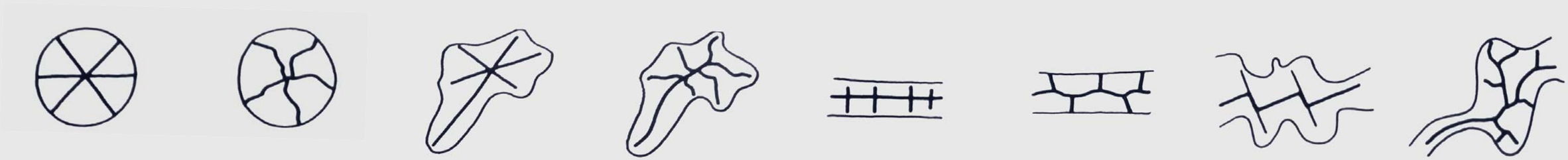
i) ***morphology*** (built typologies, public space, infrastructural, natural)
ii) ***structures*** (habitability - activity - mobility - governance - organization)
iii) ***metabolism*** (energy, material, water and information)
iv) ***networks*** (interconnectedness of ecological, social, information and other flows)
v) ***landscape*** (perception, quality, cultural, social)
vi) ***time*** (dynamics, contingency and risk)

The project proposed an analysis of the change in terms of efficiency of the territorial fabric, through an analysis of the diverse projects and interventions realized in the *RMB* in the last 20 years. In this way the effect of past and current planning practices can be assessed in qualitative and quantitative terms, and at the same time open up the debate on territorial efficiency and sociometabolic processes. Reaching that territorial efficiency cannot be thought out in absolute mechanistic terms but instead as a relative efficiency of the social metabolism of the territory.

On the margin of the National Research Plan a parallel research was initiated on the state of the art of city-data visualization. As a first step a recompilation of the available, well known or less known examples was made, in order to have an overall impression of what type of data and in what ways has been visualized. Accordingly a series of respective pilot visualizations has been proposed and planned to be developed for the *RMB*, each one treating and visualizing thematic data linked to the 6 systems of analysis. For this reasons a Joint Collaboration Agreement has been signed with the Catalan Cartographic Institute (ICC, now ICGC) to These individual attempts, beta versions, would put in test both the availability of data as well as the capacity for visualizing this available data. The ultimate goal being to create eventually a more complex, integral and synthetic visualization of the RMB, including both dynamic and static information, and serving as an online monitor of activity and processes that give form to the RMB.

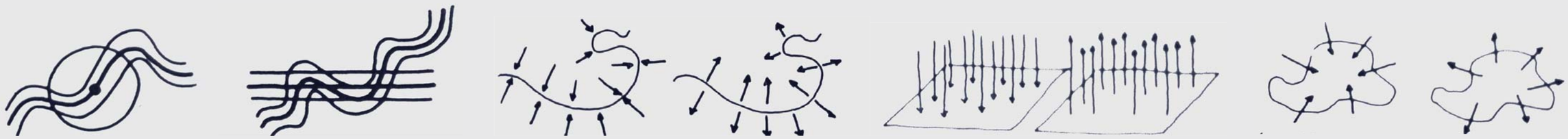
This last part has offered an overview of the conceptual, methodological advances and empirical analyses in the growing literature on biophysical features of socio-economic development, the relationship between socio-economic metabolism and land use and some initial attempts to provide definitions for the notion of land efficiency, whether local, landscape, regional or territorial. For the purposes of this paper there is no explicit need to come up with a precise mathematical formula, describing the territorial efficiency, as other authors have entered in this specific task. What lies within the scope of interest is to identify the ways that the socio-metabolic energy use and resulting landscape patterns and processes are related to this encompassing concept of territorial efficiency, and more specifically the ways that urban ecotones are seen affected by this metabolic functioning during periods of stability or during puntual perturbations / shocks, the ways the can affect overall territorial efficiency and finally how they can serve as early stage indicators of territorial dynamics and changes.

The notion of ***urban ecotone,*** updated and enriched in terms of definition from the previous theoretical analysis, is understood as a four-dimensional manifestation of urban and territorial dynamics. An invisible membrane that can enhance as well inhibit territorial efficiency based on the handling and management of corresponding flows that transverse them and drive the social-ecological differentiation of adjacent patches. Territorial efficiency understood as a rich and complex question demands an equally rich definition of urban ecotones. The co-relation between efficiency in the societal use of energy, in land-use management and the environmental quality of ecosystem functioning of the land matrix creates a three-way relationship, with an important environmental-historical perspective. In the contemporary mosaic city there is an evergrowing number of diverse information carriers, that when viewed in their totality, reveal an enriched territorial complexity, that often passes unperceived when focusing on homogeneous urban patches or when projecting monofunctional areas / zones. The added complexity utilized for describing these concepts permits to open ground for conceptual advancements in urban and territorial theory and thinking. At the same time aids in establishing criteria for identifying the driving forces and dynamics behind city growth and respectively ecotone behaviour, thus offering tips and projectual logics for a more sustainable land-use planning and growth management. Above all it can open up the debate not only in terms of disciplinary terms but also on the inhibited potential of contemporary cities. These points will be summarized in the conclusions part in continuation, along with a summary of the results of the case-study analysis.



Results & conclusions

Chapter contents



Structure, forms & dynamics by Doxiadis, C. A (1969)

I. Foreword

The analysis of this paper´s case-study, the urban region of Thessaloniki, was presented as a test-ground as well as a theoretical point of departure for studying and observing contemporary notions and phenomena concerning ecotones within the urban region. The city of Thessaloniki with its long and enduring historic evolution, linked closely to the mediterranean history and bearer of a lot of its rich cultural traits has served specifically as an idoneous example for examining such notions / concepts. As first observed in a more broader analysis and then in continuation in a more detailed analysis of the urban mosaic as it appears in the accompanying analysis atlas of the evolution / development of the urban fabric. This evolution has left discernible marks in/on the territory, now appreciated as ecotonal areas, that permit an integrated lecture of the contemporary mosaic through the analysis and observation of the evolution of these areas. The long, rich and diverse city history of Thessaloniki ensured the inclusion / appearance / consideration of the majority of contemporary and historic phenomena within its urban fabric, increasing the extrapolation value of the results to other possible analysis cases.

This next section aims to synthesize the compiled and analysed theoretical body / bibliography on ecotones and territorial processes, as a general objective, and expand it further by applying considerations, pertinent to the notion of the urban region and its conceptual definition as it emerges through the historic theoretical thinking as well as contemporary and emerging definitions. This would include notions related to social metabolism and the societal use of energy with the respective models of production of space that they give rise to. It comes to highlight the complexity features present, often latent, in contemporary urban regions that as autopoetic (bottom-up) or planned (top-down) features offer on one hand resilience by knitting a richer and more coherent mosaic while at the same time offering the potential for an overall improvement in terms of territorial efficiency, if managed properly and adequately. Again, it is necessary to stress at this point that the term *efficiency* is not used in a pure mechanistic or technocratic manner, nor as a mere simplification for measuring (quantitatively) territorial functioning. On the contrary it is thought out as a complex and hard to measure concept and that maybe before embarking on the task of measuring it numerically, we should societally debate and consider its real application and implications. That is to say, define it qualitatively, in terms of social agreements and commonly accepted terms and goals.

One of the principal objectives of this paper is to come to demonstrate this shift in the mentality of our urban perception of limits and typological / morphological homogeneity, to a more open-ended, complexity-embracing, dynamic and at the same time abstract way of looking at anthropized / urbanized territories. In this exercise of seeking unity and cooperation within the regional context, the extrapolation of the ecotone concept to the urban environment offers the possibility for establishing new / renovated synergies that can respectively activate inspiring and integral projects and common shared visions for the territory. This synthesis of information and knowledge on urban ecotones, (identifying gaps in information, testing out the ecotone paradigm in the case-study analysis, the theoretical extrapolation etc) can be both useful in the wider debate on ecotones, and especially in relation with urbanized territories that are increasingly attracting more attention, due to demographic as well as environmental reasons.

Furthermore this investigation on urban ecotones and more specifically with respect to their function as territorial indicators, (detecting human impact on functioning of landscapes/ systems, urban expansion tendencial behaviours) can reciprocally enhance our understanding and appreciation of urban functioning and enrich the current theoretical body of urban theory. At the same time the potential role of urban ecotones as territorial *configurable* / *reprogrammable* interfaces, managing flows and dynamics across the urban fabric, can also serve as instruments of urban reconfiguration and platforms for socio-ecological restoration / re-integration of territorial systems, serving thus, apart from an analysis, as a flexible planning instrument as well. The overall management of all ecotones within an urban region, thought out as an interconnected network, can increase resilience of the urban systems to external and internal shocks / impulses and contribute in mounting progressively a more vibrant, coherent and overly efficient urban structure/-s. More importantly, mark the pass conceptually from a static perception of the city to a dynamic, even contingent perspective, on urban regions and the implicated dynamic considerations.

Finally, with respect to the case-study of the urban region of Thessaloniki and the respective analysis of the chosen ecotones it has come to serve again a double purpose: *first*, to test the hypothesis and research objectives set forth by this thesis, and at the same time serve a propositive role by reimagining the urban regional mosaic of Thessaloniki and proposing its structural and functional configuration of based on the respective results and conclusions produced out of the analysis of each individual ecotonal area. These results are presented summarized for each case in a table in continuation, but the detailed and in-depth analysis for each case can be found in the analysis atlas. The compiled resulting mosaic and city-wide ecotonal structure is also presented as a concluding synthesis and proposal.

II. From natural ecotones to urban artifacts

Cognition *represents the status of knowledge of interior and exterior of a living organism. Cognition is life, "a continuous complex process rather than an historical logical capability". Every living organism has cognition, which represents the manner of connection with the exterior world. Living organisms create a structural coupling with the environment through cognition. Organization and structure, as stressed by Maturana & Varela, are the status of an entity. Organization can persist although the structure is changed. A system is embodied if it is structurally coupled with the environment. This means that a system must maintain environmental feedback in every expression of life, by mutual interactivity. In other words, the system must engage in mutual sequences of perturbations with the surrounding and supporting environment*[1].

Various thinkers have come to believe and support the idea that architecture is an extension of human cognition and as such a manifested symbiotic interaction with its environment, through its constant manipulation[2]. Unfortunately, human design has difficulty in coping with embodied cognition and transforming a designed system into what can be perceived as a cognitive autonomous entity[3]. This inherent deficiency in planning has had dramatic effects on many anthropized landscapes when imposed (top-down) planning tries to change structure and organization or invent new structures alien to the place, to its genius loci.

The term *autopoesis* (from the Greek *auto*-self and *poiesis*-creation) has been coined by Maturana & Varela (1980) to explain the character and behaviour of living organisms and systems. Apparently, conceptually distant from the landscape paradigm, in reality autopoesis directly enters several perspectives (emergence - system theory, ecology, complexity etc)that have evolved into the arena of landscape ecology. It is full of conceptual and pragmatic limitations but, nevertheless, we are sure of its usefulness to introduce some basic concepts. Preliminary concepts are necessary for a better understanding of the autopoesis theory. For instance, "an observer is someone who can make distinctions and specify that which he distinguishes as an entity different from himself." A unity is any entity (material or conceptual) distinct from a background[4]. Accordingly if we are to think of the autopoetic features of urban systems and regions, we should take into account a set of basic principles, as set out by Maturana in one of this articles[5]:

1. Farina, A. (2006)
2. Salingaros, N. A. (2008)
3. Ibid.
4. Maturana H.R. (1999) in Farina, A. (2006)
5. Maturana, H. R. (1975)

The fundamental feature that characterizes living systems is autonomy, and any account of their organization as systems that can exist as individual unities must show what autonomy is as a phenomenon proper to them, and how it arises in their operation as such unities. Accordingly the following is proposed.

*That autonomy in living systems is a feature of self-production (**auto-poesis**), and that a living system is properly characterized only as a network of processes of production of components that is continuously, and recursively, generated and realized as a concrete entity (**unity**) in the physical space, by the interactions of the same components that it produces as such a network. This organization I call the autopoetic organization, and any system that exhibits it is an autopoetic system in the space in which its components exist; in this sense living systems are autopoetic systems in the physical space.*

That the basic consequence of the autopoetic organization is that everything that takes place in an autopoetic system is subordinated to the realization of its autopoesis, otherwise it disintegrates [...] That the autopoetic states that an organism adopts are determined by its structure, and that the structure of the organism is at any instant the result of its evolutionary and ontogenic structural coupling with the medium in which it is autopoitic, obtained while the autopoesis is realized. [...] That language arises as phenomenon proper to living systems from the reciprocal structural coupling of at least two organisms with nervous systems, and that self-consciousness arises as an individual phenomenon from the structural coupling of an organism with language with its own structure through recursive self-description.

Like any large area, an urban region is tightly linked to surrounding regions as well as distant regions. These linkages often strongly affect spatial patterns and processes within the region of interest. One set of patterns might be called boundary issues because their origin is near the urban-region boundary, either just inside or just outside. Boundary issues often warrant careful attention, because they can rapidly affect the urban region, or the adjoining region, and often change over time. Inputs from an adjacent region that affect a major portion of an urban region are typically of greatest concern. Examples include a major water supply from an adjacent region's aquifer, people entering for recreation or the city's cultural resources, and industrial pollutants transgressing regional boundaries. Outputs from a region to its adjoining regions may be equally significant though of lower profile. People and goods enter and leave by any means possible and so each of those routes warrants evaluation. For example, holiday traffic is often channelled between the metropolitan area and coastal or mountain areas. Distant changes also affect

regional inputs and outputs. A high-speed rail line, new recreation areas, new markets, changes in immigration policy, and government policy changes may significantly affect a region. In short, land use in the urban region is tightly linked in both directions to other regions and for this same reason, its limits/ boundaries are hard to define.

Energy and resources are not abundant everywhere and often one or both can be in decline. As seen earlier classical thermodynamics contemplated only one ending, that of complete dissipation or heat death. The updated contemporary perspective, however, admits two possible endpoints; the classical heat death or an eventual configuration of perpetual harmony. Perpetual harmonies in particular, can emerge from the collapse of non-equilibrium configurations. At the same time the situation can get more complex as a system begins to disintegrate, where some fragmentary subsystems can decay into total dissolution and if the decline in resources is gradual enough, others might settle into a state of enduring equilibrial harmonies. Should a system acquire new structures that would drive it into the super critical stage, those gains would soon be erased as the system suffers a series of 'avalanches' that drop it back to the near-critical range. Conversely, if a system should fall significantly below criticality, either autocatalytic responses would restore it to near criticality (following a restoring / healing process) or it would collapse fully towards a heat death[6].

Interaction emerges when two unities exchange matter, energy and information. The space is the domain of all possible relations and interactions. Explanation is a process that an observer uses towards another observer. Organization refers to the relations between components that produce a unity. Structure defines the space in which a composite system exists. The autopoesis theory explains how living organisms are self-maintained through interior "programs" that are continuously renovated in order to assure homeostatic conditions. "A*utopoetic machine, as the living organism is defined as a network of processes of production, transformation and destruction of components....*". On the contrary, an allopoetic machine is a system that produces something different from themselves, like a car. The domain of the allopoetic machine is determined by the observer. Autopoietic *machines* are dominated by homeostatic processes that maintain some of the variables inside a range of values. Autopoesis opens the road to the cognitive landscape and is a formidable basis for re-interpreting semiosis, coding sciences and network behaviour[7].

6. Ulanowicz, R.E. (2009)
7. Farina, A. (2006)

The conceptual shift

> In defining boundary, Norburg-Schulz (1979:13) cites Heidegger: "A boundary is not that at which something stops … it is that from which something begins it's presencing[8]"
>
> Martin Heidegger

As demonstrated through the review of the state of the art, ecotones are important key structures for the functioning of landscapes; nutrients, water, air, materials, spores, seeds (genetic information), organisms, animals and energy in its different manifestations move across these structures. Ecotones, although they occupy a reduced space in landscape mosaics, they contribute by regulating flows across heterogeneous spaces. Natural ecotones are also sensitive to climatic change and shifts / changes in land use, and for this same reason they can be profitably used as monitoring areas, as spatial indicators of changes and dynamics (climatic, hydrological, metabolic etc.). The high biological diversity and activity (the high rate of primary and secondary production) present in the ecotones, that contribute to the overall system´s integrity (as well as adjacent´s patches) are in general relevant and key ecotonal features, although ecotones have recently been attributed another role, thinking in terms of biodiversity, and that is as sources of evolutionary novelty[9] (or innovation in social, aesthetic and ecological consideration of contemporary landscapes[10]).

In the natural system, an edge can be created by external mechanisms (*exogenous*) that control the ecological systems or by internal discontinuities (*endogenous*) that are acting in the same system. The environmental responds to the changes along a gradient, which may be gradual or linear. The response can show an abrupt interruption, probably due to a response with a threshold of one of the components composing the ecological system. Ecotones produced by natural processes have a soft gradient, while the ecotones produced by human disturbance regimes have a sharp gradient and the transition zone is often structurally nonexistent.

> *An abrupt change along the gradient of a system may originate at different levels of organization of the system. A sharp gradient may occur when a species reaches the tolerance limit, for example, as a response to environmental variables (e.g. temperature, salinity, soil contamination etc). In other*

8. Norberg-Schulz, C. (1980)
9. Smith et al. (1997)
10. McGrath et al (2007)

conditions, the abrupt change can occur in the biological responses from one species to another due to changes in competition. The response may be more complex and this condition mainly depends on the history and the evolution of the system and on the hysteretic relationship between the response and control variables. Gradual responses to environmental gradients are very common in nature.

Human induced ecotones can be used as indicators only indirectly for the influences of climatic change on human activities. Human activity produces an alteration of the spatio-temporal scale of natural processes. In such a manner, logging produces the same effect as a natural forest gap by tree fall, but across mechanisms that are moving at different scales. In other cases human activity has produced modification and perturbations of natural systems that cannot be observed in natural systems such as the urban cover and other infrastructures such as paved roads and railways[11].

As seen, an ecotone can also present different degrees of permeability according to the strength of the vector in question: wind, water, or organism movement; the transported material has more probability to be captured in the ecotone patch when the kinetic fall is higher: eg. in animals, the greater a species' body mass, more permeable the ecotone[12]. The physiological attitude may be important when considering the degree of permeability of ecotones; species sensitive to microclimate / local gradients may recognize an ecotone as a barrier and species with defensive mechanisms may be able to move more freely across ecotones than species lacking these mechanisms[13]. In a system dominated by edaphic components, the diffusion of water, energy and nutrients varies according to the texture, structure and organic content of the soil. The non-uniform distribution of these elements creates spatial gradients and the distinct forms of ecotones seen earlier. The flux of the organisms across the edges of the patches is regulated by abiotic, biotic, species-specific, and individual factors. The diffusion of an organism in a homogeneous environment is the same in all directions, but if a gradient such as light, salinity, humidity, structural complexity of the vegetation exists, then the diffusion takes a more directional pattern[14]. Ecotones are important not only for the movement of the species but also for the energy and resources moved by species, which move material from one patch to another: eg. beavers modify the hydrological flux, by creating temporary dams and this produces changes in many ecosystem cycles: the high ratio surface/volume of the dam created by beavers increases the changes at the borders and the reduction of kinetic energy due to the dam effect increases the sedimentary capacity of the particles[15].

11. Farina, A. (2006)
12. Wiens et al. (1985)
13. Farina, A. (2006)
14. Farina, A. (2006)
15. Johnston & Naiman (1987) in Farina A. (2006).

All these factors may change among the different types of patches. In heterogeneous landscapes, animals and organisms in general move not in a straight line but are strongly conditioned by the spatial arrangement of the suitable-unsuitable patches[16] and it may be expected that their behaviour would be affected by the spatial arrangement of suitable/unsuitable patches. Some differences can be perceived by animals, which can be attracted by the higher diversity and complexity of the vegetation. In fact, at the edges, there are more possibilities for nesting and increased food availability.

When the contrast between neighbouring patches is very high, the edges become true barriers. Human activity has favoured the appearance of such conditions that are more rarely found in nature. As true membranes, the edges can be permeable to some fluxes, while they are impermeable to others. The edges between the different components of a landscape are, consequently, very important for the properties of all the implicated systems. Accordingly, heterogeneity can play a relevant role in the determination of the overall efficiency of the landscape / territory by providing more contact surfaces / ecotonal areas between patches, increasing local and overall biodiversity and species interaction.

Comparisons along gradients of urbanization can capture the full range of urban effects as well as the existence of thresholds situations / phenomena. Therefore, the boundaries of urban ecosystems are often set by geomorphology, watersheds / airsheds, commuting radius, biotic / cultural / social shift or phenomenological criteria. In other words, boundaries of urban ecosystems can be set / defined in the same way and utilizing the same criteria as the boundaries in any given ecosystem study[17]. In the case of urban ecosystems, it is clear that many fluxes and interactions extend well beyond the urban boundaries defined by political, research, or biophysical reasons. Thus the delimitation of the urban region limits and definition of the respective ecotones does not serve to define a self enclosed entity but instead a framework to monitor and manage urban flows and dynamics. Urban ecology, as an integrative subdiscipline of the science of ecology, focuses on urban systems as broadly conceived above[18]. The search for limits is an everpresent practical and theoretical exercise in planning, a continual seeking of information and feedback. Theories like *bioregionalism* offered ways of finding and defining those limits from the perspective of both the physical environment and human cultural standpoint. It includes finding out what the actual limitations are regarding resource usage and availability, what limits are set by the climate , how the terrain and geology affect what can be achieved, how the social organizations provide the fundamental parameters for design, development and on-going maintenance of human settlements.

16. Johnson et al (1992)
17. Downton, P. F. (2008)
18. Pickett et al (2001)

Ecotonal Attributes & Functioning - *Summary table*

based on Bartorila, M.A. (2003), LLop, C. & Bosc, S. (2012), Strayer et al (2003)

Identification	*Origin & evolution*	*Spatial structure*	*Function*	*Ecotonal Situations*	*Projectual Logics*
Investigative or tangible	Causal or consequential	Grain size	Transformation	Peri- Urban	Limit urban sprawl ***(control dissipation)***
Manifested / latent	Contemporary or relict	Extent / Scale	Transmission	Intra - Urban	Restore continuities *(spatial & functional)*
Morphological / Phenomenological	Endogenous or exogenous origin	Thickness and dimensionality	Absorption	Natural / rural	Integrate infrastructures *(mobility, energy, information etc.)*
Scale / Grain of Reference	Endogenous or exogenous controls *(maintenance or suppression)*	Geometry of adjacency	Amplification	Infrastructural	Reactivate obsolete fabrics
Controlling Attributes	Antropogenous / Natural	Interactive or noninteractive	Reflection	Multi-scalar	Enhance complexity / organization
Scientific interest / perspective	Grade of Artificiality	Abruptness, steepness	Neutral	Latent	Landscape as a mediation tool
historical analysis / reference	Coevolution of systems	Patch contrast	***Dynamics / Metabolics***	Continuities / Incontinuities	Edge Governance
		Integrity (perforated versus unbroken)	Changes in structural / functional properties	Socio-economical shift	Interterritoriality
		Geometric shape and tortuosity	Mobility *(stationary, directional, oscillating, or random)*	Morphological shift	Articulate spatial scales
		Number of attributes (single or multiple)	Age and history	Edge Activity *(Diversity / Intensity)*	Work with the H.A.M. *(habitability, activity, mobility)*
		Offsets / congruencies of multiple & simultaneous attributes	Contingency	Edge species / elements	
				Enclave / interstice	

Ecotone classification

Ecotones exist at all scales and the attempt to classify could seem too artificial, but the classification of ecotones recognizable at the human scale assumes a relevant importance from a management perspective. Ecotones may be created by natural or human-induced interactions and can be categorized accordingly; expanding on Holland´s (1988) scheme of classification :

a) ***Ecotones created and maintained by human disturbance regimes***
(Areas that are results of a planning procedure, or constant human modification as manifested by urban dynamics eg. green belts, agricultural peri-urban land in contact with the urban fabric, mobility infrastructure, urban corridors).

b) ***Ecotones created and maintained by natural processes***
(Areas that are naturally created by the natural forces and dynamics present in the territory or areas that have been renaturalized due to abandonment, natural propagation, conservation efforts or some major natural catastrophe / event: floods, earthquakes etc. Or accordingly natural coastal areas, flooded areas created by beaver digging or local hydrology).

c) ***Ecotones produced by natural processes and maintained by human activity***
(Areas created originally by natural forces but having experienced a great degree of modification, while maintaining some minimum ecological levels, eg. a strip of riparian forest conserved and managed, urban parks / patches, territorial ecological corridors, urban rivers / streams).

d) ***Ecotones created by human activity and maintained by natural processes***
(Areas in their majority results of a lengthy human activity on the territory that have allowed for the integration of natural processes in their functioning in a symbiotic way. e.g flooded areas used for rice cultivation or as areas of water filtration, agro-forestal mosaics).

With respect to their state and functioning:

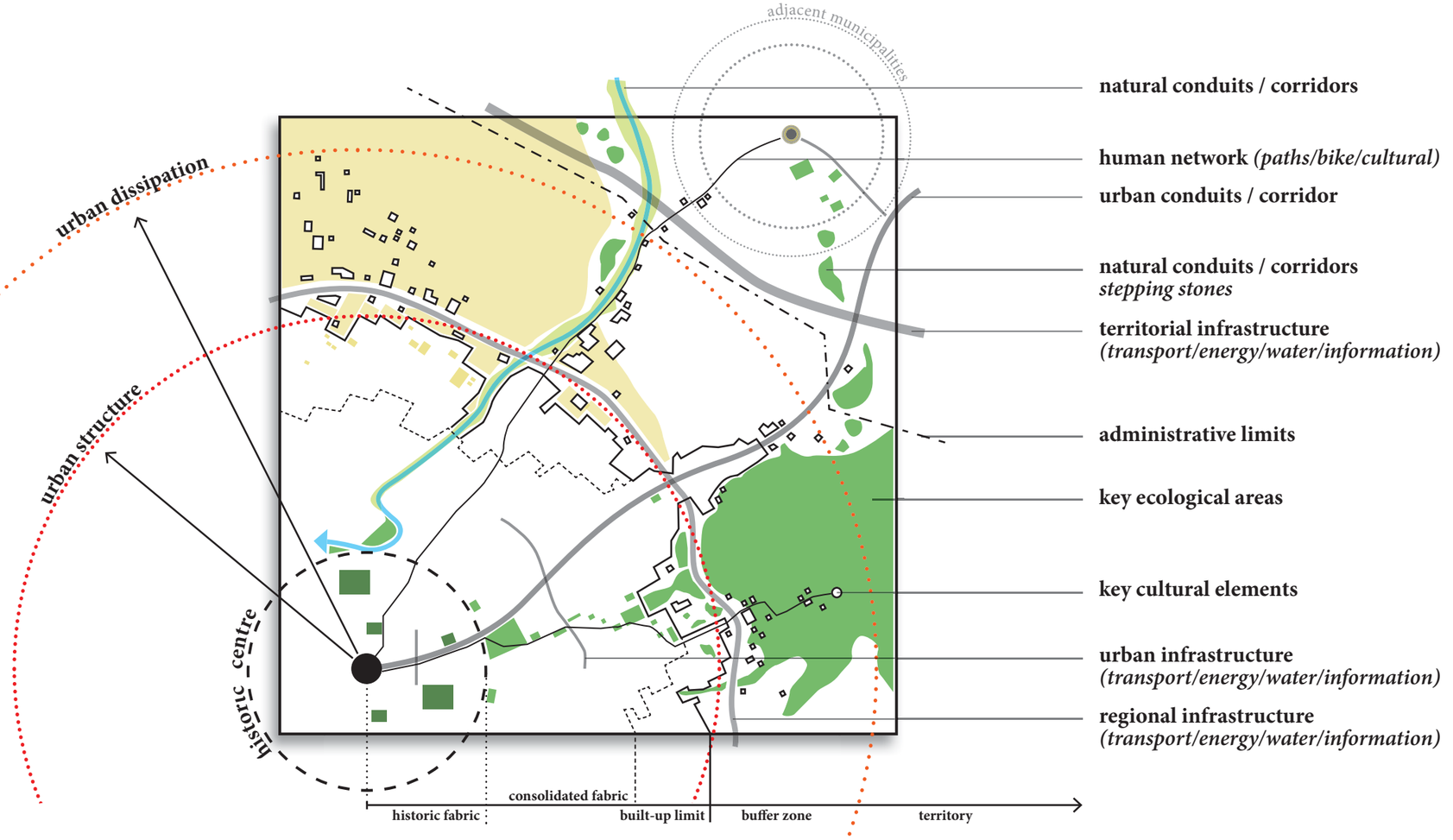
e) ***Ecotones found in a latent state within the territorial context***
(Areas that lack a proper formal organization but present a great potential as a result of bottom-up organizations emerging, top-down economic decisions or a mismanaged ecological potential or capital. Their latent potential lies in the positive impact that their reconfiguration could have on the efficiency of the local and overall territorial functioning; e.g abandoned industrial zones / enclaves, fringe peri-urban or intra-urban neighbourhoods, coastal developments).

f) ***Ecotones functioning as interfaces***
(many ecotones function or can be programmed to function as territorial interfaces, actively and selectively controlling flows and dynamics that cross them. The metaphor of the urban ecotone as a three dimensional membrane seems as quite relevant and adequate. The exterior peri-urban ecotones can be thought out as the exterior cell membranes, controlling the interaction between the inside and the outside while the intra-urban urban ecotones can be respectively thought out as the epithelial membranes lining distinct elements and urban functions while presenting several functions, including absorption or dissipation of materials / energy , protection from foreign impulses etc.).

g) ***Ecotones forming an interconnected territorial network***
(One of the most interesting propositions set forth by this research is the possibility of configuring a territorial wide network of the urban ecotones. A network with a spatial manifestation , interconnecting the contact areas or heterogeneous patches, but also a conceptual network encompassing the ongoing dynamics taking place within and through this network. This point is demonstrated better through the case-study analysis and its respective results).

dissipation
The dissipation of the urban effect (energy / material / information)happens through the transfer in urban conduits/corridors, deposition of residual material, atmospheric emissions, chemical contamination, urban services (transport / utilities/ cultural), real estate dynamics, deficient planning ordinances and guidelines etc. This dissipation of energy and entropy from the consolidated city to its outskirts goes creating emerging (often autopoetic) organizations that take form spontaneously and unofficially.

structure
The urban structure that implies a certain degree of organization as well as complexity within the urban fabric is a result of a series of simultaneous factors: the presence of a plan (and the % of its implementation), an urban network that can maintain and regenerate its parts, a coherent urban policy, a consolidated social fabric, a complete coverage of urban services etc, all factors that are manifested in the creation of an ***urban effect*** perceivable through cognition as well as readable morphologically through aerial images, plans etc.



Indeed when analysing ecotones whether natural or antrhopogenic it is necessary to consider the correlation between boundary structure and boundary function. Boundary structure is meaningless without an understanding of boundary function[19]. When trying to establish links between structural and functional descriptors of boundary attributes, a number of issues / questions emerge; Do structural and functional attributes of the boundaries in question correspond; What attributes of the adjacent patches affect the boundary function? and accordingly what attributes of the patches does the ecotone function affect? Are there any general structural features that lead to differential permeability of the boundaries? or their functional differentiation in general and in particular. These questions should be pursued and contemplated across scales and broadly across different system types. As more information is accumulated and systematized on boundary structure and function, it may be possible to predict boundary function from structural qualities or to identify critical dimensions of boundaries that are associated with certain function, such as *transformation, transmission or reflection*[20].

Temporal variability of boundary structure is emerging as a key feature / consideration of ecotonal boundaries. As variability / contingency increases, it becomes more difficult and complex to detect boundaries and apply physical models that can assume a consistency over time. Thus, the definition and classification of boundary structure should be expanded to include this behaviour of temporal variability. Some boundaries change structural features or dimensions seasonally, and the function of those boundaries may also undergo a seasonal change of variable time scales. Respectively the same structure could show temporal variability in function, acting as a boundary during one season and alternatively as a corridor during another or both (e.g. a river during different seasons or a specialized urban area over decades) as processes that control boundary features may change temporarily as well. It becomes clear then that incorporating temporal dynamics into studies of ecotone structure and function remains a logical and critical area for future exploration[21].

At the same time one of the most intriguing questions about boundaries, as contemplated and set forth by this paper, is related to the human impact on boundaries through diverse activities that modify / alter / perturbate natural boundaries or the creation of anthropogenic boundaries from scratch. Such antrhopogenic boundaries exist and have existed across all systems and scales: fortification systems, land mobility infrastructure, canal systems, built up areas, urban parks, specialized areas etc. Each of the

19. Cadenasso et al, 2003
20. Ibid

21. Ibid.

Interactions along the urban-rural ecotone - *Summary*

The following double table presents a summary of interactions that take place along the urban - rural ecotone and have systematically been systematized in positive or negative effects, for categorization purposed, based on their impact both on the human sphere as well as natural ecosystems. This list is by no means extensive but serves to demonstrate the richness and complexity of the concurring processes that could be taking place through and along such a type of ecotone. These are:

Negative effects *(-)*

Human Density. Conflicts between people and wildlife are often related to the human population density around a park or a natural area.

Contamination. While many air pollutants can be transported globally, most of them operate at a regional scale, with the most intense impact appearing in close range to the emission source.

Sound contamination can be produced by different anthropogenic sources: high noise levels from overflights over natural areas, heavily trafficked roads , industrial or recreational activity[1].

W***ater issues***. A negative effect of an urban area on a protected area typically occurs when both share a common watershed and even more accentuated when the urban area lies upstream of a protected area. Water quality issues tend to be pronounced at slightly finer scale than problems with water quantity.

Disease transmission from domestic animals to wild populations, and vice versa.

Resource / biomass depletion, In many developing countries, illegal logging and wildlife poaching in natural areas are a problem that can be exacerbated by proximity to urban areas. People collecting firewood usually do not travel farther than necessary, the distance depending on the intensity of this activity as well as its objective (recreational / heating/ cooking etc).

Light pollution from urban areas can be biologically significant over different scales where many birds and insects are attracted to light, causing direct mortality and alteration of migration patterns or inhibits the ability of people to see a naturally dark night sky

Urban land uses also dramatically increase the rate of ***fire ignition*** along the wild-urban interface resulting in forest fires and signigicant ecological perturbation.

Urban areas also also play an important role in the ***invasion / introduction of exotic species*** given the fact that exotic species thrive in landscapes that are characterised by availability of resources and elevated levels of perturbation, such as urban edges. This invason can be *accidental* (through international trade routes and entries such as ports, airports etc.) or *intentional* (introduction of exotic species in parks, exotic species as pets etc.)[2].

Energy dissipation / waste deposition from urban areas to natural areas can change dramatically the habits of wildlife or the structure of their habitats thus affecting ecological quality significantly.[3]

1. Mcdonald et al (2009)
2. Andreu, J. & Pino, J. (2013)
3. Mcdonald et al (2009)

Positive effects *(+)*

Many of the positive effects can be expressed in the terminology and context of ***ecosystemic services***, and are operative / applicable at scales from global to local.

At a global scale, many urban dwellers are pleased at the existence and proximity of protected areas even though they are unlikely to ever visit[1]. Historically, urbanization in a country has also been temporally associated with increased land protection, motivated principally by an increased societal value of the existence / proximity of natural areas leading to conservation initiatives driven by wealthy urbanites who had access to natural areas during their childhood and valued their continued existence[2]. Indeed, the creation of many early regional or urban parks in the westen world was justified mostly by such urban environmentalists in part to protect / conserve them as a recreational resource[3]. Increased proximity between urban and protected areas also facilitates use of natural areas (protected or not) for **recreational use** with implicit health & psychological effects for urban residents. For vacation travel, urban residents can recreate in protected areas far from their urban area, although most vacation travel is regional in scale[4].

While the causal reasons for the temporal association are not clear, urbanization tends to occur during the development of an economy, and the increased wealth generated by that development is at least partially used for spending on conserving environmental goods & services.

Another key ecosystemic service provided to urban areas by proximal natural areas relates to water. Natural landcover, particularly forests or wetlands, are valued for their ***water filtration*** and ***aquifer recharge capacity***, and indeed many cities rely on protected areas to ensure their reservoirs continue to supply clean drinking water[5]. At a more local scale, protected areas often provide additional ***flood-control*** and ***protection*** for cities or adjacent urban fabrics during intense rainfalls or high tides.

Similarly the presence of extended natural areas in close proximity to the urban areas has positive effects on ***air quality*** given that these areas ultimatelly act as air purification / filtration elements through the catchment of $C0_2$ as well as different suspended air pollutants originating from urban activity and metabolism.

Accordingly the presence of extended natural areas or network of areas can also have an effect on urban temperatures and thus Temperature control reducing or controlling the urban heat island effect characteristic of many urban centres worldwide.

Taking into consideration the ***intermediate perturbation effect*** discussed earlier, it can be claimed that the co-existence and co-evolution of the urban and natural artifact can lead to an overall positive effect on cities´edges . This happens when the dissipation of energy and export of entropy from cities to adjacent natural areas is done to such extent / intensity that does not surpass their natural capacity to absorb shocks and to transfrom dissipated energy into new structures and more complex types of organization.

1. Mcdonald et al (2009)
2. Nash, R. (2001)
3. Ibid.
4. Mcdonald et al (2009)
5. Ibid.

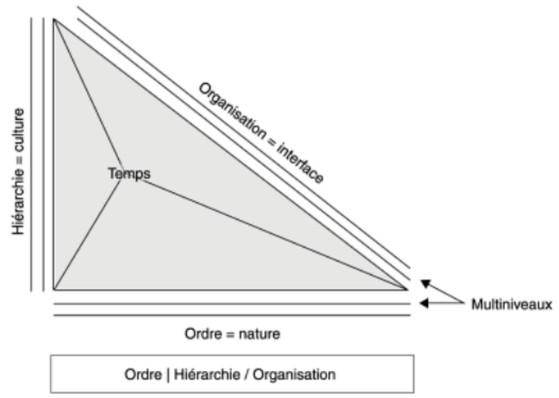
human created structures represents a type of boundary often with unique features, sometimes unparalleled in the natural settings. Many anthropogenic boundaries are incidental to a human activity and may not be obvious at first as boundaries. Studies that have examined the natural fluxes of materials or energy when boundaries are lost or created due to human activities suggest that these fluxes are altered during the process of boundary creation or loss[22]. Such studies provide the opportunity to assess how the functions of antrhopogenically generated boundaries compare with those of natural boundaries. The interaction of human and natural factors in the creation and maintenance of boundaries emerges as a research topic based on the considerations.

The importance of the presence of ecotones as critical areas has been recognized by humanity right from its early history. The first settlements, villages and cities, were situated on ecotones such as lake and sea coasts, river deltas or along mountain-plain limits[23]. The city of Thessaloniki situated between the Thermaikos gulf and the adjacent mountain range presents such an example, similar to the majority of the historic Greek cities. Accordingly, the city growth patterns developed over time, demonstrate both an "exploitation" of local ecotones as well as the creation of new ones. The case study analysis will demonstrate this point. In order to enrich the current debate the economic evaluation of ecotones in anthropogenic and modified systems can also prove quite relevant, especially when performed along different time and spatial scales, incorporating a real-cost economics paradigm to territorial processes:

> *The suppression of many aquatic ecotones such as lagoons and marshes, often claiming hygiene reasons, apparently represents a short-term economic advantage because they make available new soil for cultivations and urban development, but at longer temporal scale they represent a net cost for the disequilibrium and the resulting disruption of water and nutrient cycles at the landscape and regional level. Ecotones like marshes, river deltas and estuaries have been considered as expensive types of land to reclaim and, on the other hand, the recent discovery of the invaluable role of these areas for maintaining biodiversity represents two-faced reality: Using a long-term perspective, ecotones represent important areas for maintaining a balanced territorial land mosaic as well as key sanctuaries for an increased diversity of plant and animal species too important to be surpassed by any economic benefits[24].*

22. Cadenasso et al, (2003)
23. Farina, A. (2006)
24. Farina, A. (2006)

The four dimensions of an interface (source: Cosinschi-Meunier, 2008 in Lampin-Maillet et al, 2010)



The productivity and the functionality of territorial systems are assured and to a great extend controlled by ecotones and their respective functions. Accordingly in the case of riparian woodlands they often represent buffer zones, that reduce the eutrophication of fresh water and function as a protective barrier to catastrophic water flash flooding[25]. Human development in history has gained many benefits from the correct application / modification and management of ecotones. In this way, the edges separating and marking crop fields have been built up to reduce the wind effect, while creating small micro climates favourable to plants and animals and at the same time a complex and efficient landscape structure as in the case of the mediterranean agro-forestal mosaics. However, all these man-made ecotones are fragile structures that apart from maintenance, also need a proper and adequate management. The recent intensification of agriculture has produced the disappearance of edges from large parts of rural European areas destroying traditional agro-mosaics and respective forms of production[26].

> *"Urban Ecotones" provides a contemporary vision for how modular economic development can regenerate, rather than destroy natural systems within an expanding city region. Rather than seeing the thresholds at which commercial development meets natural systems as points of confrontation, they are approached as environments of unique richness – a synergy of diverse habitats akin to ecotones, spanning nested scales from site to region. Urban ecotones are spaces for creative cross-programming that facilitate new regenerative urban processes[27]"*

Given the construct of a boundary can be used to better understand the regulation of fluxes across any kind of heterogeneous space, as seen earlier often a model that describes heat or mass transfer can be useful for analysing and visualizing transfer of materials / energy. Flux at a boundary is regulated by factors that control the concentration gradient and the transfer coefficient. Such models have been widely employed in ecological studies of natural ecotones where population propagation or uptake of materials (eg. nutrients) is highly depended on transport and delivery to these boundaries / ecotones. Similarly they could be employed in the urban setting. Basic description of ecotonal structure as well as function will benefit from techniques employed by landscape ecologists / geographers (e.g. GIS, geostatistics) and new spatial statistics techniques[28] incorporating, apart from geographical data, dynamic live data.

25. Naiman R. J., Décamps H., (1997)
26. Tello E., & Garrabou, R. (2006), Farina, A. (2000 & 2006), Krausmann, F., (2001)
27. Jason King & Brett Milligan. (terrafluxus.com)
28. Fagan et al. (2003)

Ecotone Structuring Elements

urban green conduits / corridors

regional infrastructure
(transport/energy/water/information)

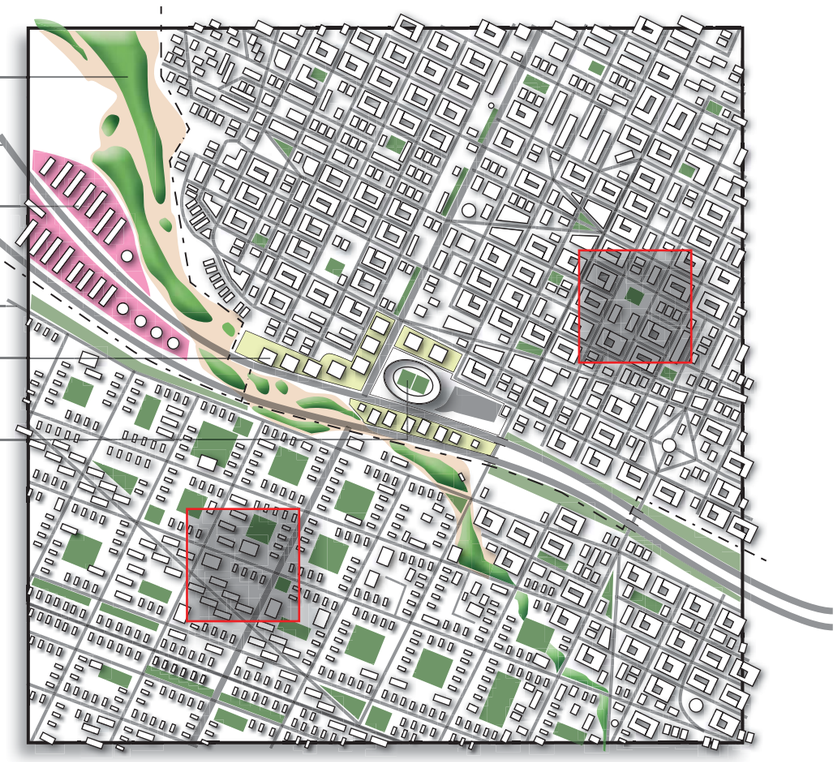
industrial / manufacturing areas

administrative limits

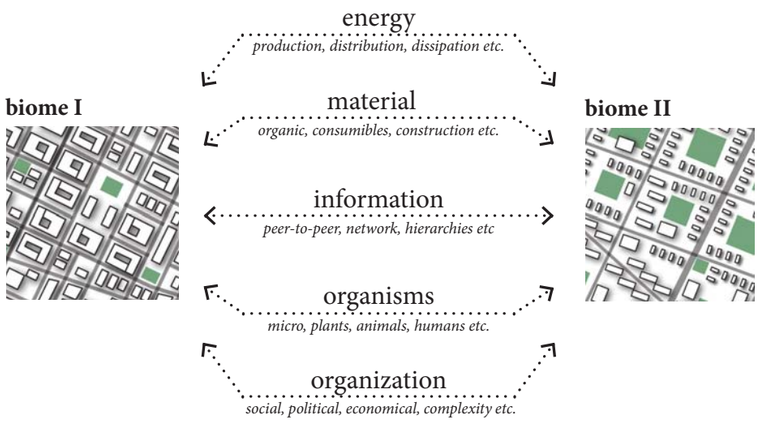
urban infrastructure
(transport/energy/water/information)

specialized areas
(commercial/economic/education/ innovation etc.)

big size / special elements



Patch Interactions

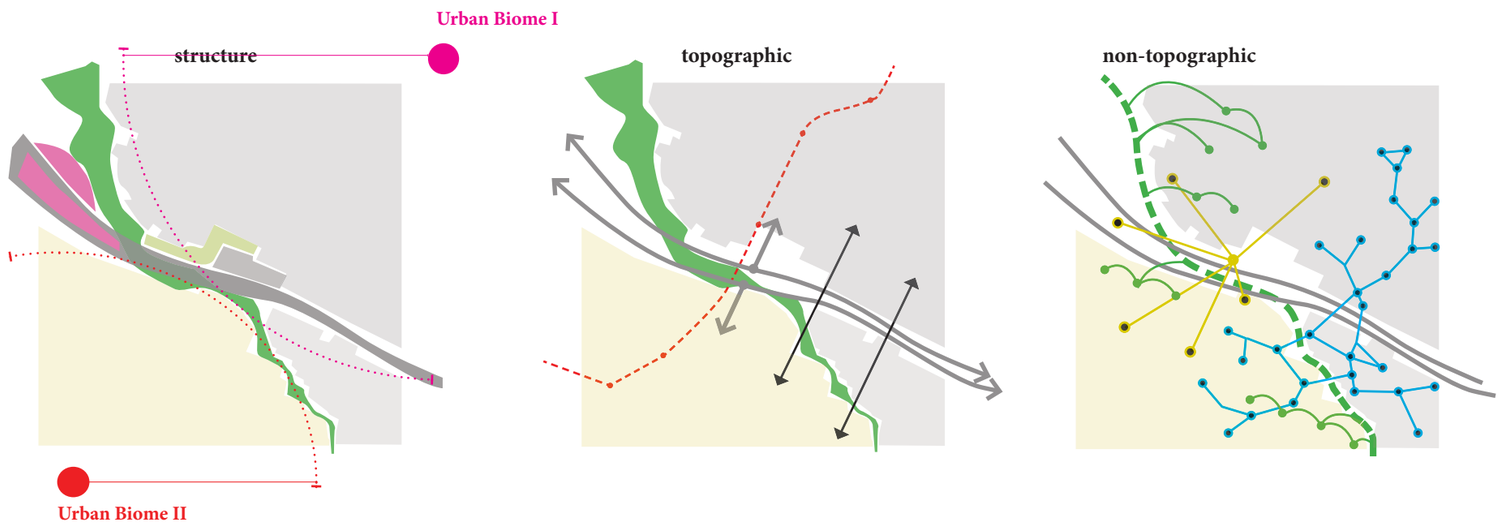


Ecotone function

Absorption

Transformation

Transmission



Fabric Differentiation

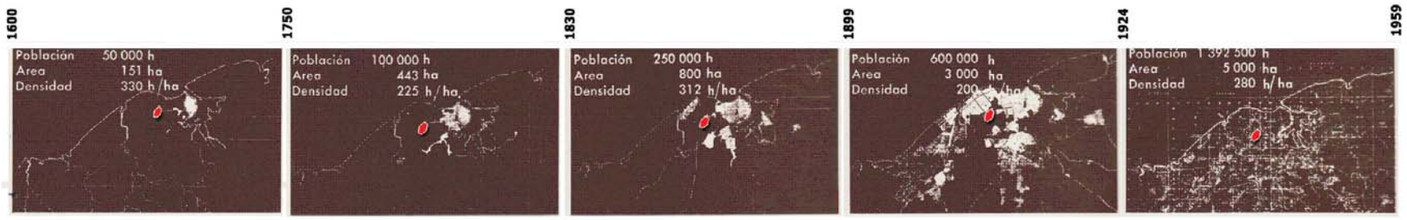
habitability
typologies / density / edificability / public & green spaces / quality

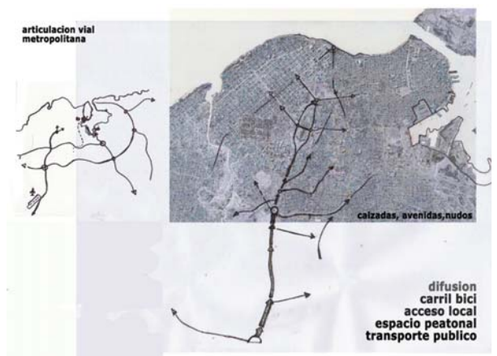
activity
modes of production / networks / social interactions / appropriation of space / hierarchies & scales

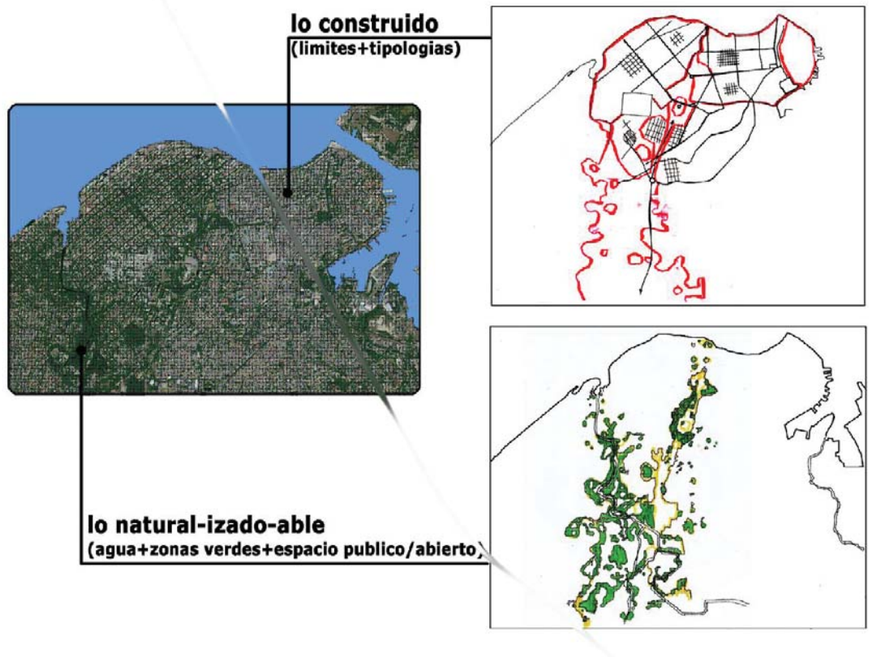
mobility
infrastructure / access to flows (public / private) / hierarchies / efficiency

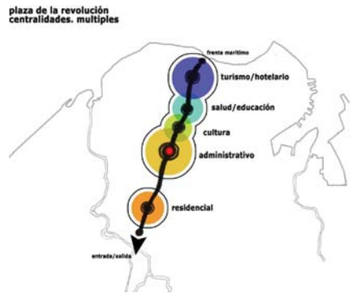
goverance
plans /ordinances / local goverance / initiatives

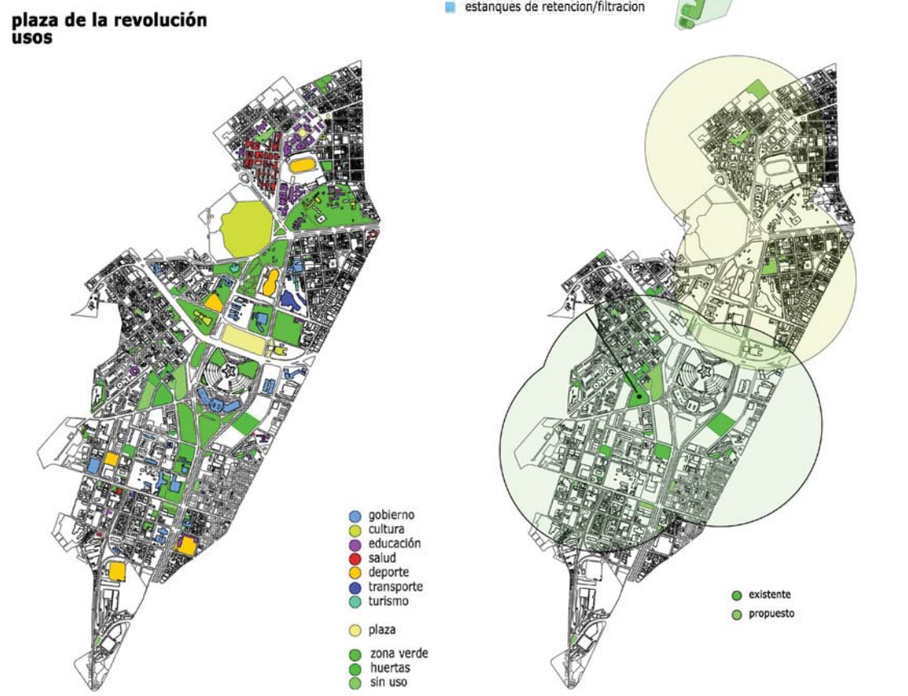
organization
structure / complexity / social fabric / coherence







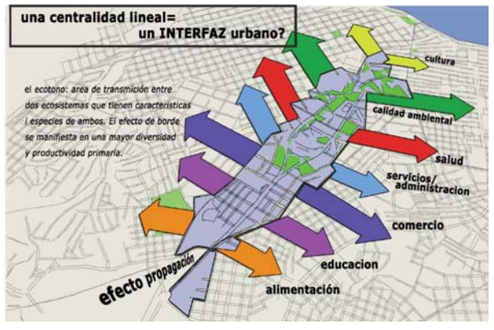


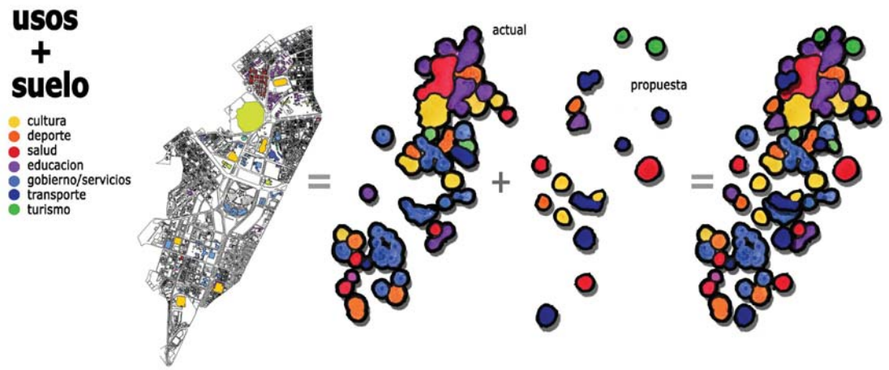


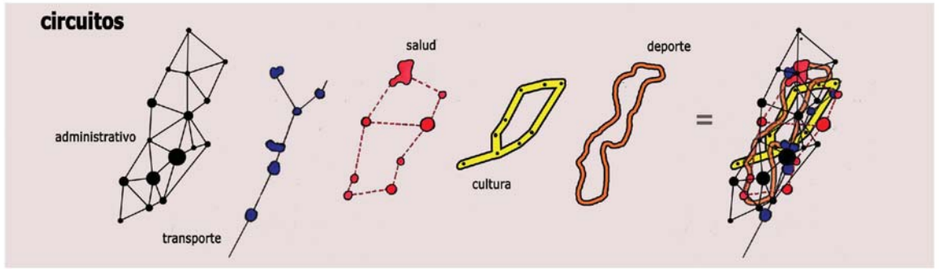
ECOTONE CASE STUDY - La Plaza de la Revolución en la Habana, Cuba / Research Seminar / DUOT - UPC, 2011

The Plaza de la Revolución in Habana, Cuba served as an early case-study of an urban ecotone and an opportunity for an initiation into the topic of ecotones in general and urban ecotones in specific. The analysis / exercise was done in the framework of a joint workshop organised by the department of Urbanism of ETSAB and CUJAE, combined with a field trip in the city of Habana.

The city of Habana and the Cuban context in general present certain particularities and differences with respect to western urban environments. But at the same time they present an opportunity to rethink and re-evaluate certain notions related to urban functioning and structure; that is the commercialization of urban soil and consequently the idea of green territorial systems as infrastructures. The *Plaza de la Revolución* with its intrinsic ecotonal nature served also served as test-ground for transferring the ecotone concept to the urban context. The Plaza formed over the years as as interstice between the area of the Habana Central (& Cerro) and the Vedado (new & old) has come to concentrate a great number of administrative and governmental buildings / functions. Given the fact that it is located along the axis that connects the airport with the historic centre it can be undestood that historically it has acquired a latent importance and a key territorial role. At the same time despite the great availability of open space (especially compared with adjaced fabrics), it is characterised by a low / temporal activity, what could be described as poor public space & green space qualities, or poor urban qualities in general. The fragmentation created by the infrastructures, vastness of open space and building masses create apart from a relative urban void, a territorial barrier as well.







Apart from the apparent problematic situation created by and due to the various chronic problems intrinsic to the area, the *Plaza de la Revolución* holds a latent potential as a centrality, due both to its location as well as the concentration of functions and official activities that it holds. Parallely the space of the Plaza as a whole holds a great potential both for relating two distinct and differentiated fabrics of the city (an a east-west axis) but also as a corridor connecting the inland with the Malecon seafront (on a south-north axis).

Respectively, the relative theoretical advance set forth by this exercise was the exploration of the notion of the urban ecotone as re-programmable interface, that is to say apart from a mere analysis vehicle, also as a planning instrument. One that permits to harness the latent potential both of the ecotoneal areas *per se* as well as of the adjacent areas, having a positive effect not only on a local level but potentially on a multi-scalar level. Signaling this way a shift of focus from the study and planning of homogeneous urban areas, to the intra-relation of heterogeneous and differentiated fabrics, as was the case with the *Plaza de la Revolución* and the city of Habana. In that case following the analysis of the area, a proposal, in the form of a framework, was formulated. One that envisioned the transformation from a void, a negative space, to an active interface that intentionally managed and exploited the present dynamics and intended to mend the fragmented urban fabric into a coherent and vibrant whole, respecting the particularities and dynamics presents in the local and extended urban scales.

Most importantly, as mentioned earlier the *Plaza de la Revolución* has served as an opporynity to perform an initial research on the concept of ecotones, and most importantly its application in the urban context. In this sense, it has served as the point of departure for this research paper and the respective analysis of the ecotones in the case study of the city of Thessaloniki.

Further research can focus the study of ecotonal situations across a diversity of urban / natural habitats as well as spatial and temporal scales, while incorporating to the maximum possible degree the present complexity of the territory as manifested in the abiotic and biotic elements that comprise it, the emerging dynamics, the chain of interactions and all the information that was impossible to consider till today due either to technical or conceptual limitations. The exercise of conceptual frameworks and comprehensive classifications of ecotone types and effects are useful tools for analysing, comparing and synthesizing the complex and rich data available in the ecotonal areas[29] of contemporary urban regions as well for advancing our contemporary understanding on the topic.

As mentioned earlier the complexity sciences have developed from a synthesis of many scientific disciplines and domains, from mathematical modelling, biology, physics, economics and so on. *The essential criterion for a complex system is a collection of elements that act independently of one another but nevertheless manage to act in concert, often through constraints on their actions and through competition and co-evolution. The physical trace of such complexity, which is seen in aggregate patterns that appear ordered, is the hallmark of self-organisation*[30]. Cities, as the higher manifestation of complexity and organization of human societies, present an ideal test-ground for contemplating and testing these ideas. Consequently city-sciences can profit significantly from this updated perspective on urban functioning and dynamics. This ordered appearance does not imply that self-organised systems are optimal in some way, but rather it asserts that such systems are resilient within local constraints.

Furthermore the introduction of the concept of ecotones comes to further enhance the current understanding of urban regions as dynamic and complex systems. Shifting the focus from the study of homogeneous, relatively stable systems to heterogeneous dynamic and even unpredictable systems is a major change in how we look at contemporary cities. The urban ecotones paradigm serving both as spatial indicators of territorial dynamics, but more importantly as a potentially powerful planning tool, can play a key role in managing and optimizing the apparent chaotic, now understood as complexity, movements of modern-day urban fabrics. Moreover, the notion of equilibrium has largely and gradually been abandoned as highly organised systems no longer are considered to tend to some steady-state but on the contrary are always in a far-from equilibrium state. As commented earlier, socio-ecosystems are intrinsically energy dissipative systems, a feature that significantly conditions their morphogenesis and development over time. Furthermore it maintains them in a constant out-of equilibrium state. The urban fabric differentiation and resulting spatial heterogeneity produced by this non-uniform energy dissipation in the territory, are what makes urban and anthropized regions so special and fascinating. Accordingly this anisotropic development gives rise to the creation / emergence of diverse and distinct ecotonal zones appearing between the differentiated fabric / biomes. Interestingly the sum of these urban ecotones, as comprehended and identified within the urban fabric, can be thought out as an interconnected network. Usually the same development patterns that mark the city growth are the ones that allow for such interconnectedness and interrelation between the different ecotone zones. The emerging and existing complexity of cities and the spatial dynamics they represent can be captured and comprehended more efficiently when viewed through the spectre of a region-wide integrated network of ecotones. Each serving as an individual spatial indicator, but when thought out as a whole providing a more complete and integral impression of urban dynamics on a multi-scalar level. Apart that this additional knowledge can have a significant impact on our understanding on city structure and function, it can also help unleash the latent potential of certain urban areas or regions. In a similar fashion the idea of having a network of interconnected interfaces, dialoguing and providing interaction between the distinct fabrics, but at the same time having the capacity of being programmable and configurable, opens up new possibilities for thinking out the city-wide planning approach.

While the emerging questions around ecotones open up numerous and diverse paths for future research, in order to systematize this advance, ecotone research *will need a toolbox, complete not only with the many methods already employed by ecologists but also with developing concepts and technologies*[31] used by other disciplines. A theoretical model development that can tackle the task of the integrating and comparing such heterogeneous and differentiated biomes found today in the anthropized territories. Cities are the exemplar par excellence and this has profound implications for how we intervene in their organisation through different forms of planning[32]. The analysis of the case-study of the city of Thessaloniki, has served this double function; firstly, test the theoretical notions / concepts notions of ecotones, especially the ones related to urban ecotones, and secondly verify the capacity of / for urban ecotones to act as reprogrammable interfaces, planning tools that can optimise fragmented, obsolete or disassociated urban fabrics.

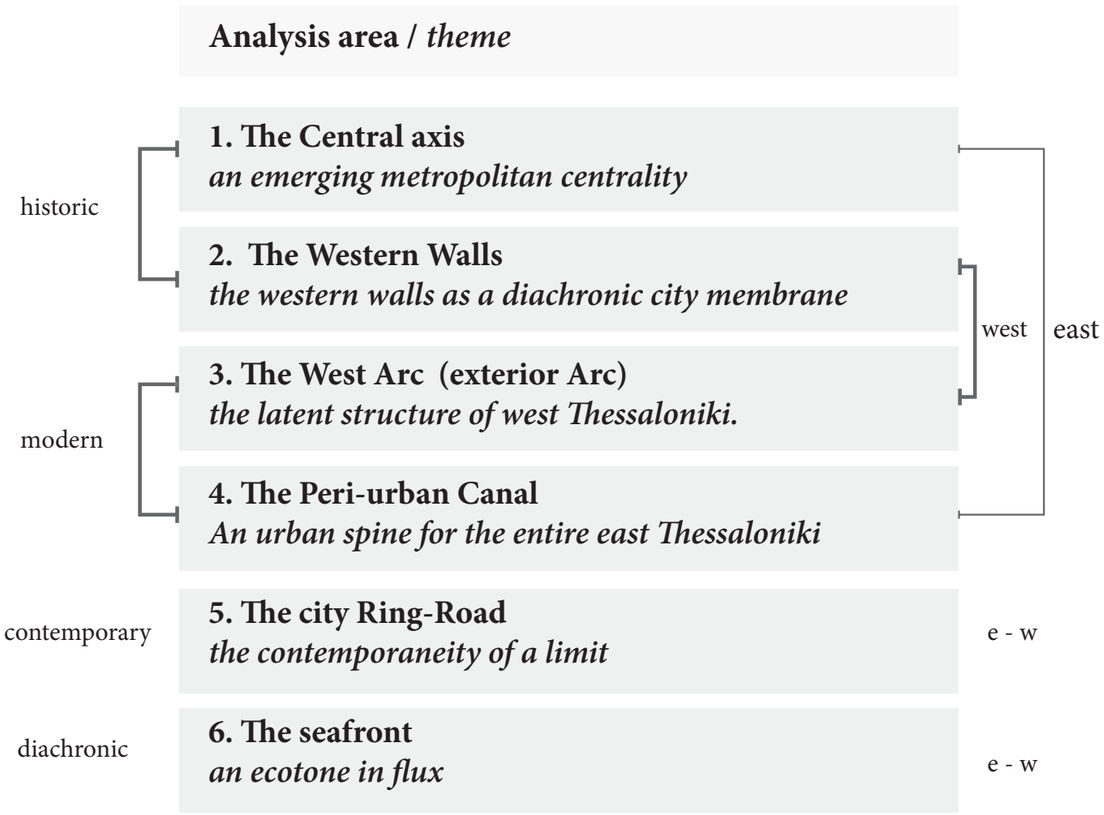
29. Cadenasso et al, (2003) & Strayer et al. (2003)
30. Batty, M. & Marshall, H., (2009)
31. Cadenasso et al, 2003
32. Batty, M. & Marshall, H., (2009)

Results

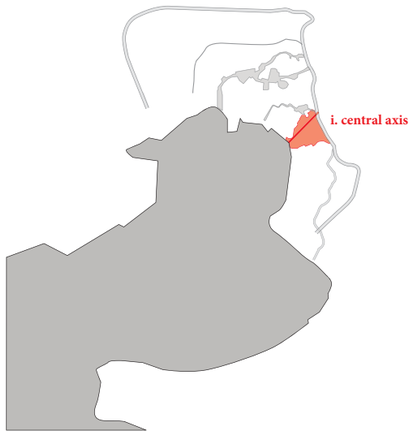
The six ecotone case-studies in the urban region of Thessaloniki.

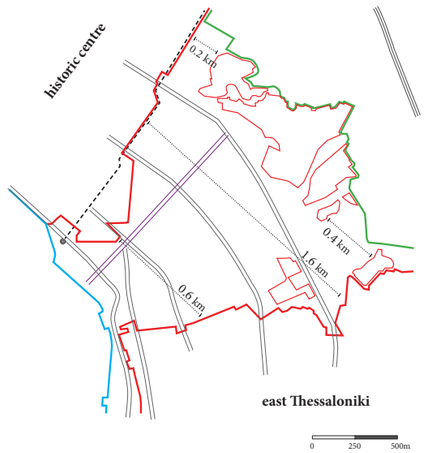
In continuation, the results of the analysis of the six respective ecotonal areas of Thessaloniki will be presented in a summarized form, along with relevant illustrations and the specific conclusions produced for each area. The analysis of diverse but at the same time related (due to historic, geographic reasons or others) ecotones, has permitted to produce a wider base of conclusions covering multitude of territorial situations that accordingly facilitate a potentially richer synthesis. A richer synthesis both in terms of geographical coverage (city-wide consideration) but also in terms of the theoretical discourse produced extending both to applied conclusions on the urban region of Thessaloniki but at the same time importantly on the definition and understanding of the concept of urban ecotones in general.

The complete analysis for each one of the six areas can be found in the second book, *the Analysis Atlas*, where each case is analysed in its corresponding chapter, permitting to reach a increased depth and detail. The diagram on the right present the order of presentation of the six areas, after which the conclusions of the sum of the analysis will be presented.



1. Central axis - *an emerging metropolitan centrality* *(p.64 - 115 in Book II)*





transverse flows

vegetation

The area of the Central Axis, the first ecotone under investigation, is an ecotonal area formed between the eastern walls and the corresponding eastern expansions limits, that coincided with one of the local streams. The Hebrard plan envisioned the creation of a predominant axis, boulevard type, structuring the area which was never materialized. Although the axis does exist today as a trace, it is found as a discontinuity, fragmented by the diverse areas located in the area and the diverse traffic axes that traverse it. The analysis tried to investigate the reasons and conditions that gave rise to the emergence of the ecotonal area, and the resulting heterogeneity encountered today. On a second level, investigate ways to restructure the area, using the Central Axis as key structuring element, taking advantage of the dynamics and diversity of activity present within the area. Following the analysis, the following principal characteristics were identified:

a) Excessive & uncoordinated edification
The areas is found in a state of pressure from adjacent and contained edification (residential & other uses) resulting as a consequence in the built up area taking over vital space, reducing and fragmenting the remaining open spaces and creating tensions points along the contact surfaces both along residential areas as well as forest areas to the north.

b) Reduction and fragmentation of free space (public & green space)
The current arrangement of buildings, in the contained areas do not encourage the interconnection and integration of open spaces. Meanwhile physical barriers (fences, walls, vegetation etc.) around the formentioned sites, as well other nearby sites (University of Macedonia, Sports facilities, etc.) do not permit public pedestrian access and prevent further connections with existing green & public spaces.

c) Vehicular and pedestrian flows
The main roads crossing the area are in general overburdened by vehicular traffic of vehicles (of periodic or sporadic nature) creating a considerable fragmentation on a horizontal level. This same increased number of vehicles creates a serious problem with regards to parking needs, the increased space they occupy and the visual effect it provides. Thus pedestrian flows, both on a vertical and horizontal level, are presented with considerable barriers / obstructions rendering the access to certain areas difficult. Bike lanes are minimal and often not respected by car users. Public transport is solely confined to bus traffic. The addition of the Metro line in the future is expected to influence significantly activity patterns and dynamics in the area.

d) Typological diversity and lack of architectural cohesion
The long historical activity in the area has produced respectively an ample range of building typologies often intrinsic to the site, creating distinct typological differentiations compared to adjacent patches. Although past attempts like the Eastern Cultural Axis have intended to apply a common architectural vocabulary in order to create the impression of spatial unity, this was achieved in certain areas and within a limited scope. The overall fragmentation of the area prevents such a conceptual unity to be reached both on a physical/ visual as well as mental level.

e) The need for a proper city structure
The revival of the idea of the ***Central axis***, as envisioned by the Hebrard plan, can prove to be a handy urban instrument for increasing accessibility and resolving issues of mobility while helping restructure the ecotonal area in its entirety. Given the imminent use change of the EXPO area, (as well as the possibility of the opening of the military installations and university campus to public access) there is a need for an integral reconsideration of the area, focusing on the reorganization / restructuring, investigating ways to mend the fragmented and currently dysfunctional fabric. On the positive side, the area hosts a diverse and rich activity (, residential, recreational, cultural, health and academic, sport etc.), creating a potential centrality advantage when it comes to rethinking possible future transformations.

f) Management of housing stock
The housing element has traditionally served as a dynamic force in the last century and needs to be considered carefully in a potential updated context. From one point there is a need to register the non-occupied apartment stock, observe deficiencies and investigate ways to restimulate the attraction that the location holds as a centrality. Also consider possible further densification where and if possible.

The detailed lecture of the area has aided in decomposing this complex micro-mosaic in its individual parts, and reconsidering its function and role in this critical location for the city of Thessaloniki. Another point highlighted through the analysis is the potential for the idea of the revival of the axis of the Hebrárd plan to help mend the fragmented fabric and serve in the wider reprogramming of the city structure.

1. Central Axis ecotone

Origin / Type		*Spatial Structure*	
type	tangible / manifested / morphological	*stuctural element*	traffic arteries
		latent element	central axis
source	anthropogenic + consequential	*shape*	funnel
creation force	east city-walls + local streams	*extend / length*	1.6 km
time of creation	roman era	*thickness (min/max)*	0.5 - 1.6 km
character	historic / centrality	*scale*	local
interest	planning / restructuring	*grain size*	Hebrárd / East grid
		sharpness	sharp

Function		*Dynamics*		*Projectual Logics*
type	amplification + transmission	*state*	active	reinstitute central axis
interaction	urban - urban (historic centre + east Thess.)	*control*	endogenous	restore continuities
		mobility	bi-directional / transversal	reintegrate / reactivate fabrics
edge activity	diverse / multiple	*activity*	vibrant / changing	manage emerging centrality
character	historic	*situations*	enclaves / morphological	enhance complexity
	emerging centrality		shift / edge typologies / latent fabrics	articulate spatial scales
grade of artificiality	highly artificial			
integrity	perforated	*impact scale*	multiscalar - local to metropolitan	

A transformation of this local mosaic can then be thought out based on these points, aiming to heal and repair the fragmented fabric. This task that can be achieved by connecting public and green spaces on a network base, managing and rerouting the various flows and evaluating and introducing old and new activities and thus reaching a significant restructuring of the local fabric.

The ***Central axis*** emerges from the analysis as a key element and an important urban planning tool for mending the fragmented local landscape. The question of continuity, accessibility and consequently mobility are the most pertinent questions in this case that need to resolve the existing conflicts and barriers present in the local fabric. The axis in its totality starts from the seafront, until it reaches the Tellogleio Art Institute. Although conceptually the analysis recognizes a conceptual extension of the axis that reaches all the way to the Ring road. So in reality we can talk about two distinct parts: ***i)*** *lower part,* the part from the sea to the Teloglion Institute and the part that corresponds to the 1997 proposal extension, where certain points of conflict with the principal road arteries need to be resolved while establishing the desired continuity, dotting it with certain points of centrality and vibrant public spaces. ***ii)*** *upper part,* the part from the Teloglion Institute and all the way up to the ring road which has a distinct character, crossing a completely different type of fabric. The projectual logic in question is that of the interaction and connectivity of the urban fabric with the adjacent natural environment. Other key elements to be highlighted are the following:

- ***Pedestrian axes*** facilitating emerging pedestrian axes principally of transversal character uniting the historic centre with the eastern extensions and serving as activity and soft mobility conduits.
- ***Urban arteries / conduits*** that serve an important function as mobility corridors and could in a wider reconfiguration of the area scheme play an upgraded role by combining existing activities with the introduction of new ones, an overall improvement of public space amenities and accessibility and by efficiently managing vehicular and / or soft flows, public and private along its length as well the parts& patches that they connect. If we consider the central axis as part of the macro-structure (hard) these arteries could be considered as forming and structuring the local micro-structure (soft). These smaller scale interventions can help reticulate and propagate the central axis effect on a larger scale and accelerate the process of integration with the rest of the urban fabric.
- ***Nodes*** are points of intersection of flows that hold a key role in the overall functioning of the city structure, discerning two distinct kinds: **i)** existing traffic nodes that need to be reconsidered due to their current malfunctioning and on the **ii)** emerging nodes that appear after the analysis and in the case of a potential restructuriation of the central axis. The management of the various flows (vehicular or not) and the upgrading and highlighting of the public space are the two key issues in this spot.
- ***Connectors*** refer to certain kinds of interventions that intend to reestablish continuity and overcome fragmentations caused by the intersection of incompatible flows. They come to prioritize pedestrian flows over vehicular flows or resolve conflicts of the two. These could come in the form, for example, of either overpass pedestrian/bicycle bridges, priority pedestrian passes, or subterranean vehicular passes.
- ***Urban voids / latent spaces***, refer to areas that are present within the contemporary fabric, and are either bound to change use or currently holding no use. Given the importance of the area and the special occupancy terms that exist, these areas ,whether big or small in size, could play a key role in transforming and dynamizing the existing fabric.

The prior analysis of the ecological layer of the area and its correlation with the updated conditions highlighted by the analysis of the anthropogenic layer can provide more insightful conclusions. The old local streams of the area can serve as key lineal and structuring elements for generating new green spaces but also importantly for restoring the sea-forest connection and providing opportunities for ecological and hydrological restoration. These streams are ***i)*** *Evagelistria Stream* ***ii)*** *Saranta Ekklisies / Eastern Stream* ***iii)*** *Military Corps Stream*. These old stream paths offer viable ways to create accessible green spaces that, given their lineal nature, can also serve as structuring elements. Contrary with the *Central Axis*, with its rigid nature and maybe more civic character, the stream paths emerge as organic parallel alternatives for re-sawing the local fabric, eliminating present fragmentations and barriers that characterize the current mosaic. The degree of ecological restoration that could be achieved by an intervention on the specific area would depend greatly on the motivation and driving forces behind the restoration effort.

Public & green spaces

Built-up area

Barriers

Public & green spaces

Public & green spaces

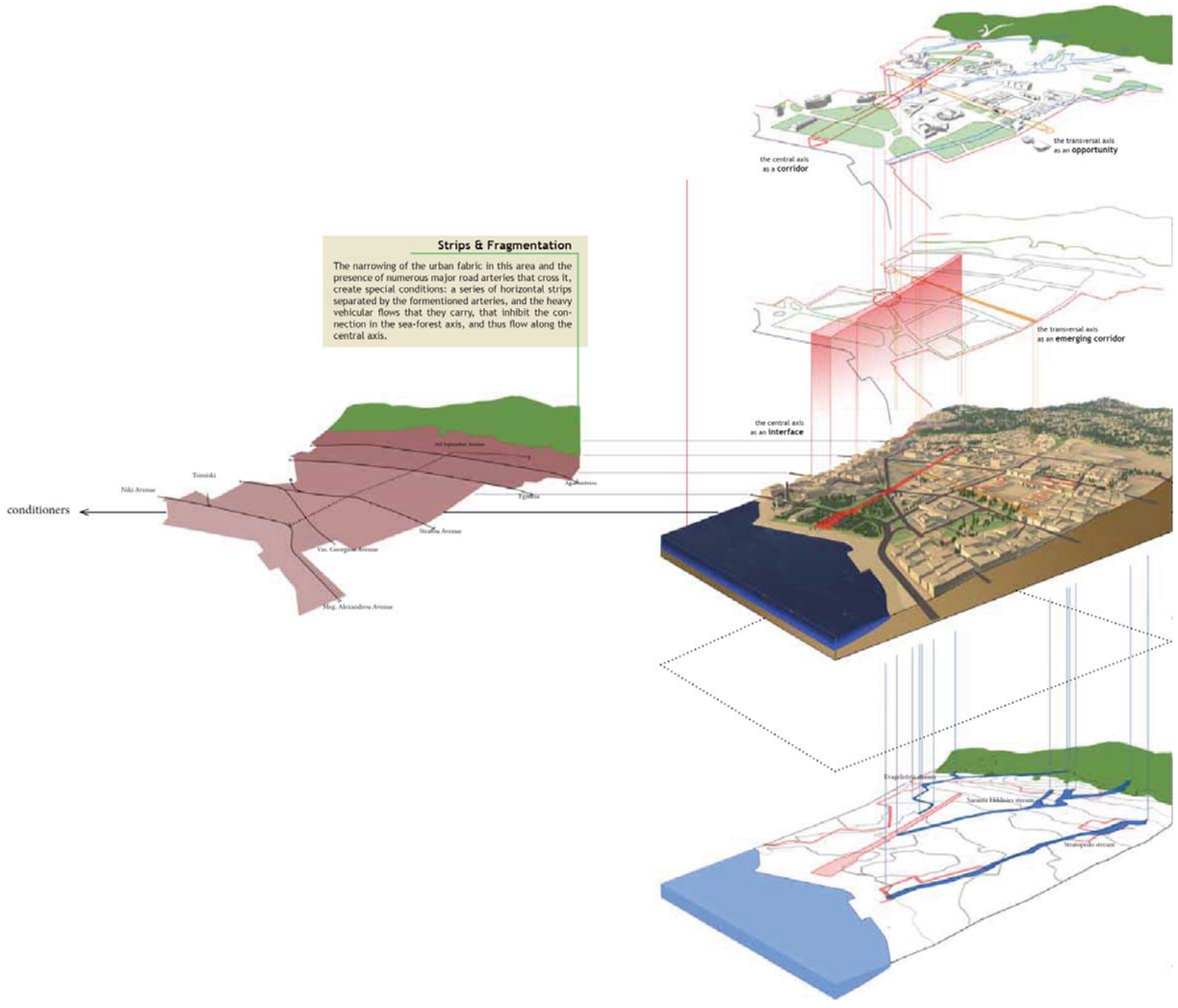
Pedestrian flows

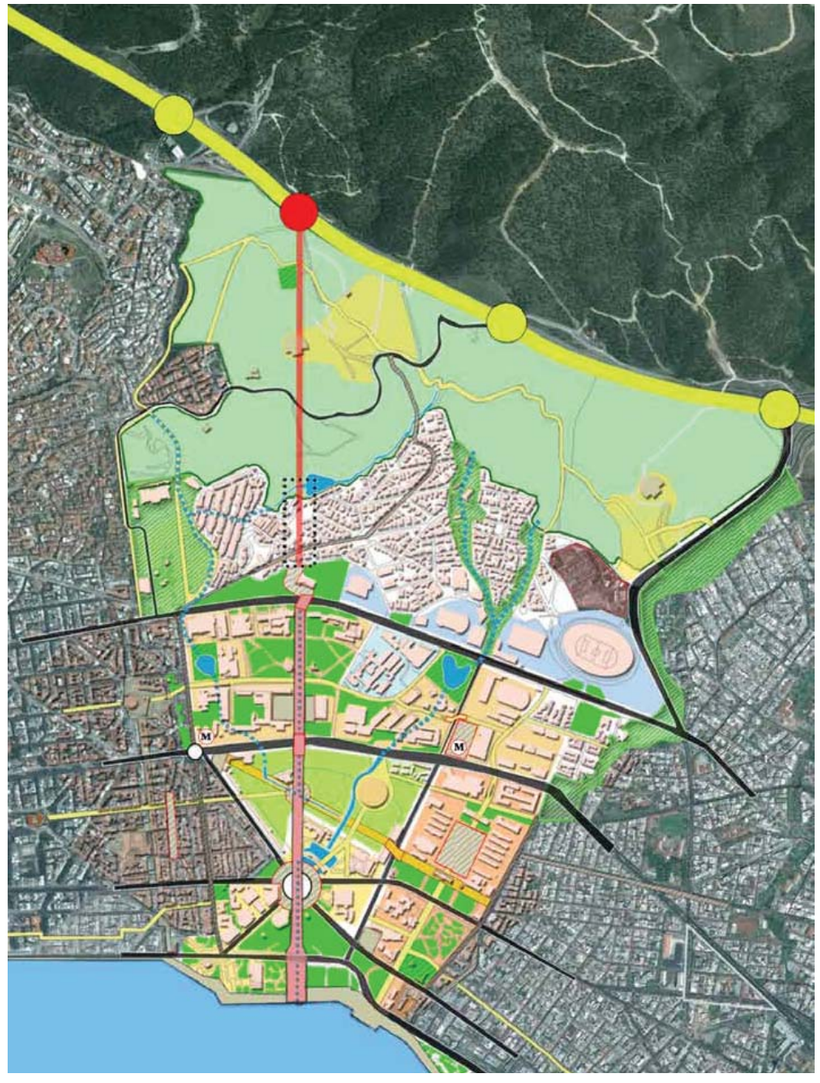
activity

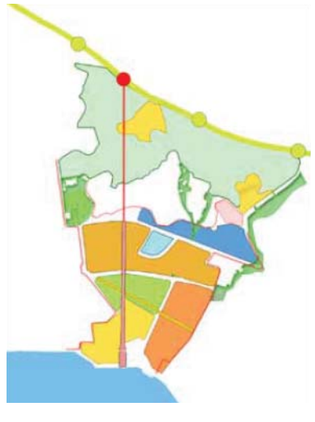
Situations and conditions

Edge Analysis

The re-structured mosaic - *The Central Axis as support structure for an emerging centrality*







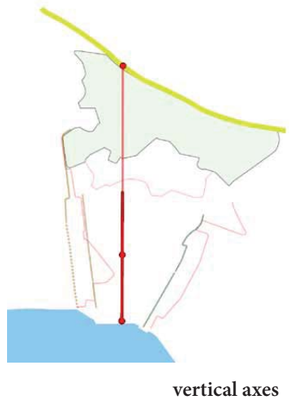
zones of activity

urban structure

public space structure

ecological structure

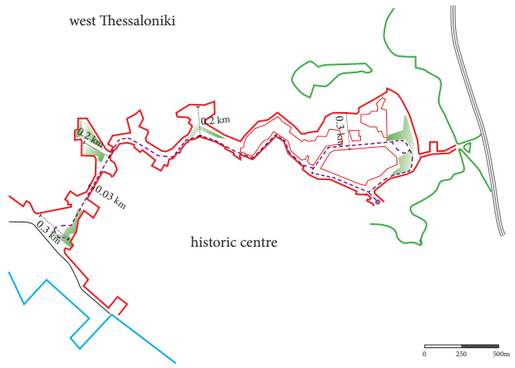
transverse axes



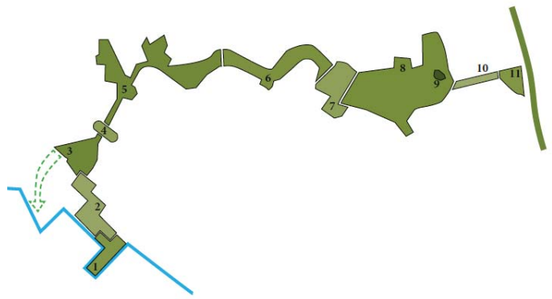
vertical axes

networks

2. The western walls - *the western walls as a diachronic city membrane* *(p.116 - 171 in Book II)*



Environments



Areas

The second ecotonal area under investigation has a linear character, emerging along the western walls of the historic city. Traditionally the entrance of commerce and goods of the city, the walls were dotted with city gates that facilitated this communication. Accordingly along this path, or its vicinity, a series of key buildings and activities were located taking advantage of this increased accessibility to city flows. After the explosion of the city the city walls remained as a latent element, exerting nevertheless certain filter functions, manifested both in morphological as well as phenomenological aspects.

The analysis of the area tried to reach a better understanding of the current situation and functioning and dynamics of the area along the inner arch as well as of the western walls as a city membrane, utilizing this understanding as a base for rethinking /reimagining the overall functioning of the area, and set the base for possible proposals/ interventions. A transformation of the local mosaic should be thought out utilizing the inner arch as a central structuring and reprogrammable urban membrane / element (urban interface), aiming to restructure and reactivate the dense urban fabric on both sides of the city-walls , and at the same time establish continuities (corridor function) and connections of open and green spaces on different scales (eg. sea-mountain connection, trans-wall connections /connectors) and across both sides of the wall. This task can be achieved by connecting public and green spaces with the inner arch (serving as the structural spine) and with each other forming a network of public/open spaces for the area. The various existing and projected flows also need to be considered and managed accordingly to adjust the mobility factor to the updated conditions. Thus the objectives of a reprogrammation / restructuration of the ecotonal area should follow two principal axes:

- On a first level the inner arch can serve as a lineal ***structuring element*** that creates can create an ecological and civic corridor that connecting the city port with the Seich-Su forest, through the interconnection of existing and new green and public spaces. With a approximate length of 3.5 km (and an average width of 40-50m) the Inner Arch can contain and connect a considerable amount of green areas. The importance of these areas is even greater considering the high density of the adjacent areas and the low ratio of green areas per citizen. The connection of the corridor with the forest over the Ring Road Barrier is another question that still needs to be considered.
- On a second level the Inner Arch can serve as an element for the regeneration of the extended area by acting as the backbone of a wider ***network*** of green spaces. This network apart from the Seich-Su forest and the city walls corridor includes the rest of the patches of different sizes present in the fabric: ***i.*** the grove/forest of Sykies ***ii.*** existing parks ***iii.*** unoccupied lots with vegetation ***iv.*** interior patio of urban ***v.*** streetside vegetation (acting as connectors) and vi. interstice vegetation.

Putting in relation existing and new green spaces by inter-connecting them on a micro (*district*) and macro-scale (*sea-forest connection*) and interrelating the two scales are the two principle objectives of the restructuration. As far as hydrologic functioning is concerned the situation along the inner arch with the high densities and scarcity of large open areas creates unfavourable and complicated conditions for an integral restoration of the hydrologic scheme. Nevertheless in conjuction with the network of green and open areas in the area it can offer alternative ways to handle the water urban cycle and protect the area from unwanted situations (flooding, erosion etc). The pronounced geomorphology along the Inner Arch can provide many clues for its proper management.

As far as ***city structure*** is concerned, a reconfigured inner arch maintains and pronounces evenmore the radial urban structure that appears on the west extra-mural area. The emerging radial structure consists of 3 concentric corridors each one with distinct characteristics: ***i)*** The arch along the city walls of a principally pedestrian-public space character ***ii)*** The urban civic artery that runs along Riga Feraiou street that can host an increased intensity and diversity of activity in order reactivate the urban fabric ***iii)*** the avenue that runs along Andrea Papandreou and Eleftheriou Venizelou that can carry an important traffic flow towards the Ring Road node. Interconnections and inter-relations between the three can help to knit a even tighter and more coherent urban fabric. All three arches encourage the forest-sea connection while connecting important / key areas of the west Thessaloniki area. The updated situation along the interior arc as it emerges from the analysis and the restructuring proposal is presented in continuation. The individual parts/ elements that compose this reprogrammed city structure are the following:

- ***Inner Arch***. As seen earlier the western city-walls can be divided into four broad sections / parts: **i)** The Top-Hané enclave **ii)** The Thessaloniki section, that more or less follows the Hebrard Plan grid, **iii)** the Sykies section, that presents different typologies and densities as well as adjacency of the urban limit to the city walls, **iv)** the Akropolis section, a well defined area / enclave, with low residential densities,with the *Eptapyrgion* at

2. West Walls ecotone

Origin / Type		*Spatial Structure*	
type	tangible / manifested /	*stuctural element*	city-walls
	morpho / phenomeno -logical	*latent element*	" "
source	anthropogenic + consequential	*shape*	lineal - sinuating
creation force	NW city-walls + local streams	*extend / length*	3.9 km
time of creation	roman era	*thickness (min/max)*	0.03 - 0.4 km
character	historic / social / intramunicipal	*scale*	local
interest	social / restructuring	*grain size*	Hebrárd / west grid
		sharpness	sharp

Function		*Dynamics*		*Projectual Logics*
type	reflection + absorption	*state*	latent	reinstitute wall continuity
interaction	urban - urban	*control*	endogenous	integrate social infrastructures
	(historic centre + west Thess.)	*mobility*	bi-directional / transversal	reactivate obsolete fabrics
edge activity	cultural / social	*activity*	low / emerging	hightlight monumental character
character	historic / social	*situations*	intra-urban interaction /	enhance complexity
grade of artificiality	highly artificial		socio-economic shift / edge	facilitate intramunicipal inter-action
integrity	unbroken mostly		activity / latent fabrics	
		impact scale	local to municipal	

it eastern end and a key position with easy access to the Ring-Road. Focusing though on the Inner Arch as an urban element we can see the formation of sequences of different ambients that are created along its course, from the sea to the Seich-Su forest: **1.** Port Cultural Pier **2.** Connector **3.** Top Hané **4.** Vardaris node **5.** Thessaloniki walls **6.** Sykies Cultural Neighbourhood and city walls **7.** Vlatadon Monastery **8.** Acropolis **9.** Eptapyrgion **10.** Connector **11.** Agios Pavlos Sport Center where it reaches the Ring Road and continues to the Seich Su-forest.

- ***Pedestrian Axes***, make reference to transverse paths that facilitate trans-wall (and thus trans-municipal) connections, structuring and potentially generating significant urban activity along their course. At the same time they act as connectors / corridors and structuring elements for the creation of the local public/ green space network.

- ***Urban Arteries*** make reference to existing urban arteries that hold an important position as mobility corridors and could in a wider reconfiguration of the area scheme play an upgraded role, combining existing activities with introduction of new ones, and an overall improvement of public space amenities and accessibility. The radial structure arteries are one category while another one are the transverse arteries like Lagadas or Egnatia Avenue.

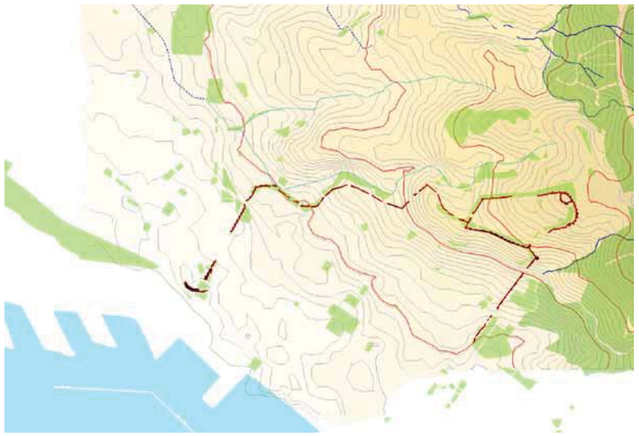
- ***Socio Cultural Fabric,*** refers to the rich fabric of archeological and cultural traces / elements present in vicinity to the city walls and ultimately related to their presence and historic function. The formation of a cultural network of spaces with the city walls acting as the reticulating element is another important and pending project.

- ***Public Spaces*** One of the main objectives of the restructuration of the Inner Arch should be to create a network of interconnected public and green spaces, forming thus a coherent and resilient urban / civic structure. The Inner Arch can serve as the central spine for interconnecting existing and new spaces on either side of the city-walls, enhancing connectivity and interaction.

- ***Voids / Latent spaces,*** areas present in the contemporary fabric and especially in vicinity to the Inner Arch, and are currently holding no use or are in a latent state. Given the importance of the area and the special occupancy terms that exist, these areas although small in size could play a key role in transforming and dynamizing the existing fabric introducing new and provisioned activities and increasing the attractability and activity along the Inner Arch.

The sum of these different elements hold the potential to reconfigure the socio-economic aspects of the Inner Arch and its overall reprogrammation as an effective urban interface, increasing efficiency along and near the key ecotonal area. Key to the efficiency issue is the management of ecological and social and flows. The analysis of the ecological layer (*biophysical matrix*) of the area and its correlation with the anthropogenic layer of the urban activity provides more insightful conclusions and highlights latent opportunities. The adjacent to the walls areas have experienced a rapid and uncontrolled edification that prohibits at an early stage a radical transformation of the existing fabric, but nevertheless its interpretation provides significant clues for basing / planning subsequent interventions.

Summarizing, the principle characteristic of the ecotonal area of the western walls is the socio-econonomic filter character and the implications that it holds, and the latent corridor function that it is presented with. It is interesting to observe the documented transformations along the western walls, while comparing them with the ones in the case of the Central Axis ecotone and the eastern walls, understanding that the western walls are an administrative limit between two municipalities, while in the case of the eastern walls the eastern walls are included within the municipality of Thessaloniki. Thus the different treatment in terms of planning and ordinances is an important factor when considering the distinct realities in the two cases. Accordingly when considering key strategies for a potential restructuration of the western walls ecotonal area these could be: ***i)*** the increase of connectivity along the axis, ***ii)*** pronounce the corridor aspect of the inner arch, ***iii)*** continue with the ongoing effort to liberate the city wall space and highlight the monumental character, ***iv)*** and on a parallel level knit together a dense and coherent network of public and green spaces aiming for a more efficient and resilient urban structure. All objectives require transmunicipal cooperation and coordination and thus any effort would depend greatly on the efficiency of the governance factor implicated in the process.

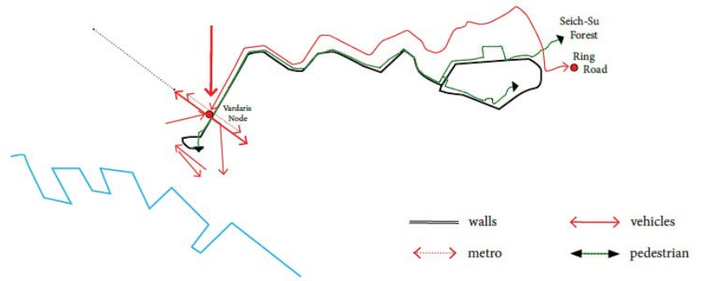


Local geomorphology and hydrology

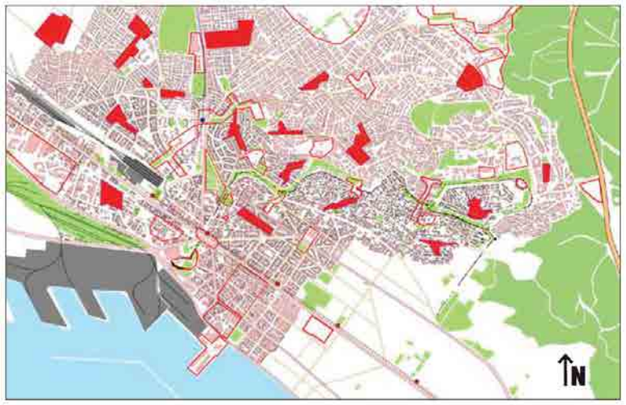
The original local streams superimposed on the contemporary urban fabric

Activity Assessement

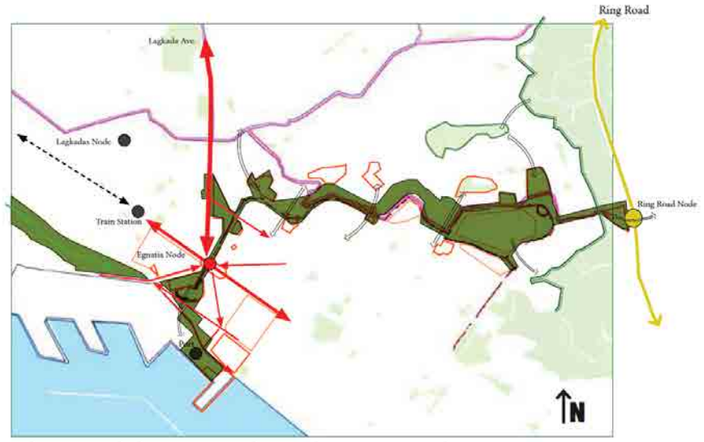
Functional Analysis



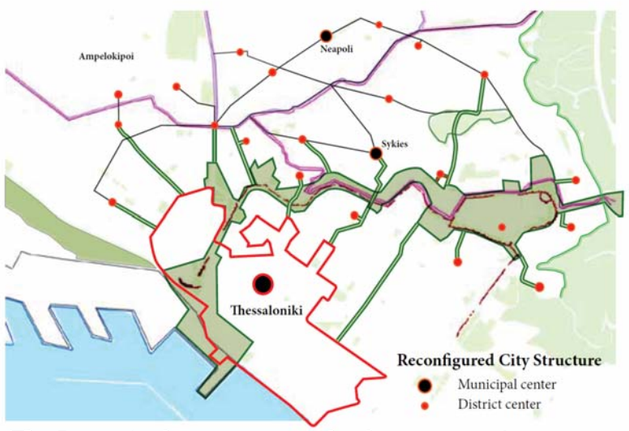
The Western Walls as an Urban Corridor



Present and latent urban activity

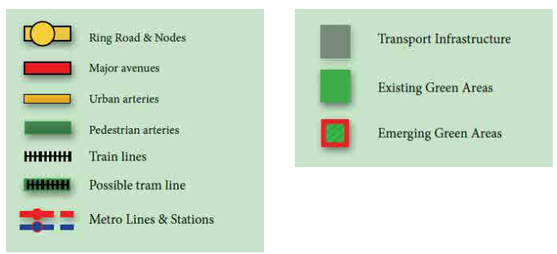


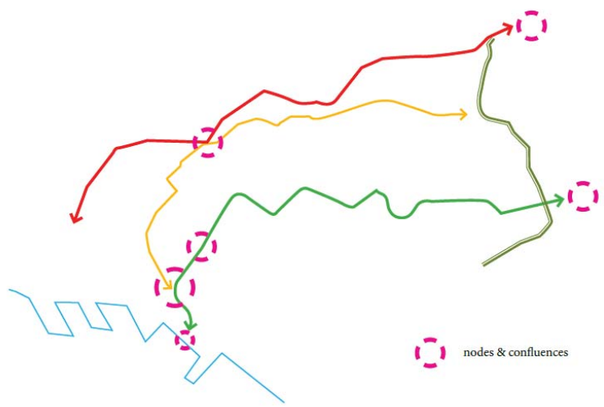
Flows and dynamics along the inner arch



The Inner Arch as a green and urban structuring element.

The re-structured mosaic - *The Inner Arch as a vibrant membrane*

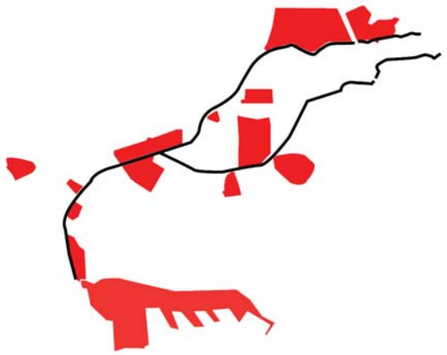




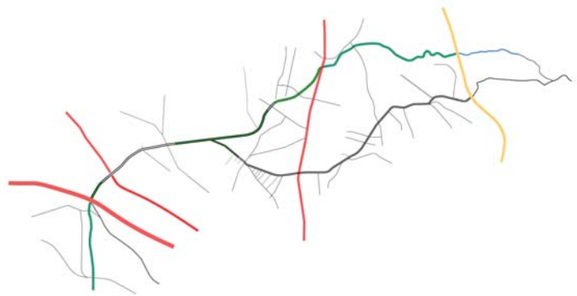
Radial Structure and the Inner Arch

3. The West Arc (exterior Arc) - *the latent structure of west Thessaloniki.* *(p.172 - 239 in Book II)*

big areas



transverse flows



The third ecotonal area under investigation is the West Arc, formed along the course of the earlier *Dendropotamos* stream, now substituted by an avenue that goes by the same name. Having passed through different succession phases, from a natural environment to an urban limit, to an intra-urban limit, the ecotonal area still contains to different extends remnants of the different phases. The analysis of the area aimed to synthesize the distinct and heterogeneous fragments in order to formulate a detailed lecture, an impression, of the present and latent complexity in the regional mosaic of west Thessaloniki. Meanwhile the analysis recognizes the need to correlate and interpret any results in conjunction with the results of the analysis of the interior arc to produce a complete and more precise impression of the extended western area, and of a potential scheme of reconfiguration that could emerge from the present and latent conditions within the fabric. Main objective of this synthesis is to highlight the position and function of the exterior (in relation and conjunction with the inner arc) in the contemporary fabric in a multi-scalar way, searching to detect the true regional potential of this key urban element.

The macro urban structure of the west arc is articulated, on a first level, by the principal *hard* infrastructures that span a great part of its territory and condition the urban structure & function. This structure can be divided into two basic categories, based on the directional and formal nature of these elements; ***i)*** the transverse axes that stem from the historic centre, (Vardaris Square), and provide a transverse connection with the peri-urban and exterior area of the urban region, and ***ii)*** the radial elements and the corresponding radial urban structure that is formed by the series of co-centrical arcs that appear on the western parts of the city. These two systems seem to coexist on the territory, superimposed on each other both in spatial and functional terms. The form of this radial structure is to a great extend a result of the local geomorphology and the course of the preexisting local streams. The Dendropotamos river that corresponds to the actual course of the exterior arc, was with the course of time covered up, proclaiming flood protection and hygiene reasons for the intervention. The subsequent drainage and hydrological works that took place converted and covered the majority of the water courses to give ground and form to the posterior urban arcs.

The updated role of the exterior arc in the wider city structure as it emerges from the analysis demonstrates a relation of the double arc (exterior arc & interior arc) with the rest of the radial city structure (connections / relations) and transverse axes (nodes / synergies). The prospect of the addition to the public transport network of the subway metro system, in the immediate future, creates additional points of considerations and a potentially more complex and rich structure & fabric to consider. Along with additional puntual interventions and transformation this gives form to an emerging latent structure of great potential.

Accordingly, the potential restoration of the ecological layer of the area needs to be considered, on a diversity of scales. The analysis of the ecological layer of the area, demonstrated the predominant role that the aquatic element had in the past, and the mark / influence that it has left on the contemporary regional and urban fabric. The exterior arc as an urban structural element can serve a key role in integrating diverse activities over a considerable length through the western urban fabric. At the same time, from an ecological perspective it can also form an important lineal green element for connecting / docking existing green spaces, generating new ones and ultimately restoring the sea-forest connection. The local streams in the contemporary fabric are found in a compromised condition and under a constant pressure from conflicting uses along and inside their course. Inside the limits of the interior Ring-Road the streams start to disappear but their course can still be discerned by the superficial green patches and corridors that form along their past course; while in the peri-urban zone, the streams are found in a varied state, from natural, semi-natural or endangered state. Nevertheless as stated, the hydrological memory of the terrain is still discernible. and can serve as the basic grid for structuring a regional green system. Along the exterior arc and the extended western area a series of interventions have been planned for by the flood protection master plan of 2009, with regards to water management and flood protection issues.

The flood protection plan specifically and the hydrological management in more general terms, are key themes with regards both to the ecological and the urban functioning of the local and regional landscape. The addition and reintegration of new and existing green and blue areas, should also contemplate the possibility of the utilization of natural restorative and conservation techniques as well as possibilities for storage and reutilization. Individual consideration / analysis of each stream can reveal in more detail the real potential for restoration and healing of the local hydrological circle on a local and wider scale. Nevertheless the streams´ courses acting as green corridors in combination with the existing and new green patches allows for the consideration of a network of green and open areas for the western Thessaloniki area, with a considerable potential positive effect on efficiency with regards to the hydrological functioning. Certain characteristics need to be taken in consideration when recomposing the ecological structure, based on the existing and potentially recovered green areas. The principle objectives of the proposed structure should be:

3. West Arc ecotone

Origin / Type		*Spatial Structure*	
type	tangible / manifested / morpho / phenomeno -logical	*stuctural element*	Dendropotamos avenue
		latent element	Dendropotamos stream
source	anthropogenic + causal	*shape*	lineal - sinuating
creation force	drainage / mobility infrastructure	*extend / length*	7.3 km
time of creation	roman era	*thickness (min/max)*	0.05 - 0.7 km
character	historic / social / corridor	*scale*	local / regional
interest	social / restructuring / mobility	*grain size*	west grid
		sharpness	diffuse

Function		*Dynamics*		*Projectual Logics*
type	amplification + transformation	*state*	latent / emerging	reinstitute ecological integrity
interaction	urban - urban	*control*	exogenous	Restore continuities
	(west Thessaloniki fabrics)	*mobility*	bi-directional / transversal	integrate social /mobility infra-structures
edge activity	cultural / social / mobility	*activity*	high / emerging	reactivate obsolete fabrics
character	historic / social	*situations*	intra-urban interaction / socio-economic shift / corridor activ-ity / latent & obsolete fabrics	hightlight industrial heritage
	emerging cent			enhance complexity
grade of artificiality	mostly artificial			facilitate intramunicipal interaction
integrity	unbroken mostly	*impact scale*	regional to metropolitan	

1. ***to establish continuity along the green corridors / connectors***, resolving any conflicts along the course, and providing possibilities for urban regeneration and overall upgrade. Continuity, needs to be fulfilled in diverse aspects: first, by establishing the primordial sea-forest connection through the establishment of a principal key green corridor along the course of the exterior arch; and secondly in guaranteeing continuity for secondary axes connected to the exterior Arch, while at the same time resolving conflicts and taking advantage of latent and emerging potentials in the area.

2. ***increase inter-connectivity between the green patches and corridors.*** The composition of the spatial scheme of the ecological structure / system is based on a respective patch-corridor-matrix composition that guarantees the considerations expressed earlier. In this structure, the axis of the Dendropotamos river and its respective vegetation, appear having a protagonistic role, attributed to a great extend to the local hydrological hierarchy. Connecting to this core artery are the branches of Xiropotamos, the branch of Polichni, the branch of Oreokastro, and the branch of Evosmos-Kordelio. The principal and larger patches are primarily found in the areas of the old military installations. These areas that already host important patches of vegetation, with their re-entry and reintegration of their surface to the urban fabric, can provide an additional 243.7 hectares of potential green areas. The peri-urban green is another key issue, since it is located on critical urban interface zones and at the same time is testimony of the underlying biophysical matrix.

3. ***pronounce the corridor aspect of the exterior arc as a key element of the urban structure.*** The exterior arc acting as a structural spine for the west urban Thessaloniki can host new uses and activities and rejuvenate the entire local urban fabric of West Thessaloniki. The integration aspect also refers to the integration of flows and modes of mobility in the western area. Apart from the provisioned metro lines, the proposal contemplates a light rail system crossing a considerable part of the arc, as proposed in the original 1997 competition and envisioning transport oriented development options along its course.

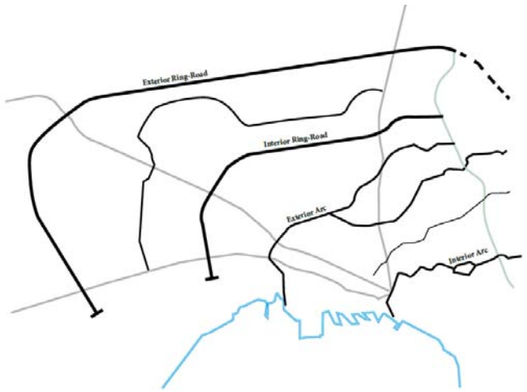
4. ***achieve a maximum diffusion over the regional fabric*** increasing accessibility and regional resilience. The mobility / accessibility factor, is considered by connecting existing and emerging key areas of the urban fabric through public transportation and multinodal stations combining hard and soft mobility flows. The question of accessibility of public spaces and services is another vital question that can be satisfied only through the establishment of an interconnected and coherent open space network interrelating open spaces and areas of activities through a system of vibrant urban corridors / arteries.

5. ***harness the potential of existing and emerging complexity.*** The area of influence of the west arc covers a great extension, in which a multiplicity of patterns, territorial situations and dynamics take place. At the same time it contains a diversity of typologies and related range of activities, as well a plethora of latent or vacant spaces. The proper management of flows and the establishment of an efficient urban network can help to highlight and facilitate the emergence of the eco-socio-cultural wealth present and latent in the contemporary fabric.

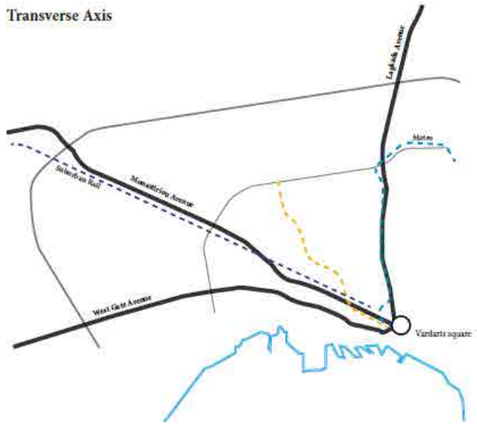
Summarizing, a proper restructuration and management of the sum of the areas that comprise the ecotonal area of the wet arc, should aim to uphold urban sprawl expansion by condensing urban activity while at the same time increasing urban - natural interaction, through the establishment of a regional ecological network as well as a careful work with ecotones of different scales present within the area. As a general rule, it should maintain the radial structure formed by the two arcs (interior and exterior, the ring road structure and smaller axes) reinforcing it with transverse connections that interconnect the local urban and ecological systems, resulting in a richer, more complex and resilient fabric. Resilience in this particular case, also has strong socio-economical implications and considerations given the present situation and conditions in the area. Although an isotropy in morphological/typological terms would be undesired, the contrary could be send in terms of diffusion of habitability standards, employment, mobility, knowledge access etc; questions with direct social connotations.

Activity patterns

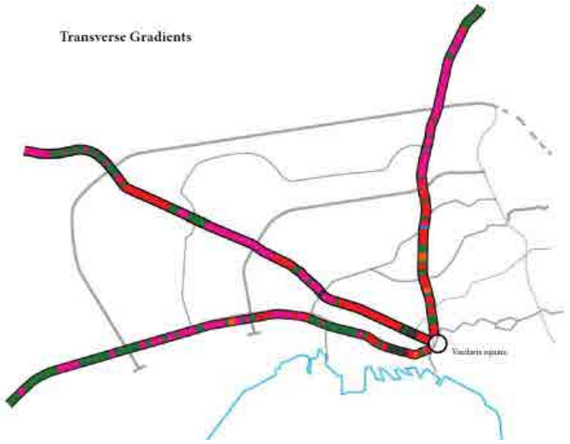
Radial structures



Transverse Axis



Transverse Gradients



Emerging Mosaic & Structure

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- Green Areas
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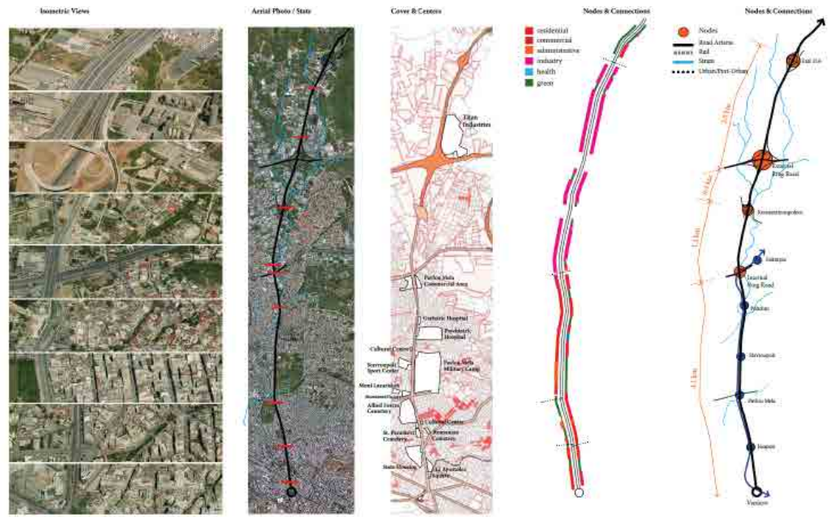
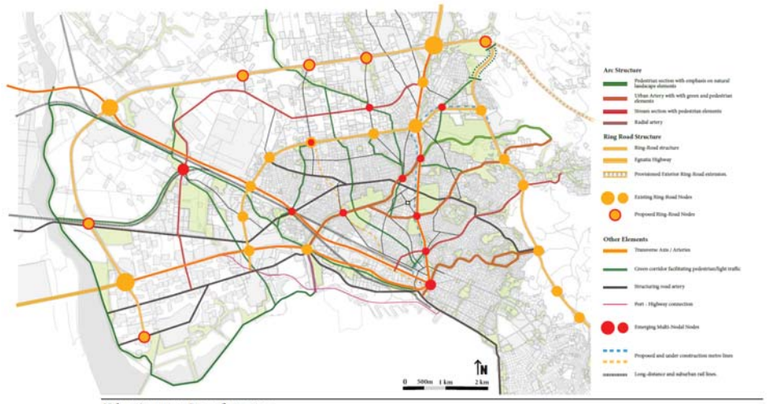
Transverse axes analysis

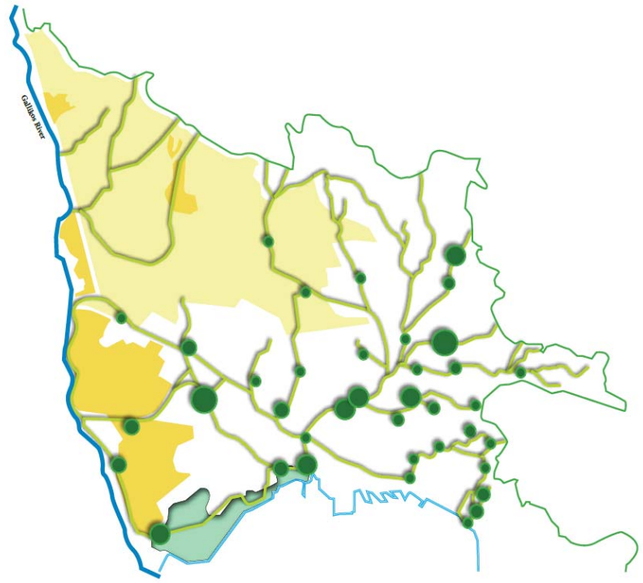


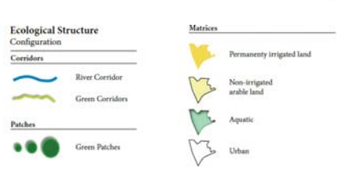
Ecological structure

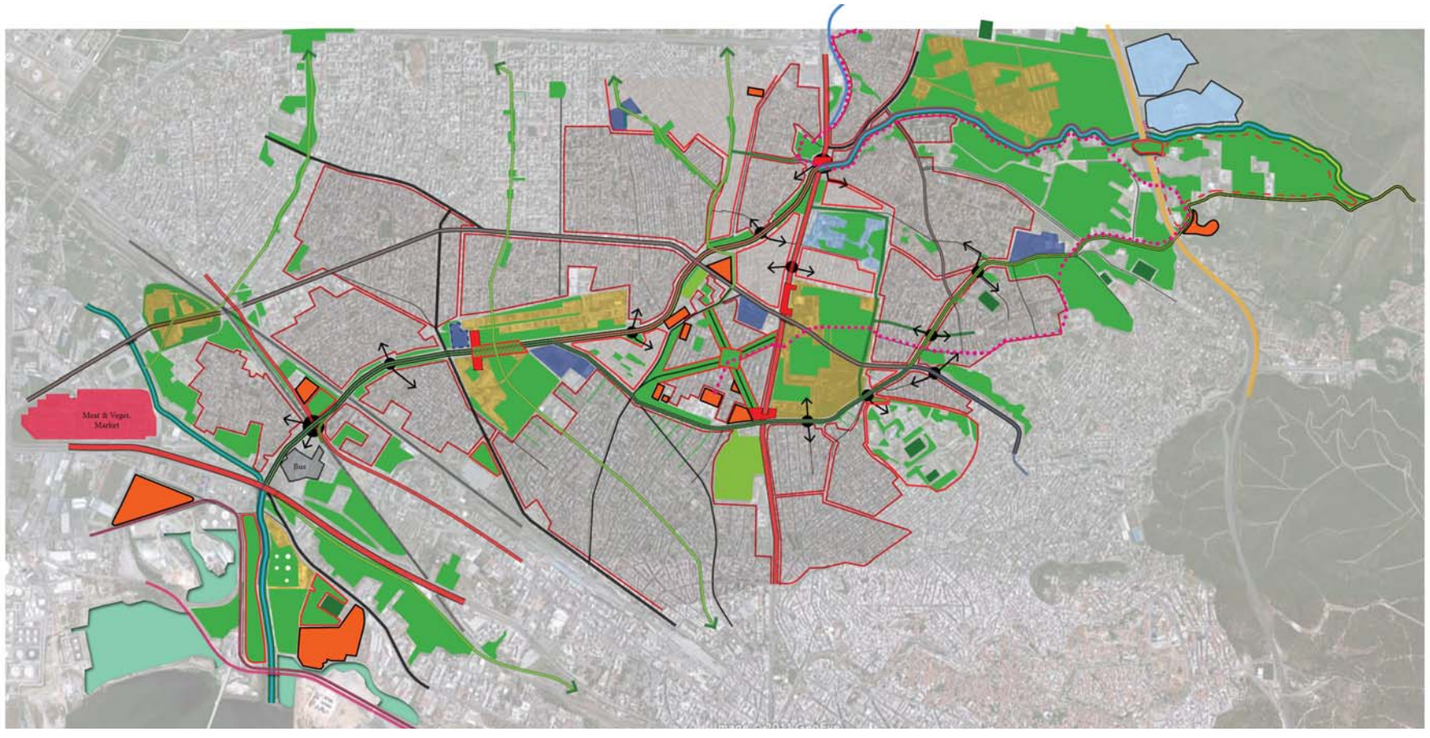


Urban Structure Reconfiguration
Synergies and continuities

Mosaic of West Thessaloniki -
Spatial Distribution and configuration.

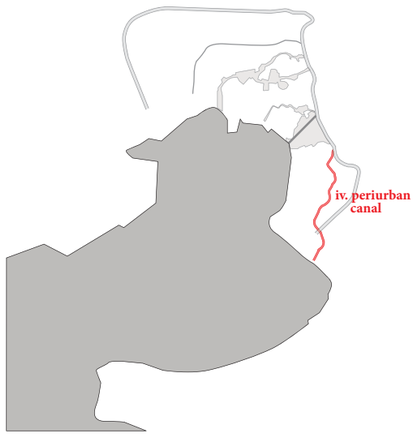


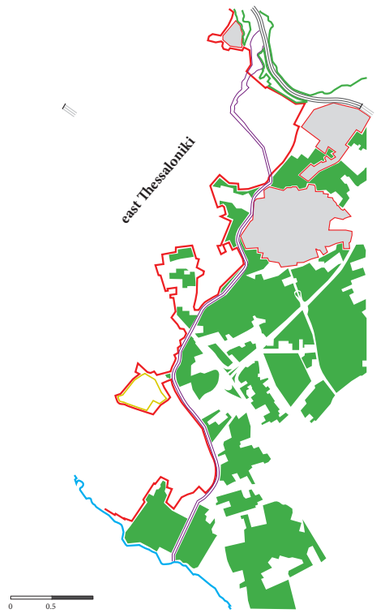


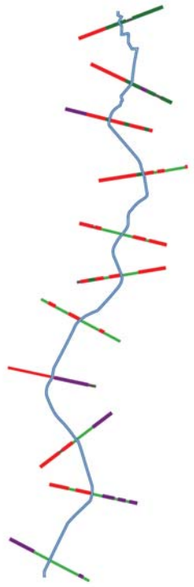


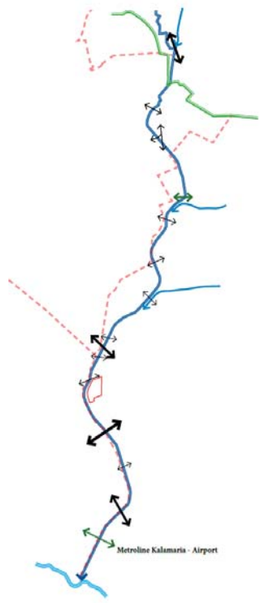
The re-structured mosaic - *A reprogrammed exterior Arch*

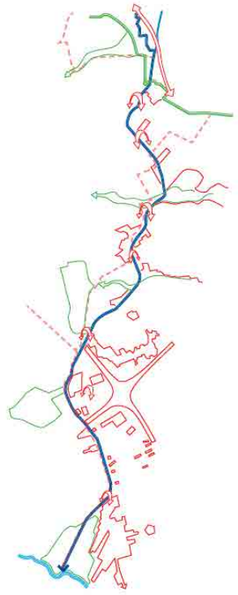
4. Peri urban canal - *An urban spine for the entire East Thessaloniki* *(p.240 - 289 in Book II)*











The fourth ecotonal area under analysis is the south-eastern city-limit with its respective peri-urban space, formed along the peri-urban canal a flood protection infrastructure built in the 50s, connecting the Seich-Su forest with the Mikra area seafront, while draining all regional streams of East Thessaloniki. The analysis / lecture of the local mosaic aimed at a better understanding of the current situation and functioning of the area of East Thessaloniki, with the peri-urban canal in mind as a structural element, understanding its potential for serving as a base for rethinking / reimagining the overall functioning of the area. A transformation of the local mosaic re-thought utilizing the regional canal as a structuring element, aiming to restructure and rejuvenate the dense urban fabric on one hand, and at the same time establish a sea-mountain connection, managing adequately the diverse flows, activities and dynamics present in the area. An emerging regional mosaic and city structure comes out though the analysis, whose individual parts/elements are described in continuation:

The ***Regional canal*** emerges as a key regional element and an important urban planning tool for reactivating the fragmented local landscape and at the same time provide / generate vital open public spaces for local residents. The question of continuity and consequently mobility is the most important that needs to considered and resolved whereas conflicts and barriers arise. The regional canal disembogues into the Thermaikos bay in the vicinity of the Mikra area. It originates northward all the way by the Ring road crossing a stretch of almost eight kilometres. Thus in terms of continuity, it is convenient to think of the regional canal as one continuous element. At the same time, the ecotonal area of the canal acts as an urban limit, holding respective filter functions. A series of diverse activities, intrinsic to this area, have appeared over the years along the canal, taking advantage of its once limit function and the relative availability of space. In terms of flood protection, the canal as an infrastructure maintains its function, draining the majority of the streams of East Thessaloniki, although overdimensioned. As a urban open space it is currently not fully accessible. After an initial observation and for this paper´s purposes the canal can be divided respectively into two distinct parts based on the distinct prevailing conditions in each area:

Lower part : corresponds to the section from the seafront in Mikra to the height of Meg. Alexandrou / Vergina street in Pylaia, a section that has traditionally served as an urban limit for the city of Thessaloniki. On the exterior side it borders with the Pyléa Development and Leisure area developed over the periurban agricultural area of Pylea. Given the situation and characteristics of this section it can potentially serve the role of a urban/peri-urban interface, controlling and monitoring urban growth and activity across its path. Certain points of centrality and potentially key public space value emerge along its path. Additional attention should be applied to the edge zones / interstices created between the canal and the urban fabric as well as points of conflict with the principal road arteries. The eventual construction of the metro line will provide the axis with increased accessibility in this lower section. The key objective in this section is to achieve the desired continuity along this section, succeed in relating the canal with its surrounding context (public & green spaces) and provide conditions that can attract public activity and flows, facilitating accessibility and an increased mobility. At the same time control the limits of urban expansion on one side and diffused non-residential activity on the other.

Upper part : corresponds to the section from Meg.Alexandrou street and all the way up to the Ring-Road at the node of Triandria and presents a distinct character from the previous section crossing a completely different context of a dense urban residential character. The more important issue here is the question of accessibility to the green/public areas and the introduction of new green spaces where possible or necessary within the dense urban fabric, facilitating with their interconnection the creation of a coherent green network. The proximity of the canal to a dense urban fabric ensures sufficient flows and activity that needs to be facilitated by addition of soft flows, access points and vibrant public spaces. The regional canal for this upper part takes the function of an urban ecotone, with certain socio-economic characteristics.

Although the regional canal on its own, with an 8.3km length holds an important structural weight, it is not sufficient to structure adequately the east Thessaloniki area in its entirety. Nevertheless, as it emerges through the

4. Peri-urban canal ecotone

Origin / Type		*Spatial Structure*	
type	tangible / manifested / morphological	*stuctural element*	peri-urban canal
		latent element	canal & local streams
source	anthropogenic + consequential	*shape*	lineal - sinuating
creation force	drainage / flood protection infrastructure	*extend / length*	7.7 km
		thickness (min/max)	0.5 - 1.6 km
time of creation	1950s	*scale*	local / regional
character	barrier / corridor /	*grain size*	east urban grid / peri-urban parcels
interest	eco-social / restructuring / soft mobility	*sharpness*	diffuse

Function		*Dynamics*		*Projectual Logics*
type	absorption + reflection + transformation	*state*	latent / emerging	reinstitute canal continuity
		control	exogenous & endogenous	integrate social infrastructures
interaction	urban - peri urban	*mobility*	bi-directional / transversal	reactivate obsolete fabrics
edge activity	residential / social / mobility	*activity*	high / emerging	enhance complexity
character	historic / social	*situations*	intra-urban interaction / socio-economic shift / edge activity / latent fabrics	facilitate intramunicipal interction
grade of artificiality	mostly artificial			hightlight natural / ecological character
integrity	unbroken mostly			
		impact scale	regional to metropolitan	

analysis the regional canal as an existing regional element can serve as the backbone for the further restructuring and reticulation of the green structure along this part of the urban fabric. If one considers the addition of the old local streams as new reformed green areas, lineal elements branching off in different points along the canal, then the real potential of a wider restructuring is made more evident. The regional canal apart from serving its primary function of flood protection at the same time it can be upgraded to the status of as a major green axis that opts to change drastically the existing urban fabric. In continuation the possibilities for restoration along the old stream paths be analysed in more detail to detect additional possibilities for intervention along their path and points of connection / interaction or other important elements and situations:

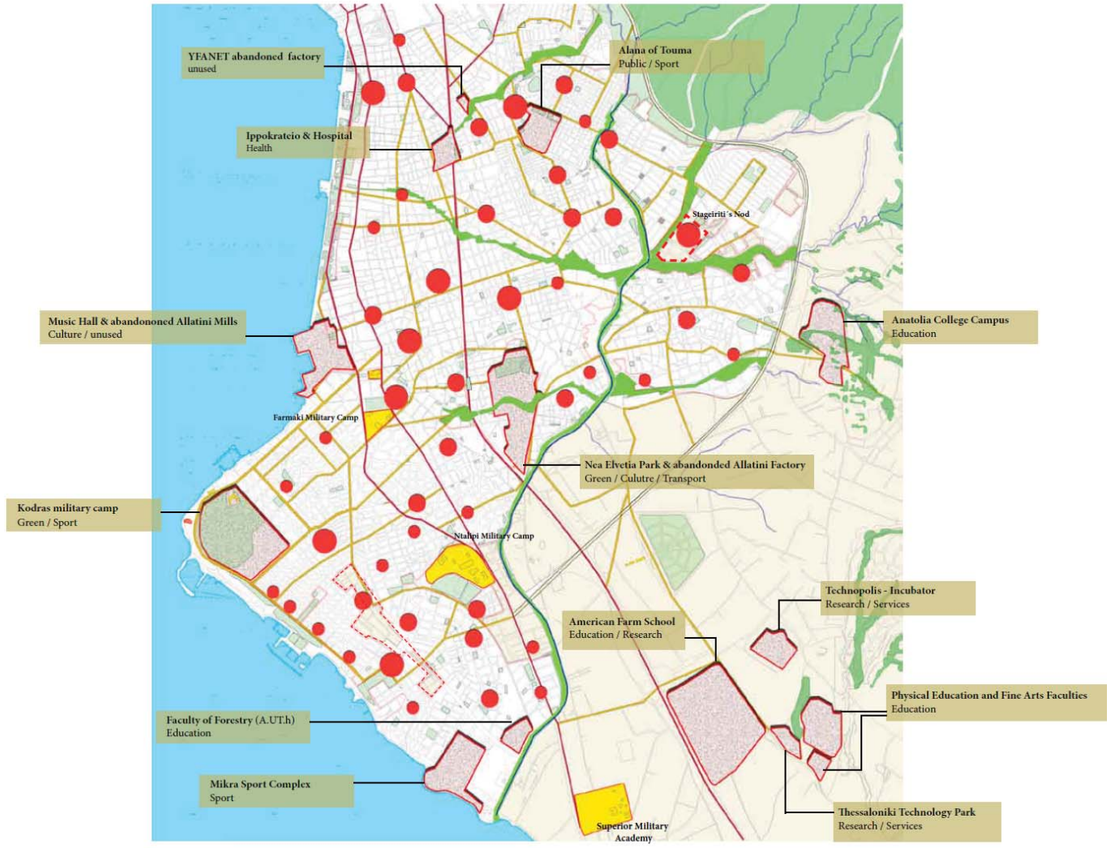
- ***Konstantinidi Stream***. The Konstantinidi stream-path is still discernible from the Ring Road all the way to the Ippokrateio hospital. Inside the path stream one encounters diverse activities authorized and unauthorized: informal settlements, sport & educational facilities, etc. The Ippokrateio hospital complex can serve as a green patch, given the availability of potential green spaces and its connection with the streams could have benefits both for hospital as well as urban users. The stream presents considerable vegetation along its contemporary path, and thus an ecological continuity / corridor can be established along.

- ***Kivernion / Big Stream.*** The Big stream was the most prevalent of all the local streams in the area. Currently the stream can be divided in two sections; the part on the upside of the regional canal, with the Eleorema and the Stageiriti tributary streams still open and in a semi-natural state; and the one on the downside, crossing a dense urban fabric and being restrained in smaller widths throughout its course. Nevertheless, the stream crosses an important stretch and reaches the seafront at the height of the Folk museum and the Goethe Institute, lined with green areas for the most part of its length. Continuity along the path is feasible, with the possibility of forming a green corridor connecting the seafront with the peri-urban and the forest area.

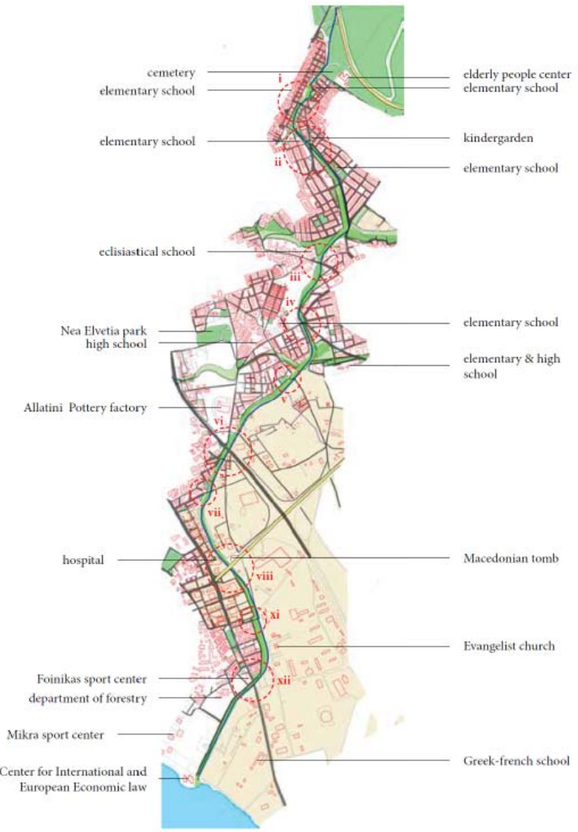
- ***Ntepo Stream.*** The trace of the third stream is harder to follow through the urban fabric but with careful observation smaller patches do appear and a cognitive continuity can be discerned, composing a considerable corridor extending from the inner Ring Road all the way to the Ntepo district in the area of the former Farmaki military camp. As mentioned the continuity along this corridor is harder to achieve but is of equal importance with the formentioned streams , since it helps structure public space in newly built peripheral areas and provides additional access to the regional canal and the sea-periphery axis. While the hydrological restoration and preservation can only be applied to the currently existing unaffected area, as well as in part of the Nea Egnatia park.

In conclusion it can be affirmed that the reutilization/recycling of the old stream-paths offer a viable way to create accesibe green spaces, that given their lineal nature can serve as ecological corridors and key regional structuring elements at the same time. Complementary to the effect to be generated by the intervention along the Regional canal, the stream paths emerge as side alternatives for re-sawing the local fabric, eliminating the effect of present fragmentations of the current mosaic and structuring in conjunction with the regional canal an extensive network of public/green spaces for the East Thessaloniki area. Apart, given the local conditions this new structure could improve significantly the accessibility as well as the mobility issue especially for pedestrian and non-motorized vehicles. In addition to the regional canal and surrounding areas, the further inclusion of the stream paths could add 8.9 km of lineal open/public/green space. This project would then aim in: **i)** taking advantage of the stream paths that today are presented in various states but still hold a potential for regeneration; **ii)** establishing a sea-mountain connection both for ecological restoration as well for citizen mobility; **iii)** establishing a urban-periurban *protocol*, identifying limits, then edges, interstices and areas of intervention. If we are to take under consideration the green areas, existing and proposed, an updated structure emerges, this time a more extensive and integrative structure that creates numerous opportunities for intervention on the urban fabric. This restructuration can lead towards a significant ecological restoration of the local landscape and at the same time a drastic improvement of habitability-activity-mobility indicators.

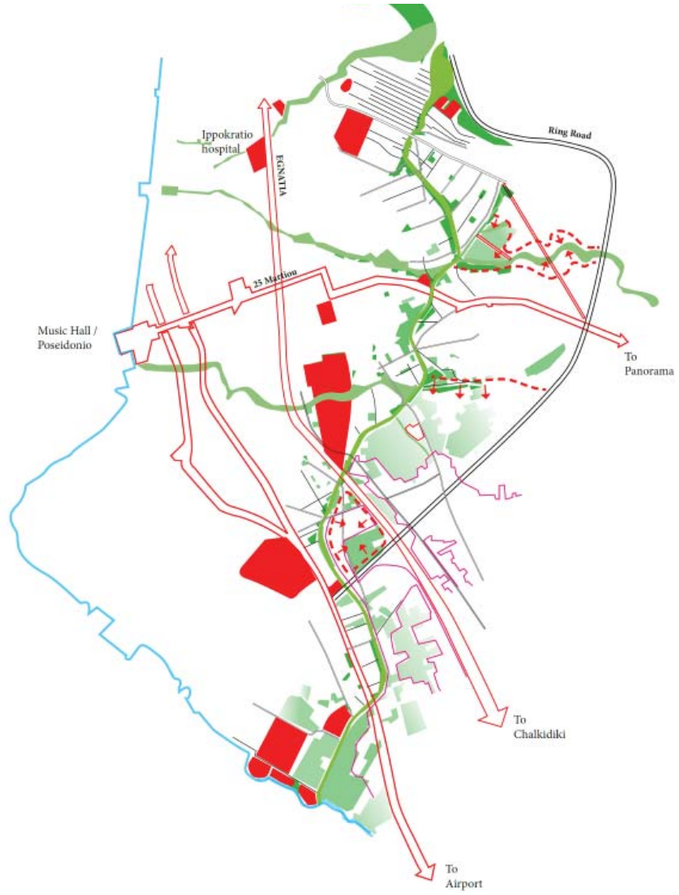
Urban context

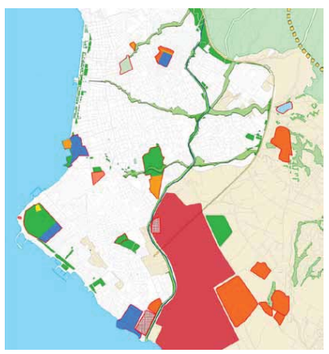


Edge Activity



Emerging Mosaic & Structure



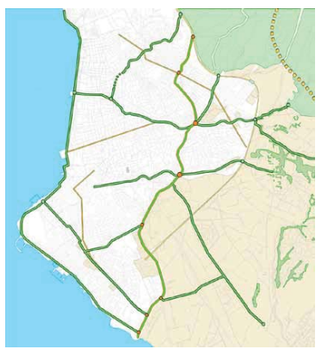


environments

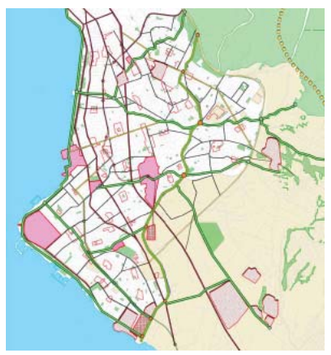
centralities

activity

mobility

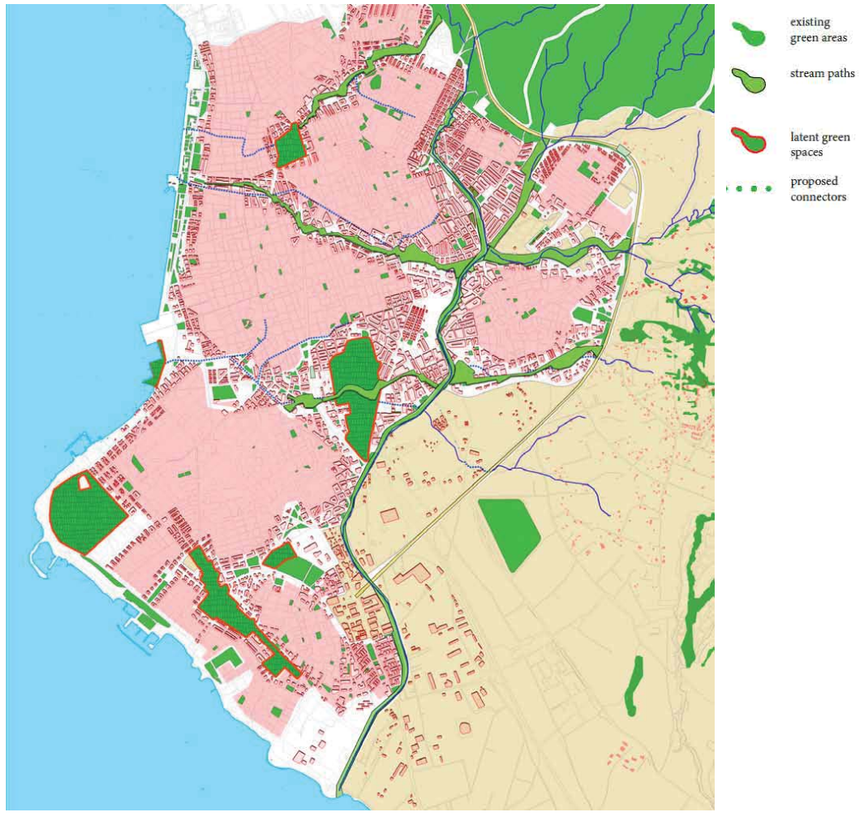


ecological structure

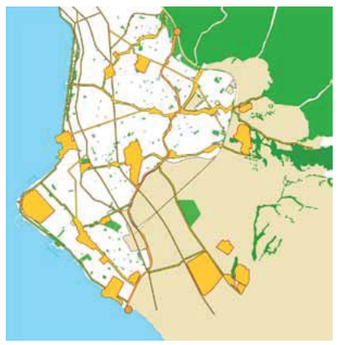


urban structure

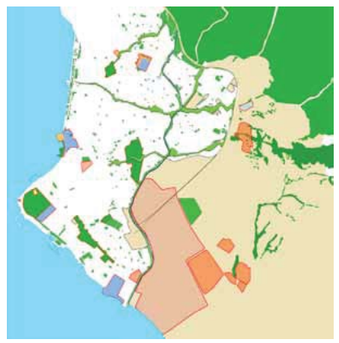
The re-structured mosaic - *The Ring Road structure as a peri-urban interface*



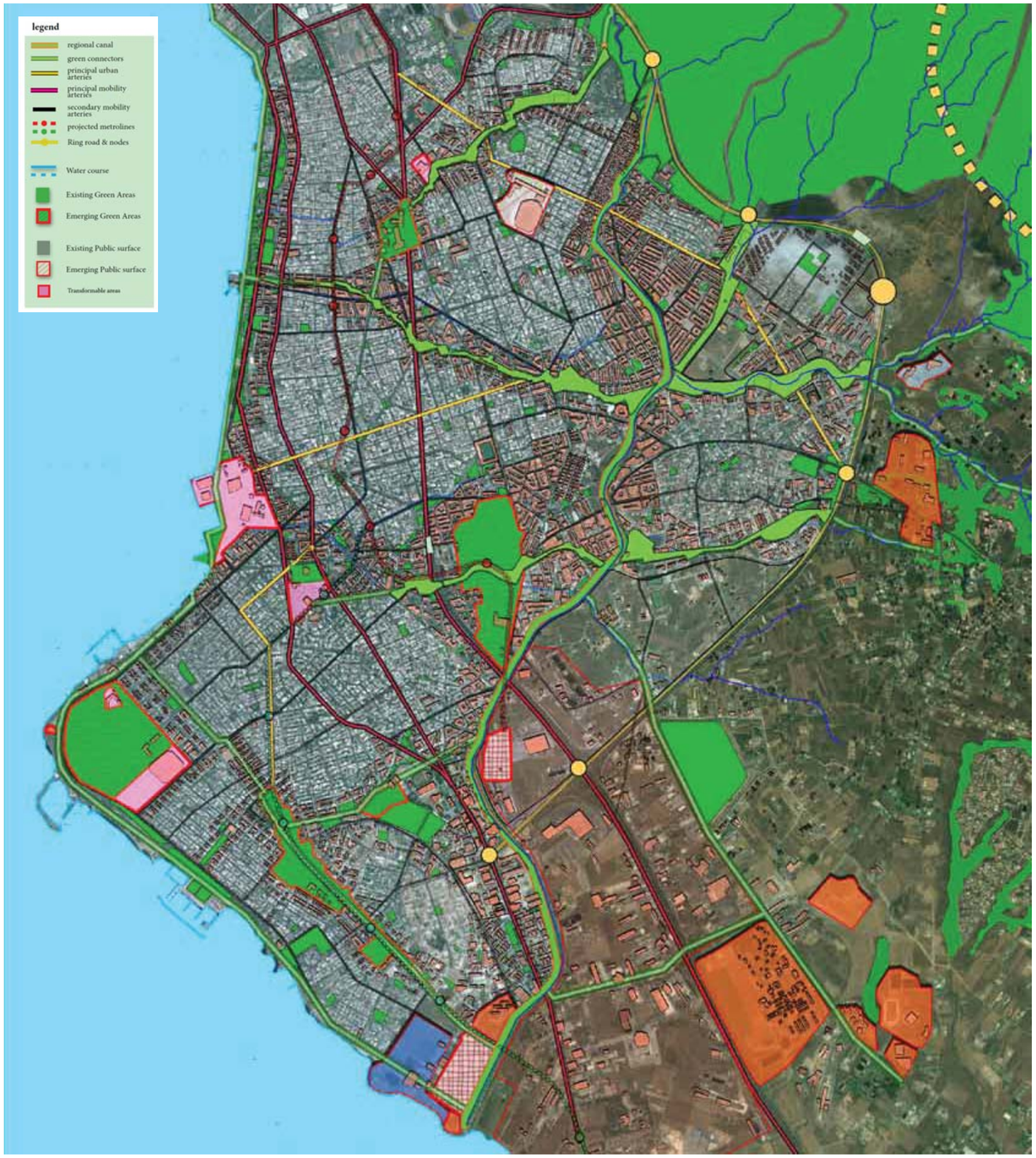
The emerging urban green structure



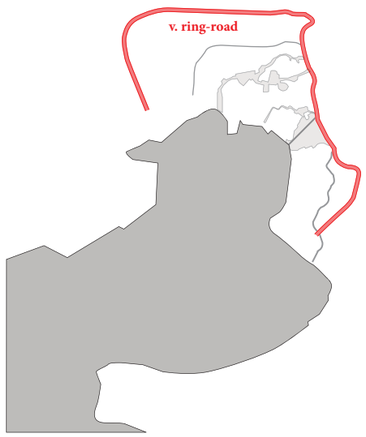
emerging structure

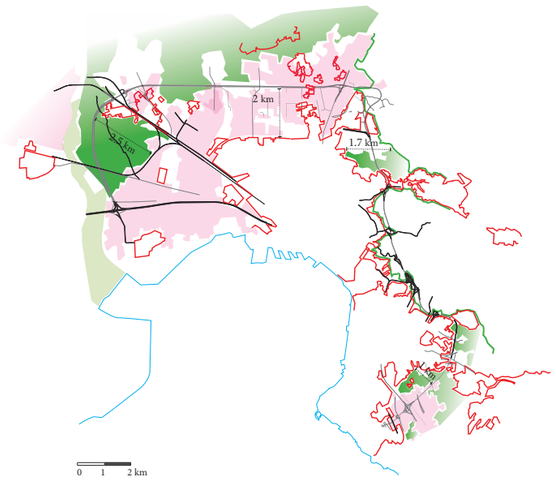


zones of activity

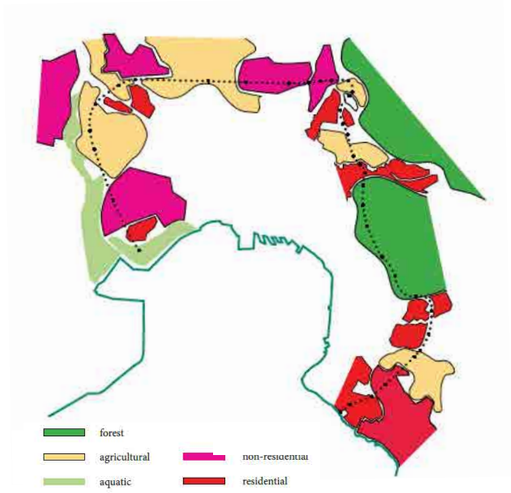


5. Ring-Road - *the contemporaneity of a limit* *(p.290 - 321 in Book II)*

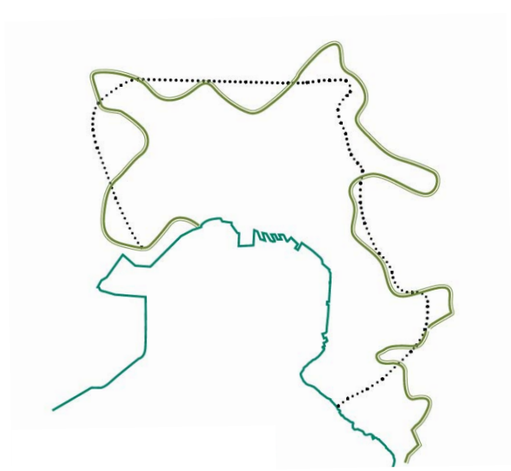




environments



urban-natural contact



The fifth ecotonal area under analysis is the limit that emerged after the construction of the Ring-road mobility structure (περιφερειακός) of Thessaloniki in the span of the last two decades. Currently it serves as a contemporary limit of city expansion and respectively holds diverse barrier functions. The analysis of the individual sections, and their subsequent synthesis produced a general impression of the conditions, situations and dynamics formulated along the Ring Road structure. The chosen analysis structure consists of the constructed section of the West Outer Ring as well as the Inner Road in its entirety. A series of initial and general conclusions can be made as they emerge out of the analysis, before entering in more specific question / issues:

1. The Ring Road is a key mobility infrastructure that crosses the Thessaloniki peri-urban area without providing a corresponding adequate urban structure / organization along its course.
2. The Ring road structure provides convenient access to urban fabrics for the Inner Ring, while the Outer Ring is characterised by long distanced access nodes, bypassing key points.
3. The non-residential activity that has developed gradually along the adjacent to the Ring Road spaces adapted for the most part an improvised and informal character with the exception of few nodes that have developed poles activity around their area.
4. Part of the Inner Ring Road runs through or in close distance to the Seich-Su forest forming a pronounced urban-natural ecotone, creating a barrier effect and a respective fragmentation of the forest areas.

Edge Activity / Big areas along the limit

The Ring road structure has served as a major activity attractor element in the Thessaloniki urban region. The availability of unoccupied space in the peri-urban area gave rise to the appearance of big-sized areas even before the construction of the Ring Road. Such examples are the industrial areas on the west peri-urban area like the EKO refinery, the Sindos Industrial area or the Titan cement factory; or the respective areas on the eastern peri-urban areas off a different character, such the Anatolia Campus, the American Farm School, the Military Academy or the various retail stores; all began appearing along exit highways / axes of the city. The construction of the inner-road at a first stage, attracted new activity of diverse character; retail / commercial, leisure , sport and health related areas of variable size as well as degree of connectivity/accessibility to the ring road. These activities have developed certain characteristics of clusterization, creating distinctive ambients along its course; the industrial / manufacturing character of the west section of the ring and the retail/leisure character of the east section. The middle section given the proximity to the forest areas as well as the dense urban fabric has allowed for the development of smaller areas, that seek the easy access to the ring road. The construction of the western Outer Ring as part of the Egnatia Highway has reinforced the peri-urban sprawl effect but without providing an adequate structure for the adjacent space along its course. Considering the contemporary conditions and activities along the Ring Road theres an urgent need to think of possible ways to structure and monitor development of the peri-urban space and to reprogramme the Ring Road structure so it can act as an efficient urban interface, with its course acting as a dynamic and vibrant corridor and at the same time a city membrane, reprogramming the current urban - periurban (natural) ecotone.

Permeability & Connectivity

The question of the Ring Road as a barrier presents a certain amount of complexity and is of particular interest in this ecotone analysis. The analysis structure chosen highlighted the differences between the inner and outer ring, in terms of manifested heterogeneity. The inner Ring-Road running in a closer proximity to the urban fabric presents a greater permeability for transverse flows (streams as well as transverse mobility flows) as well as an increased accessibility to adjacent urban fabrics. On the contrary the Outer Ring Road (western), being part of the Egnatia Highway, follows different standards and thus demonstrates different technical characteristics. Permeability of the outer Ring is limited and variable, a situation that creates disconnections along its course especially for preexisting mobility paths, and natural ecological corridors such as streams. The cut and cover tunnel of Konstantinopolitika is an example for achieving the continuity effect and one that could serve as an example to be repeated accordingly.

Limits & Ecotones

Through the analysis it was shown how the Ring-Road is located in the interstice of key territorial ecotones, anthropogenic & natural. On the west side (first analysis section) the highway is running along and in the vicinity of a key territorial ecotone, between the western agricultural plains and the urban fabric, consisting both of residential and non-residential activities, with a major presence of industrial activities. In its westernmost part, it runs parallel to the Gallikos river. The second section is running along a different type of ecotone, but also of key

5. The Ring-road ecotone

Origin / Type		*Spatial Structure*	
type	tangible / manifested / morphological	*stuctural element*	Ring-road infrastructure
		latent element	local continuities
source	anthropogenic + causal	*shape*	radial
creation force	mobility infrastructure	*extend / length*	32 km
time of creation	1990s - today	*thickness (min/max)*	0.05 - ? km
character	barrier / corridor	*scale*	metropolitan / regional
interest	mobility / restructuring / city limit	*grain size*	peri - urban grid & parcels
		sharpness	diffuse

Function		*Dynamics*		*Projectual Logics*
type	absorption + reflection + transformation + amplification	*state*	active / expanding	restore continuities (social / ecological)
		control	exogenous & endogenous	integrate mobility infrastructures
interaction	peri urban - rural	*mobility*	edge & bi-directional	reactivate obsolete fabrics
edge activity	residential / secondary & tertiary	*activity*	high / increasing	limit urban sprawl
character	mobility / limit	*situations*	peri-urban & rural interaction / morphological shift / ecological	enhance complexity
grade of artificiality	partly artificialized			work with the city-limit
integrity	unbroken mostly		discontinuities / latent fabrics	facilitate intramunicipal interaction
		impact scale	metropolitan to territorial	ecological integration

importance, the urban-forest ecotone. This ecotone has been growing in length with the expansion of the city and its approach and pressure on the adjacent mountainous forest mass has created a thin but pronounced ecotone of increased complexity, diversity, and intensity as far as edge activity is concerned. The third section, developing between the urban fabric of Pylea and Kalamaria on one side and the plain of East Thessaloniki, presents similar characteristics to the first but lacking its industrial character. The ecotone gradient passes from a residential to a semi-natural /agricultural use, to non residential uses, (eg. retail / commercial /educational use). Taking into consideration the above points it can be argued that the Ring Road structure is part of a wider territorial ecotone, or better said, it is the main structural element of an emerging contemporary ecotone, corresponding to the one between the urban built limits and its surrounding territory / choros. A contemporary mosaic that recognizes the peri-urban area as a key ecotonal area occupying a critical area for the urban function, while hosting a diversity of uses / fabrics (urban & natural) of local & regional reach and importance. Thus the respective strategies proposed need to consider these ecotone characteristics in order to be able to propose adequate improvements. These fall under two broad categories:

A. Selective Permeability

A first group category the strategies refer to ways to achieve a selective and intelligent permeability of the limit, permitting ecological continuities and flows on one part, and controlling and managing urban activity and expansion on the other. This can be achieved through the establishment of connectors and respective green corridors that can provide the city with a great length of lineal green spaces, but more importantly a easier access and thus interaction with the peri-urban and natural areas. A further improvement of the permeability of local streams, will further improve the ecological functioning on a regional scale. (The creation of a number of cut-and-cover tunnels along the course of the Ring Road serving as connectors both for natural patches and between urban districts on both sides of the highway.) The construction of further connectors (urban & green) can reduce the barrier effect of the Ring Road and restore the continuities disturbed by the initial construction of the highway. Accordingly urban continuities :Take advantage of these puntual permeabilities and upgrade these points of urban continuity in terms of accessibility and activity. The whole idea of selective permeability is based on the conception of the configuration of the ecotonal area as a programmable interface. This paradigm can be best seen in the section of contact between the Seich-Su forest and the urban fabric. A dynamic interface in place could increase the urban-natural interaction, knitting a higher complexity and developing a synergic relation. This can be accomplished by defining precisely the limit line, the activities along the edge as well as the transversal connections.

B. Edge Activity

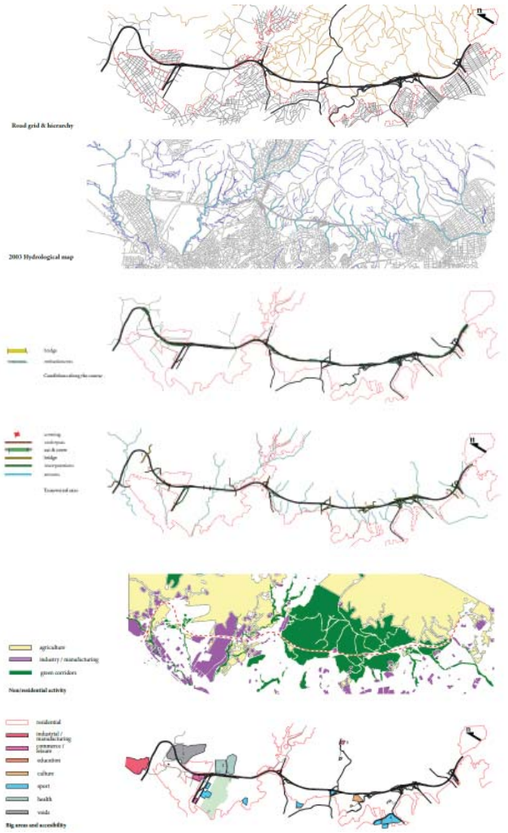
The second set of strategies refers to ways to achieve a vibrant and dynamic edge activity taking advantage of the present and and enhancing / activating the latent potential of the local mosaic. To achieve this two general factors are taken into consideration: ***the diversity*** of types of activities and the ***intensity*** of each activity in relation to the sum of the activities. These strategies are the following:

- The definition of delimited areas and consolidation of existing regional ***poles of activity*** of different types present along the Ring-road course: ***i)*** *health poles;* taking advantage of the high accessibility that the proximity of the existing health installation have to the Ring Road, and to natural areas. ***ii)*** *manufacturing & industrial* ***poles;*** structure and contain diffused secondary activity within the existing established activity areas, updating and upgrading their functionality to modern standards and contemplating their resizing coherent to contemporary needs and conditions. ***iii)*** *regional retail poles,* Structure well-defined retail poles including the big size stores as well as smaller and diffused activity. These poles will offer advantages for the relocation of businesses with the offering of services, accessibility as well as high quality public / open spaces.

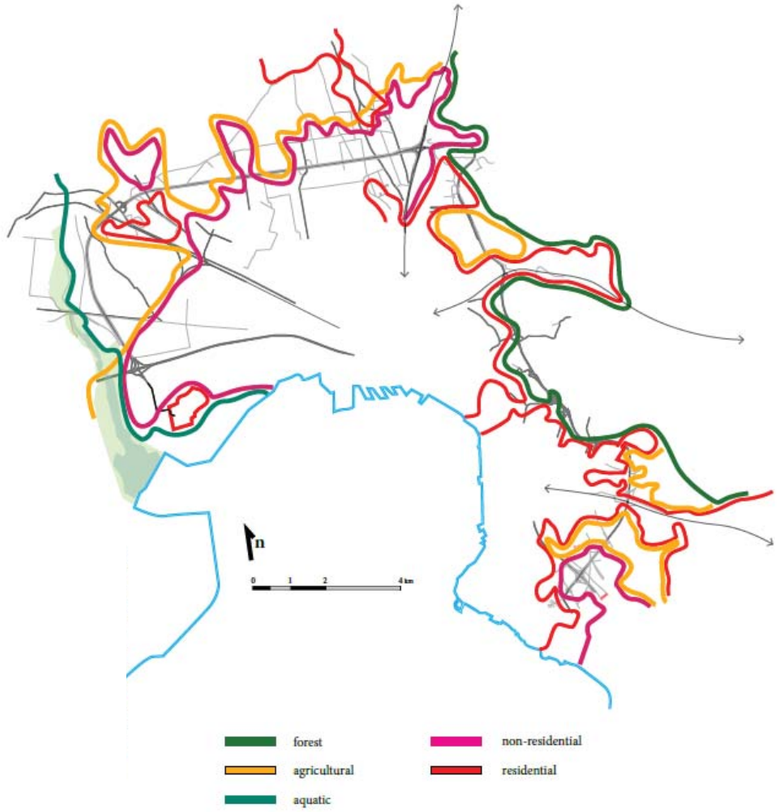
- ***latent spaces / voids reactivation*** : These areas as seen can be summarised in two big areas: ***i)*** *old military camps* and ***ii)*** *industrial voids;* areas that can provide the opportunity for creating new green areas (patches) as part of the wider regional green structure and for upcycling obsolete industrial buildings and infrastructures, updating them with diverse contemporary uses, having as an ultimate goal the creation of new key activity poles.

- ***Repair local fragmentations*** caused by infrastructure excess, considering the elimination of surplus infrastructures to improve and repair the fragmented landscape. The creation of a green buffer zone established

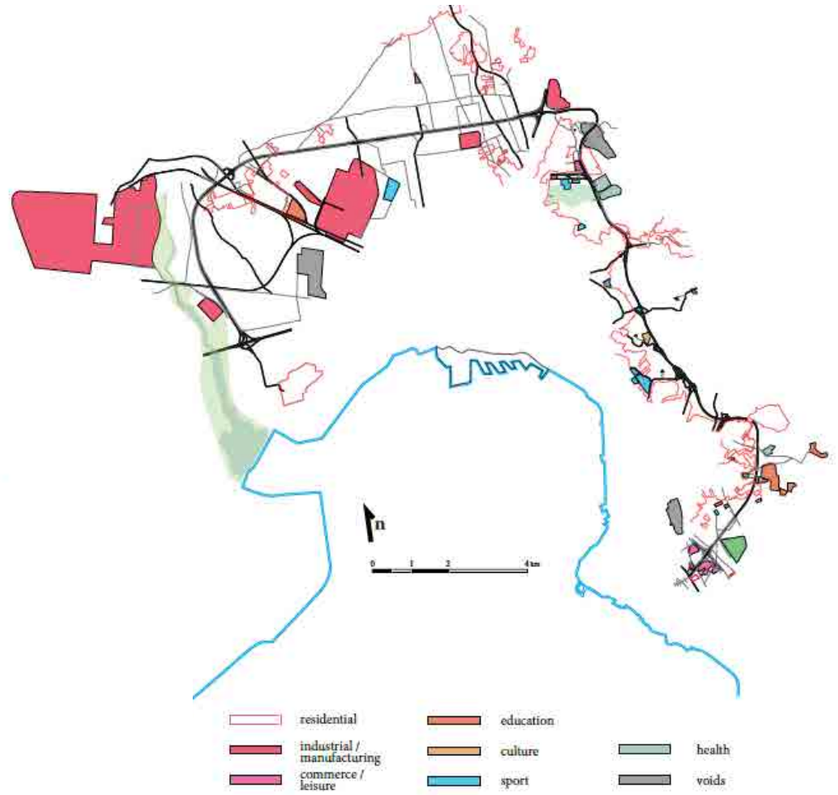
section analysis



ecotones



big-size areas and accessibility



between the urban settlements and the Ring-Road highway, a green city-ring, acting as buffer zone reducing and controlling noise and atmospheric pollution caused by highway traffic. This could provide with a significant upgrade / improvement in terms of landscape quality to the areas adjacent to the Ring Road, reducing landscape / environmental impact of the infrastructure. On another level these particular edge areas could also be utilized apart from creating lineal green zones to accommodate light rail or bicycle flows along the peri-urban area and also structure the productive agricultural areas found in the peri-urban area of the city, critical bioproductive reserves for the urban region that need to be recognized as such, offering them an added value. The establishment of delimited areas/poles of activity and the relocation of diffused (secondary / tertiary) activity and concentration within these areas will aid in reclaiming previously consumed natural and agricultural land. At the same time it can aid in establishing efficient and productive activity areas. At the same time adequately structured ecotonal limits between the peri-urban low-density residential areas in contact with these key natural reserves and bioproductive areas.

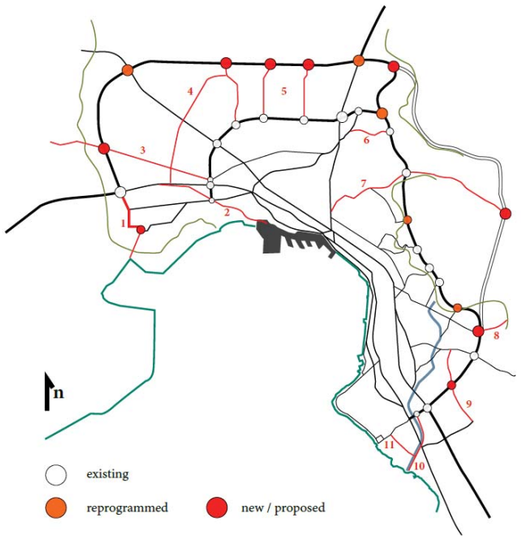
- In terms of mobility, the Ring -Road structure and especially the exterior need to dotted with additional access points and also consider possibilities for creating dynamic and productive highway nodes. Many of the nodes of the Ring Road structure have served as attractors of principally sport and retail facilities. Their reconfiguration and upgrade can enhance existing activity along the Ring Road and structure activity patterns along its course. There is also a need to reconsider its traffic capacity and function within the overall scheme, including in this consideration the introduction of soft flows, such as suburban rail, bike and foot paths, connecting the diverse environments encountered along its path.

The emerging mosaic of the peri-urban area and the Ring Road as it comes out of analysis and suggested strategies for restructurating can be seen in the diagram on the next page. The updated structure and function can also be seen along with the natural structure (biophysical matrix), the delimited activity areas and attraction / innovation poles. The Ring Road structure infrastructure passes to be converted from a territorial pathology to an integrated an dynamic urban element. And from a peripheral edge zone, reprogrammed into a vibrant and structuring urban-natural interface capable of managing activities and dynamics in the peri-urban area and the entire urban region.

The re-structured mosaic

The Ring Road structure as a city-limit interface

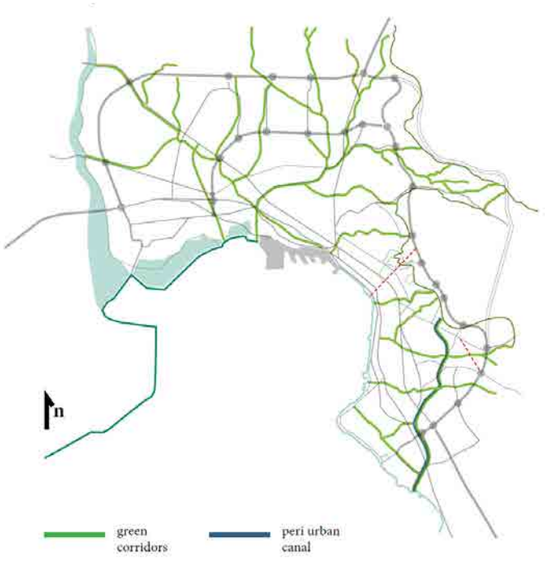
Ring Road and hard mobility structure.

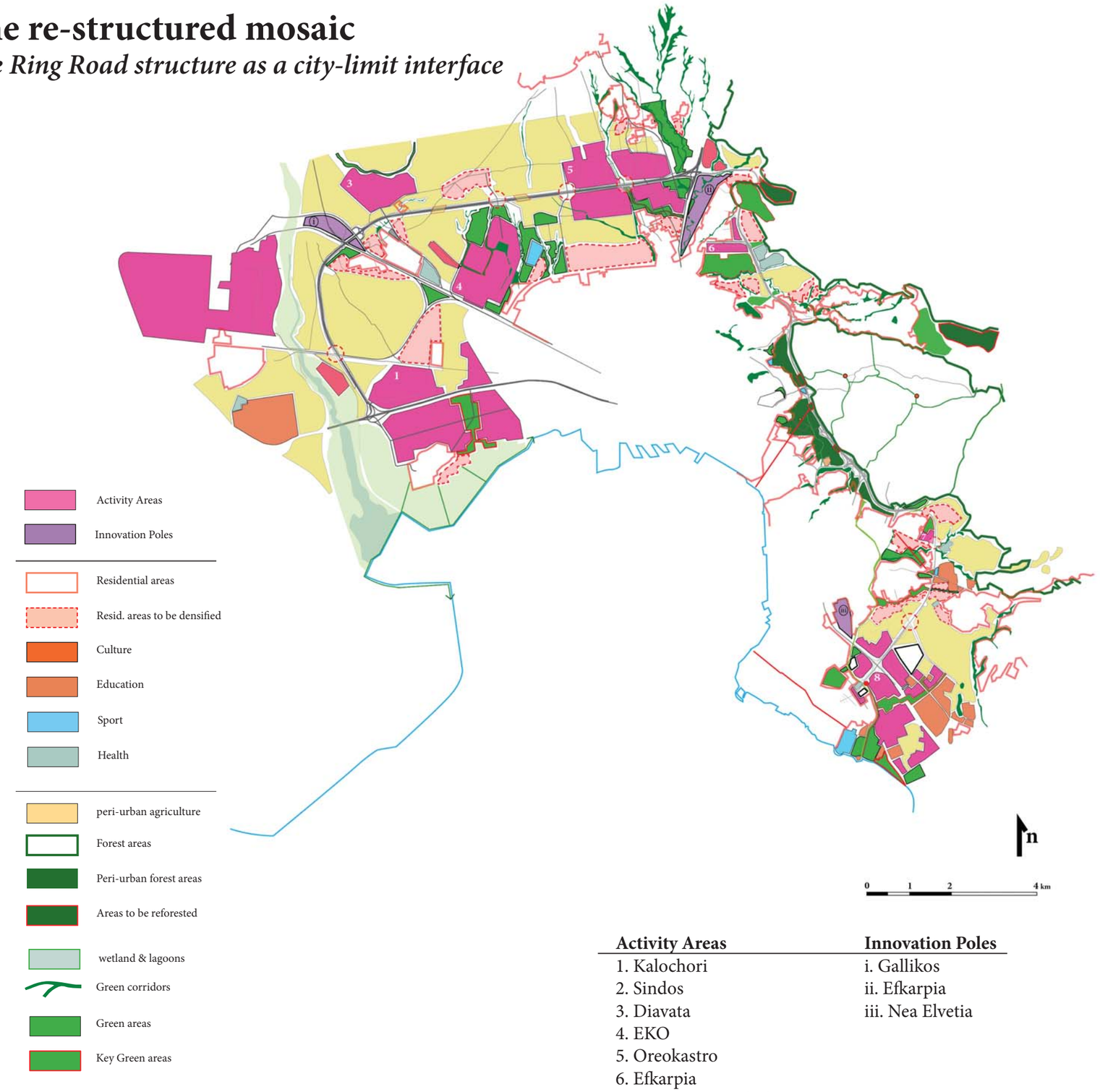


New / upgraded arteries

1. Connection Kalochori
2. Port access
3. Sindos-Thessaloniki axis
4. Intermediate Ring
5. Exterior/Interior Ring connections
6. Karatasiou access
7. Thessaloniki-Retziki axis upgrade
8. Kipoupoli access
9. East West Pylea axis
10. Peri-urban canal axis
11. Kalamaria - canal connection.

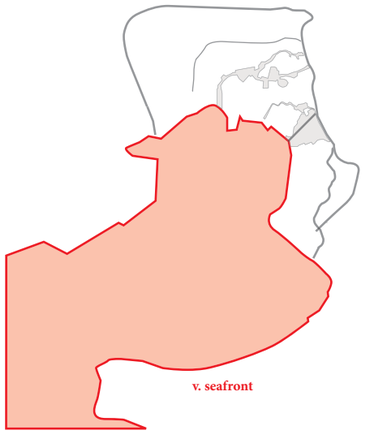
Ecological structure and continuities

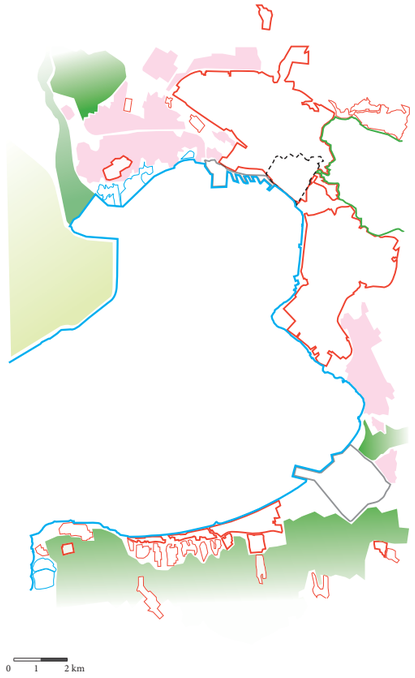




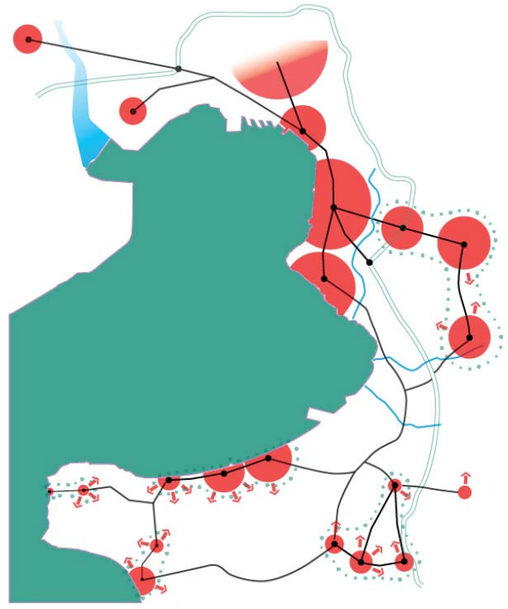
Activity Areas	Innovation Poles
1. Kalochori	i. Gallikos
2. Sindos	ii. Efkarpia
3. Diavata	iii. Nea Elvetia
4. EKO	
5. Oreokastro	
6. Efkarpia	
7. Konstantinopolitika	
8. Pylea	

6. The seafront - *an ecotone in flux* *(p.322 - 413 in Book II)*





ekistic network



ecological structure

The last ecotone under analysis is the key territorial ecotone of the sea-land ecotone giving form to the respective Thermaikos and Thessaloniki bay. The analysis examined both the wider conditions along the Thermaikos-bay but also the Thessaloniki bay in more detail along the urban region´s limits. The extended bay being a recipient of the water and sediments coming from numerous rivers, has a fluctuating character with its coastline having shifted significantly in the last two thousand years. Respectively this past century the development of the urban fabric and human settlements have surpassed by far the limits of the historic centre, extending on both directions along the coast, overcoming previous natural obstacles that created unfavourable conditions, such as the swamps / wetlands on the north coast - west of the historic centre as well as the ones one the southern coast, in the Peraia and airport area. In conjunction with sociopolitical conditions with economic growth and reltive stability permitted an unprecedented human development along the coast. Today there is a continuous built urban front starting from the seaport and extending almost to the exit of the peri-urban canal, and a second one on the south coast, of a lower & seasonal activity starting at the settlement of Peraia and extending to the west all the way to Agia Triada. Public accessibility is possible along most of these urbanized fronts, while in the rest of the cases, it presents a restricted or even unformed state.

Accordingly numerous activity poles have been attracted by the conditions along the coast and decided to locate along its course. These naturally include big-size transportation facilities like the airport and the sea-port (with the respective barriers that they create), functional areas (industrial, commercial) with big size installations; medium sized specialized areas for sports and culture or emerging centralities (eg. Central Axis); or smaller size pieces, like public spaces, tourism installations, marinas, parks and sport facilities. At the same time, there are numerous areas of variable size that are either found void or in a latent / transitional stage. These are characterized either by ***i)*** their strategic position (ex Kodra camp, Megalon Emvolon, International Expo) ***ii)*** their vicinity to important installations (eg. areas around the airport) ***iii)*** their historic character (Aeneia archeological site) ***iv)*** their emerging ecological and landscape value (Kalochori & Angelochori lagoon) ***v)*** and the reconnection potential that they present. A careful consideration of these areas and their function, taking into consideration the wider context of the bay, could help diversify and dynamize the activity and flows along and towards the coast, resolve conflicts and enhance the overall structural and functional scheme. The question of continuity is essential for achieving the interconnection of these areas, mobility fluidity and a structuring on a large-scale, taking into consideration issues of public accessibility and reconnection, ecological or social.

As far as natural / ecological activity is concerned it is encountered in a endangered and pressured state. On the western coast, the tri-delta estuary area with the Gallikos river create an important natural and ecological zone and historically a considerable limitation for the westward expansion of the city. Then there are the wetlands of the Kalochori area, and the Angelochori lagoon on the tip of the Megalon Emvolon, while small remnant are found around the vicinity of the airport. Agricultural areas and semi-natural areas are still found in gran extension in the same area (Megalon Emvolon) and more limited along the exit and course of the Anthemountas valley river on the east coast of the bay. As fas as ecological functioning is concerned, the bay is connected with the inland via various corridors, principally river / stream corridors, the majority of which have experienced to a bigger or smaller extend the effect of human modification, or are anthropogenic in nature. These corridors provide connection on a short scale (e.g. with the forest of Seich-Su via the peri-urban canal, or old streams inside the fabric of East Thessaloniki) or a larger regional scale (Anthemountas & Gallikos river). Respectively there are occasion where there are barriers / limits, obstructing and fragmenting these corridors. Examples of these barriers are the ones created by the highway along the Perea-Neoi Epivates axis, the eastern and western Thessaloniki urban fabric or the big size facilities like the airport and seaport.

The opportunities that arise out of the analysis of the bay, and the proposed strategies can be seen in the diagram on the next pages. They demonstrate the vibrant activity and emerging role that the seafront has come to occupy. The seafront analysis following with the investigation of the conditions and dynamics along the city´s Ring road, as well as the rest of the ecotones under analysis, will permit to correlate the distinct scales and dynamics, in order to provide a more comprehensive depiction and synthesis of the city´s structure and mosaic.

5. The seafront ecotone

Origin / Type		*Spatial Structure*	
type	investigative & tangible / manifested /	*stuctural element*	coastline / seafront
		latent element	seafront activity
source	morphological	*shape*	radial
creation force	natural + anthropogenic	*extend / length*	21 - 45 km
time of creation	hydrological / human activity	*thickness (min/max)*	0.02 - ? km
character	diachronic	*scale*	metropolitan / terriorial
interest	limit / corridor	*grain size*	varied
	ecological / social / cultural	*sharpness*	sharp varied

Function		*Dynamics*		*Projectual Logics*
type	absorption + reflection + transformation + amplification	*state*	active / evolving	restore edge continuity
		control	exogenous & endogenous	restore seafront accessibility
interaction	sea - terrestrial	*mobility*	edge & bi-directional	ecological integration
edge activity	diverse	*activity*	high / increasing pressure	integrate mobility infrastructures
character	mobility / limit	*situations*	ecological degradation / ecological & social discontinuities / / latent fabrics	reactivate obsolete fabrics
grade of artificiality	partly artificialized			limit urban sprawl
integrity	unbroken mostly			enhance complexity
		impact scale	metropolitan to territorial	landscape as a mediation tool

Following the analysis, a synthesis of the emerging mosaic along and adjacent to seafront was performed taking into account both the results of the previous analysis chapters with the respective detected situations and the corresponding opportunities that were identified. These served as the base for developing adequate strategies for reprogramming the existing mosaic with the aim of converting the contemporary edge area of the seafront into a dynamic and resilient edge that can guarantee ecological functioning while integrating human activity efficiently. A mosaic that recognizes the seafront area as a key ecotonal area performing a critical ecological function and serving as a major attractor for the urban activity in a diversity of ways (anthropogenic & natural) of local and regional reach. Thus the respective strategies proposed need to be considered in terms of ecotonal characteristics in order to be able to better comprehend its proposed function and its potential effect. These are presented in continuation summarized in two broad categories:

A. Emerging poles of activity / Edge activity

In the first category of strategies are included the ways to take advantage of existing activity and conditions that prevail along the ecotone and to aid with the consolidation of latent fabrics and emerging poles of activities. Areas whose restructurating can permit the reestablishment of continuities, transverse or longitudinal, managing of flows and activities, their intensity and their impact. These emerging poles as they come out of the analysis are the following: ***i)*** Dendropotamos taking advantage of the location on the western entrance of the city to propose an ecological restoration of the rivers delta ***ii)*** the Cultural Port, opening up the port to civic use ***iii)*** the Central Axis, emerging as a regional centrality area ***iv)*** The Nea Paralia pole, at the height of the Thessaloniki Nautical club ***v)*** Poseidonio, a multifaceted pole with cultural, sport and education activities ***vi)*** the Karampournaki area, with its advantageous position, and the latent space of the Kodra military camp ***vii)*** the Mikra area with the extensive sport facilities and educational centres right at the end of the peri-urban canal corridor. In parallel one needs to consider the key function of the seafront as a corridor, and the conditions that prevail along its course.

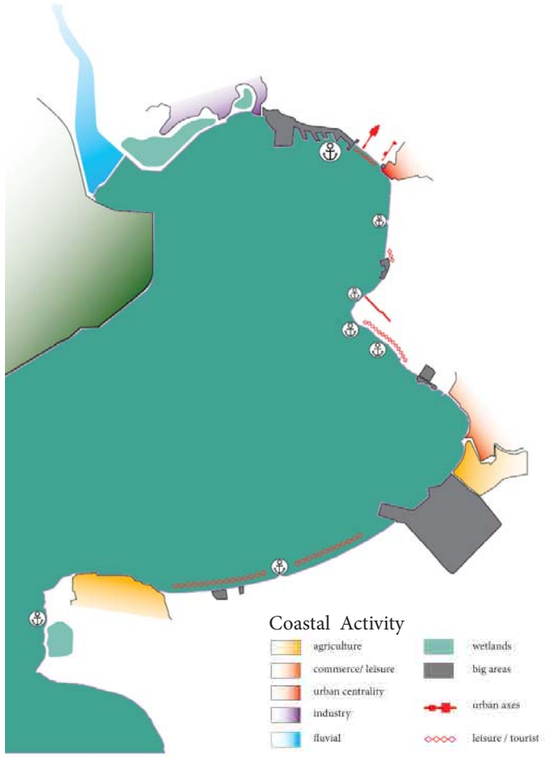
B. Edge structure

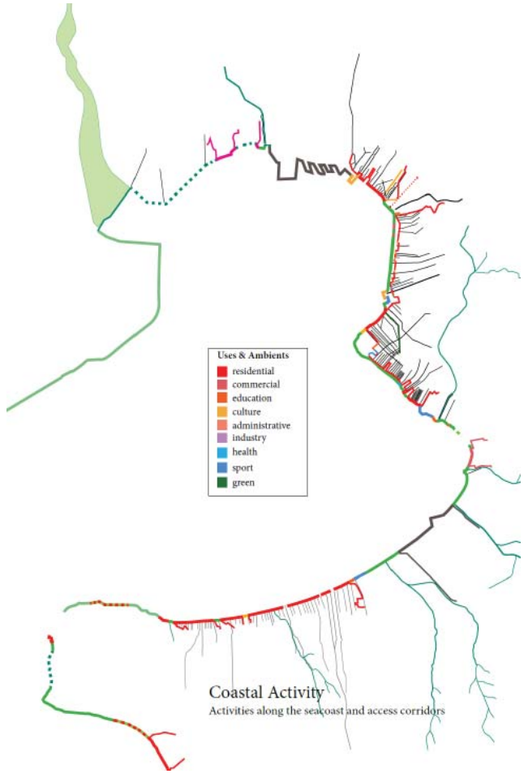
The second set of strategies refers to ways to achieve a vibrant and dynamic edge activity, taking advantage of the existing and emerging poles, the local biophysical mosaic in terms of connectivity and latent potential and providing an adequate structure for their develòpment. To achieve this, two factors need to be taken into consideration:

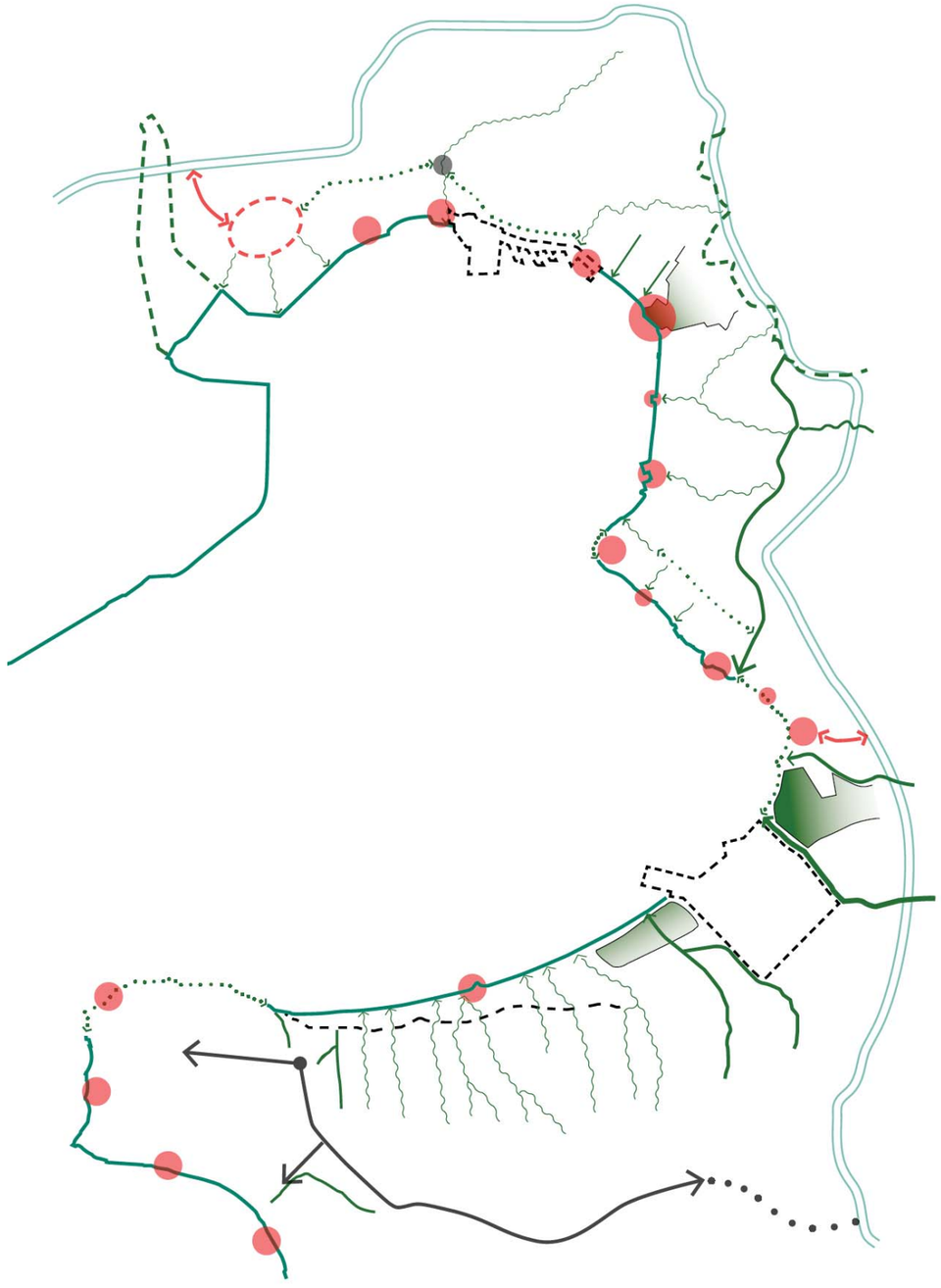
- ***Seafront Continuity*** : The question of seafront continuity contains two implicit questions; public access to the seafront, and consequently uninterrupted access along its course. The restructured mosaic proposes a continuous seafront all along the city´s seafront with adjacent wetland areas included, making them open to natual flows and the public. The area of the port is an exception and a rerouting is proposed on the edge line of the Lachanokipoi area and the port. The rest of the route encompasses different environments and settings as well as intensity of activity, making evident the different rhythms present in the territory and highlighting the vibrant character of the edge area.

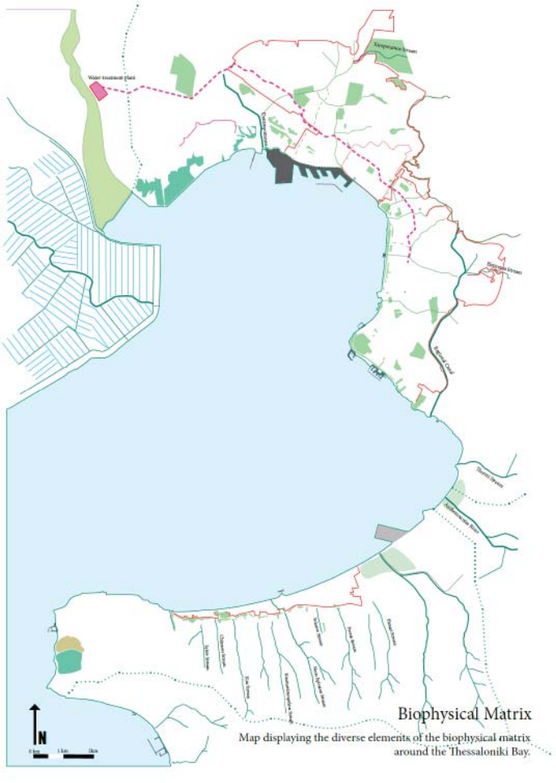
- ***Accessibility / Connectivity***: The question of accessibility is of critical importance for ensuring the necessary quantity and quality of flows, charasteric of a healthy and vibrant edge area. Correspondingly there are two considerations with respect to the question of flows: ***i)*** natural flows : making reference to ecological connectivity (vegetation, hydrologic, fauna) and quality indicators (diversity, intensity, interactions, complexity) as well as ***ii)*** anthropogenic flows : referring to the question of social and public use of the seafront as a common resource and social/cultural heritage as well an important everpresent cultural landscape.

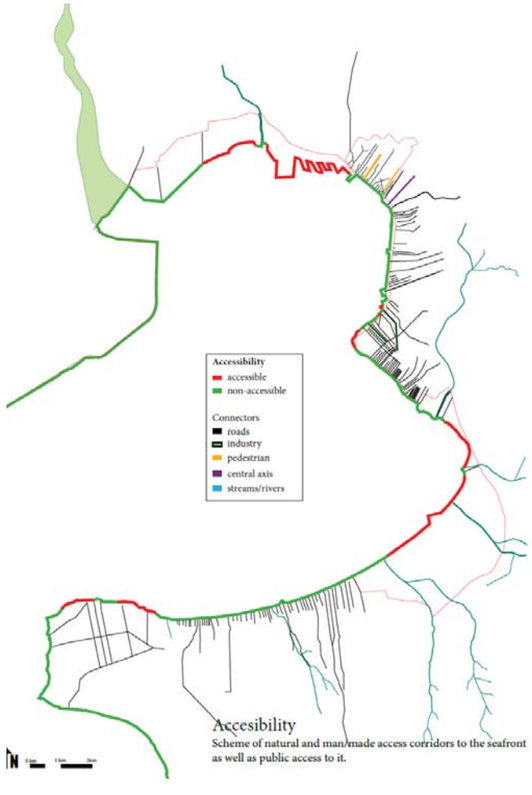
The seafront ecotone being the more complex in nature, highlights the importance of multi-scalar, multi-criteria analysis for performing an integral lecture of its structure and function. In the case of Thessaloniki, it highlighted the importance of this key ecotone for the city of Thessaloniki, both on a large-scale (territorial, regional) as well as micro scale, utilizing a distinct toolbox for each case, suitable for each situation and space and proposing respective measures for its improvement.


Coastal Activity
agriculture
commerce/ leisure
urban centrality
industry
fluvial
wetlands
big areas
urban axes
leisure / tourist


Uses & Ambients
residential
commercial
education
culture
administrative
industry
health
sport
green
Coastal Activity
Activities along the seacoast and access corridors


Opportunities and emerging strategies
corridors
commerce/ leisure
wetlands
barriers
corridors
urban corridors
reconnection
green limits
barriers

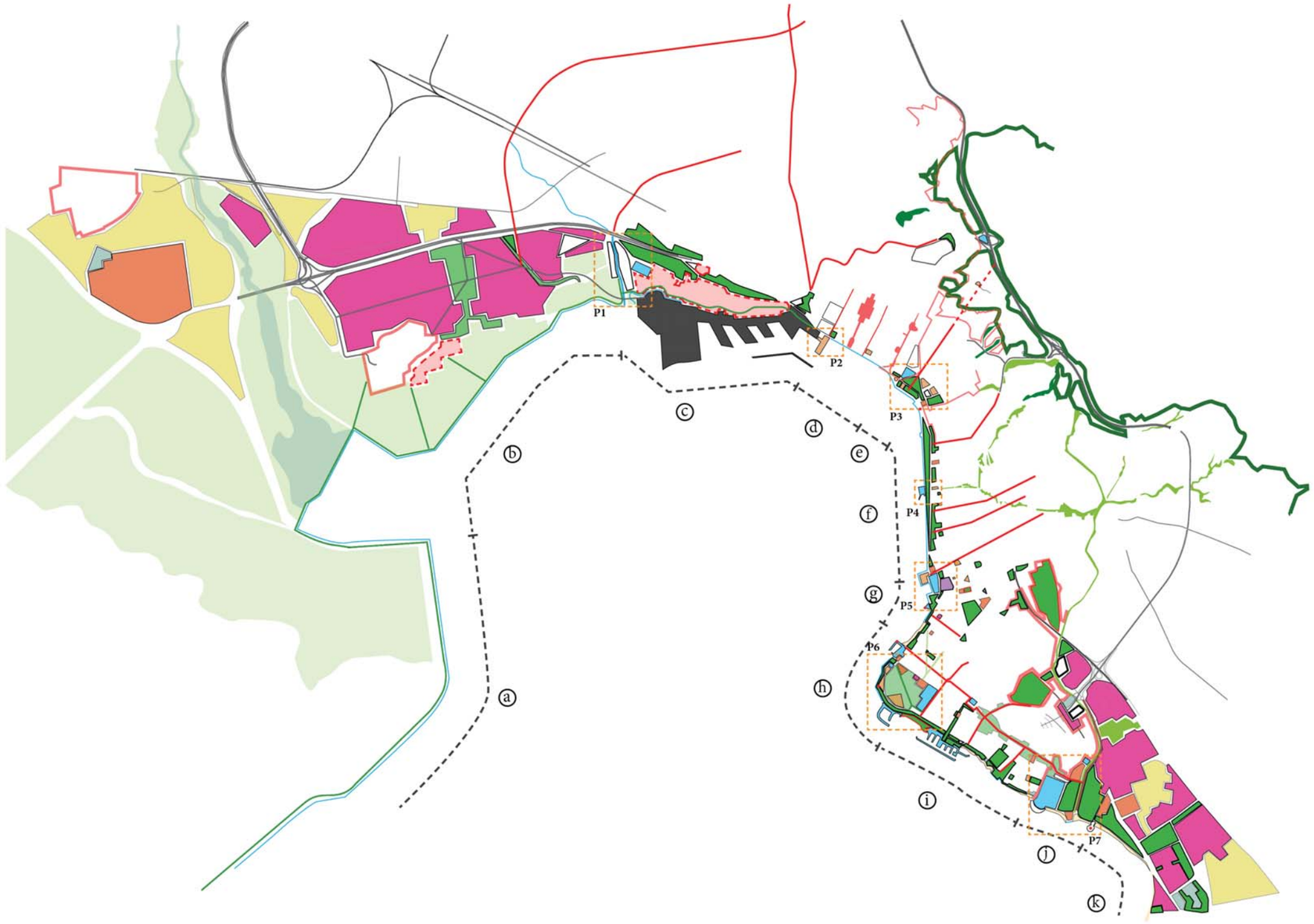

Biophysical Matrix
Map displaying the diverse elements of the biophysical matrix around the Thessaloniki Bay.


Accessibility
accessible
non-accessible
Connectors
roads
industry
pedestrian
central axis
streams/rivers
Accesibility
Scheme of natural and man-made access corridors to the seafront as well as public access to it.

The re-structured mosaic - *The seafront as a vibrant ecotone*

Index key

- Activity Areas
- Innovation Poles
- Residential areas
- Res. areas to be densified
- Sport
- Health
- Culture
- Education
- peri-urban agriculture
- Forest areas
- Peri-urban forest areas
- Areas to be reforested
- Wetlands
- Green corridors
- Green areas
- Key Green areas



Poles of activity

1. Dendropotamos
2. Cultural port
3. Central axis
4. Nea Paralia
5. Poseidonio & Music Hall
6. Karampournaki
7. Mikra

Coastal Environments

a. Delta natural park
b. Gallikos and Kalochori wetlands
c. Port (Cargo & Passenger)
d. Historic Centre waterfront
e. Central axis waterfront end
f. Nea Paralia waterfront
g. Karampournaki beach
h. Karampournaki walk
i. Aretsou & Nea Krini beach
j. Mikra Sport pole
k. Pylea waterfront

Case-study specific conclusions

After the presentation of the six ecotonal areas and their respective results / conclusions, this next section will present a series of more general but nevertheless case specific conclusions produced based on the sum of the analysis results coming out of the interpretation of the urban region of Thessaloniki and the six respective ecotone areas, in an effort to be presented as a synthesis that can be beneficial to the broader objectives and the question of ecotones studied in this paper.

- The typological and social fabric ***complexity*** (manifested as typological diversity and diversity of activity along the ecotone, as well as interaction between adjacent patches) present in each ecotone is directly analogous to the age of the ecotone in question. Thus, the historic ecotones, formed along the city-walls surrounding the historic centre, are encountered today with a long / diverse and minifested historic activity that is easily perceivable both in the built-up typologies as well as the diversity of activity present within. This makes sense given the fact that older ecotonal areas have experienced the majority of the (urban) succession phases experienced by the city of Thessaloniki and its territory.

- Nevertheless there are certain differences that can be noted between the east and west historic ecotones and this is due to different reasons. Ones can be attributed to the location of the city with respect to the local geomorphology and the respective routes / conduits formed historically. Given that the west side was the traditional trade entrance to the city, a lot of key transportation (e.g port, train station) were built on this side. Which brings on the table the question of the ***planning dimension*** of the ecotonal areas, as presented through the city plans and specific localized interventions, many of which with discernible social overtones. The different treatment that the Hébrard plan offered for each area, consequently influenced its contemporary form and structure. Before the implementation of the plan along the central Axis area, the area presented many characteristics similar to the west historic ecotone.

- As seen in the analysis and as claimed by this paper, the urban centre of the city of Thessaloniki, the regional point of gravity of urban activity, has shifted slightly to the east of the historic centre, along the *Central Axis* area. This ***emerging centrality***, along with the relative availability of space, explains the increased appearance of typologies and activities with a character of centrality along the Axis and with less frequency along the West walls ecotone and gives tips for their proper future management.

- Respectively, the emergence of the two "modern" ecotones (*the peri-urban canal & west arc ecotones*) are in both cases related with the creation / construction of water-infrastructure works (drainage & flood protection) that accordingly gave rise to the two ecotonal areas, each with distinct characteristics, and a certain time offset in their time of appearance. The distinct historic periods that each ecotone appeared, have accordingly influenced its character and structure. The location of industry and manufacturing activities, sings of the early industrialization of the city, and military installations along the west arc (and their respective abandonment and decadence in continuation) contrast with the peri-urban landscape of agricultural and low to mid-density residential typologies along the peri-urban canal to the east. Planning directives and decisions have again played a key role in this east-west differentiation.

- The ring-road ecotone today receives the majority of ***contemporary growth*** of the city, given the availability of space and accessibilty of flows. This growth comes less in the form of residential typologies and more in terms of secondary and tertiary type activities, of different sizes. Naturally, big-size typologies find space for installing themselves along the Ring Road ecotonal area, consuming indiscriminately precious peri-urban agricultural land, while taking advantage of the increased mobility / accessibility that the ring-road infrastructure offers on a city-wide and regional level. A respective overall drop in terms of landscape / territorial efficiency is experienced due to the formentioned reasons.

- The ***growth dynamics*** of the city can be better understood when observing the contemporary expansion activity taking place along the Ring-Road ecotone, while taking into consideration the parallel implosion of the traditional city centre as a commerce and gravitational centre. Accordingly, a key opportunity is presented along this limit for carefully re-planning the city limits, by applying adequate planning logics and strategies. When adequate planning is applied at the first phases of urban succession, it remains as a type of *planning heritage* for subsequent stages / phases as can be seen in the case of the Central Axis area. This can also be seen easier in cases related to ecological preservation of strems or other key ecological areas or the logical structure and organization of human networks and settlements (routes, interaction, commerce, cultural landscapes etc.)

- Similarly the seafront / seacoast ecotone is another key ***spatial indicator*** of urban and territorial dynamics. The unprecedented occupation of the seafront which came to the expense of local ecosystems resulted in a significant ecological perturbation and deterioration of local and territorial, maritime and wetland ecosystems. On the other hand, despite the high value and preference given by antropogenic systems to the seafront, it still presents certain deficiencies in functional terms, principally the question of continuity (a direct result of a lack of adequate integral management in its totality), the quality of public space, the activity present within and finally the key question of accessibility to the seafront. Its diachronic and dynamic nature, manifestation of the rich socio-cultural activity found along, render it as one of the most important ecotones in the region.

- It is also made evident through the analysis of the six cases the importance of the presence of a ***structural element*** inside the ecotonal areas, whether *active* (the Ring Road, the seafront) or in a *latent state* (Central axis, the West Arc), as an element that can potentially structure a future reprogramming of the local mosaic. Thus any transformations can hold a common point of reference and relevant to each territory in question, linked to it history and evolution.

- The planning experience in the city of Thessaloniki demonstrates a lack of capacity of ***intramunicipal cooperation*** for joint projects excepts when state coordinated. The obsolesce of the West Arc competition, a by-definition intramunicipal project, and its overall impact, or the chronic incapacity to deliver a undisturbed continuity along the seafront, outside the Municipality of Thessaloniki are examples of deficiently coordinated intramunicipal projects. Exception can be seen in the case of the peri-urban canal or the Ring-Road highway, precisely because they were constructed as central planned State infrastructure, indifferent in their integration and attention to the territory and local landscapes.

- It also demonstrates the difference in ***planning practices*** in each municipality, exemplified in the case of the west-walls ecotone, located along the municipal limits (between *Thessaloniki & Neapoli - Sykies*). The contrary can be seen in the case of the Central Axis that is included in its entirety within the municipality of Thessaloniki, and presents a more legible structure and overall treatment.

- Indeed, the spatial configuration of the sum of the ecotonal areas in the urban region of Thessaloniki can be seen forming a ***ecotone network*** structure, with the (two) *historic* and the (two) *modern* ecotones forming in a radial fashion out of the historic centre and the contemporary ring-road and seafront ecotones interconnecting and completing the formentioned network. The historic evolution of the development of the city, following a *northwest-southeast* direction (as conditioned by the coastline and local geomporphology) is to a great extend responsible for the form and morphogenesis of the urban region and the emergence of its ecotonal areas. An evolution that has been accompanied by the development of urban infrastructure (drainage and flood-protection canals, rail. avenues and ring-road highway etc.) that respectively have conditioned and given rise to respective ecotonal areas in their corresponding urban succession phases. Nevertheless, this ecotone network as spatially manifested today, and as chosen for analysis by this paper, covers the greatest part of what has come to be the urban region of Thessaloniki and allows for the detection and identification of spatial dynamics on a region-wide level. It also allows for the detection of a increased complexity, interrelating spatial structures and dynamics.

- The ***scaling*** question, the correlation of the different scales of analysis, between the regional level (with its respective ecotones and mosaic structure) and each ecotone (or their emerging network) is necessary and can give hints for a more efficient integration of the urban fabric (and anthropogenic activity) with the territorial mosaic, its structure and function. It also permits to understand the shift in societal metabolic practices, manifested in the different morphotypologies and respective flows. The seafront ecotone with its dynamic nature, or the forest-urban ecotone are key areas for testing such concepts and for highlighting the importance of a multi-scalar analysis for identifying continuities, limits, patterns, complexity and accordingly applying adequate projectual logics in / on the territory

- Apart from the spatial/territorial interpretation of the regional mosaic of the Thessaloniki urban region that the ecotones permit as spatial indicators, they also allow for the rethinking / re-configuration / re-programming of each of the respective ecotonal areas as well as the entire ecotone network. Thinking in ecotones as ***configurable interfaces*** permits to consider a diversity of specific questions such as edge activity and diversity, permeability, continuity (of flows, natural / anthropogenic), connectivity (or interconnectivity) or more general questions such as ekistic development, territorial efficiency, ecological integration etc, on a city or region wide level. It also demonstrates the multi-scalar character and complexity that the ecotonal areas can carry, a characteristic that was demonstrated through the analysis, and formulated into a synthesis and shown at the end of this chapter.

The conclusions produced from the analysis of the case-study of the Thessaloniki urban region and the six ecotonal areas are relevant naturally to the specific city in question but also aspire to be extrapolated to different case studies and contexts. In this way they are thought as a contributing to the general question of ecotones and more specifically of urban ecotones, as it is forming within the broader debate on city science and complexity. In order to complete the synthesis, a graphical representation in the form of a synthesis map, is presented in the following page, along with a summary table, presenting the spatial & graphical representation of the specific results. The theoretical debate is concluded with the presentation of the general conclusions, pertaining exclusively to the question of ecotones, as produced through the case-study analysis (extrapolating the specific to the general) and parallel bibliographical / theoretical research.

Ecotone	*Territorial situations*		*Projectual Logics*	
1. Central Axis ecotone	crossings / nodes new modes of accesibility trapped facilities residential islets green enclaves	stream traits axis discontinuities latent spaces fabric remnants / memory	reinstitute central axis restore continuities reintegrate / reactivate fabrics manage emerging centrality	enhance complexity articulate spatial scales
2. West Walls ecotone	barriers hydrological traces archaelogical / cultural traces emerging public spaces fabric discontinuities	interstices fabric remnants / memory city wall permeability latent spaces / latent green spaces	reinstitute wall continuity integrate social infrastructures reactivate obsolete fabrics hightlight monumental character	enhance complexity facilitate intramunicipal interaction
3. West Arc ecotone	archaelogical traces stream traces residential islets obsolete military camps industrial remnants	emerging public spaces flow generators / attractors fabric discontiunities emerging and existing poles of activity ecological space occupation	reinstitute ecological integrity Restore continuities integrate social / mobility infrastructures reactivate obsolete fabrics	hightlight industrial heritage enhance complexity facilitate intramunicipal interaction
4. Peri-urban canal ecotone	ecological crossings peri-urban agriculture stream traits incontinuities scattered grren areas	big-size retail nodes / crossings stream occupations industrial remnants emerging poles / environments	establish canal continuity as a corridor integrate social infrastructures reactivate obsolete fabrics enhance complexity	facilitate intramunicipal interaction hightlight natural / ecological character
5. Ring Road	urban dis / continuities big size industry big size retail obsolete military camps industrial voids	fragmentation by infrastructure nodes with activity pressure on productive land permeability connectors	restore continuities (social / ecological) integrate mobility infrastructures reactivate obsolete fabrics limit urban sprawl	enhance complexity work with the city-limit facilitate intramunicipal interaction ecological integration
6. Seafront	landmarks infrasrtucture barriers intense edge activity voids / latent spaces connection with other ecotones	emerging poles degraded ecosystems activity related conflicts leisure activities undefined relation / connection	restore edge continuity restore seafront accessibility ecological integration integrate mobility infrastructures	reactivate obsolete fabrics limit urban sprawl enhance complexity landscape as a mediation tool

SYNTHESIS MAP

General conclusions on urban ecotones

The correlation of the bibliographical research analysis and the results of the case-study analysis of the six ecotones of the urban region of Thessaloniki can help extrapolate the specific results into more significant general results, and vice versa, regarding the study of ecotones, natural or anthropogenic. These conclusions are presented in continuation, in correspondence with the research question set forth in the beginning of the thesis.

RQ1. One primordial question that comes up when initiating the research is the type and degree of analogies that can be made between natural and anthropogenic (eco)systems. Accordingly, with respect to the issue of ecotones what similes exist in the respective area of anthropogenic ecotones? What are the common points as well as principal differences (phenomenological or functional) between naturally formed ecotones and artificial / antrhopogenic ecotones? And methodologically speaking to what extend can urban ecotones be functionally classified so as to facilitate comparisons with respect to origin, structure and ecological /social processes?

As demonstrated through the bibliographical and theoretical research and analysis, the introduction and evolution of the organic perspective with respect to the city and territorial sciences has gone through various theoretical and conceptual stages in order to reach the current state-of the art. The contemporary discourse often balancing on the borderline of conceptual and practical simplifications, should aim at highlighting the added complexity (identified through the conceptual advances and technological advances) as well as special characteristics of anthropogenic territorial systems and their respective interactions. Urban ecotones similar to natural ecotones emerge as key elements for understanding as well as planning contemporary urban regions, and for this reason an analogous systematization is necessary to describe such processes and dynamics. It is important to keep in mind both the intrinsic character of cities as dissipative socio-ecosystems as well as the desired societal goals set forward for cities and regions when performing such a comparison to avoid falling in the formentioned trap of simplification. Although natural processes are more than present in the urban environment (understanding the *ecology of the city* paradigm) and affected by its processes, the societal layers superimposed on the territory create additional dynamics / considerations. At the same time scaling studies have demonstrated the similarities in the behaviour of biological systems and human settlements, in terms of growth and metabolic pace, and the common traits among all cities independently of location or context. An integral perspective for comprehending urban processes should accordingly define an adequate model / platform for basing future planning as well as harvesting the potential of emerging bottom-up processes and networks, the latent complexity of the territory. Urban ecotones as conceptual vehicles can serve as spatial manifestations of past and ongoing urban / territorial dynamics and processes and at the same time as test grounds for the monitoring and management of these same dynamics inherent in the urban environment.

RQ2. Ecotone research has indicated that ecotones provide stability for the resource patches they separate; if this is true it is useful to know at what spatial and temporal hierarchical scales they operate, are effective ? What has been the importance of ecotones in maintaining local, regional and global (bio)-diversity and what potential do they hold for the future management of territories? In answering this question it is vital to identify the key attributes (processes and components) of ecotones that impart resistance and resilience to the adjacent patches. That is to comprehend the ways that socio-ecological system boundaries influence biotic diversity and flows of energy, materials (and information) and the distinctive functions that they can have (filter / barrier /corridor etc.) and intensities they can exert.

Ecotones, whether natural or anthropogenic operate and are interconnected over a potentially wide range of different scales, each scale affecting and controlling distinct elements and factors of its function. Thus when contemplating an increased efficiency in their functioning, an intra-scalar perspective is imperative. But when considering to analyse or modify specific characteristics of the ecotone (e.g. permeability, accessibility) it is imperative to choose the appropriate scales (*spatial & temporal*) that are more pertinent to each case / question. The two principal characteristics of ecotones, that is the presence of an increased (bio)***diversity*** and an augmented ***intensity*** of activity (*edge activity*) along the ecotonal areas, creates the potential for working with an increased complexity along and near these areas: interrelating adjacent heterogeneous patches, taking advantage of pronounced (and unpronounced) edge activity (*latent potential*) along the limits and weaving a more coherent and resilient network of urban activity by configuring an urban network of interconnected /interrelated elements and fabrics. The dynamic character of cities and urban regions with the successive and often simultaneous phenomena of urban explosion and implosion, development and obsolesce, configuration and disconfiguration, render the ecotonal areas as key areas for comprehending past, present and more importantly upcoming tendencial patterns of urban fabrics and regions in general. Question of energy dissipation or information interchange are key in understanding these processes. The adequate management of these dynamics, as manifested in the ecotonal areas, can indeed produce an increased stability for the adjacent patches. Taking into consideration *the intermediate disturbance hypothesis* ecotones could indeed be configured in such a way as to achieve an overall improvement in terms of function and activity, always when this is done in accordance and respecting the natural and social capacity of the territory in question. Again in order to be able to succesfully configure these attributes one needs to consider them in a multiscalar frame, adjusting scales and rhythms.

RQ3. Considering the autopoetic qualities of the territory and especially those specific to the urban /antrhopogenic regions (ekistic patterns, succession phases ...), what are the correlations that can be made between urban ecotones and the development / evolution of the urban fabric. In what ways can ecotones serves as indicators of past and present activity and as descriptors of the distinct urban phases characteristic of the historic evolution of each city.

Accordingly, as demonstrated both in the case-study analysis of the urban region of Thessaloniki and other cases / references, urban ecotones (understood as anthropogenic artefacts) can appear / emerge through various stages of the urban expansion / growth, their appearance and development conditioned both by existing natural elements (eg. geomorphology, local hydrology etc.) or respectively puntual natural phenomena (e.g floods, fires etc) or artificial & antrhopogenic super-imposed elements (infrastructures, city plans, planning directives etc). Historic urban ecotones that have appeared early in the evolution of cities (as in the case of city-wall ecotones) can thus hold key evidence (morphological & phenomenological) of the distinct and successive phases of urban expansion, as manifested in the built environment and the respective social fabric of the areas involved. Contemporary ecotones can accordingly hold accordingly special value for highlighting tendencial behaviours or acute phenomenas related to specific events or impluses, especially the ones in contact with natural areas, or areas of special attention (social, economic ...). The recognition of certain morphological / typological (industrial buildings, shopping malls, informal / illegal housing) and functional traits are evidence of typological manifestations and heterogenization of the city evolution, each ultimately tied to certain historic phases. The respective forces and dynamics that gave rise to each phase, accordingly conditions the form, function and succession / transformation phases of these ecotonal areas. The importance of the presence of a (potential) structural element is key for maintaining a territorial evolutionary coherence and common reference for development. The differentiation in each successive phase depends on a variety of factors linked to each historic phase and ultimately related to the social metabolism of the territory with its spatial tangible and intangible manifestations as well as more general socio-economic conditions or historic events.

RQ4. Thinking / imagining in ways that urban ecotones can function as territorial interfaces, one needs to consider in which ways they can facilitate integration of urban biomes / ecosystems within the wider territorial ecological matrix and also the functional / operation links that connect urban ecotones with the wider urban metabolism scheme and the overall territorial efficiency? It is interesting to consider ways that humans have affected, taken advantage and or have maintained and restored ecotonal areas in the past consciously or unconsciously. What has been and what can be the role of the ecotones in the management and restoration of a changing environments, and more precisely what potential do they hold with respect to urban fabrics? How can the diversity of flows associated with urban ecotones respond to environmental, socioeconomic and development changes, in terms of climate, land use and atmospheric processes ?

This theoretical and practical exercise of contemplating urban ecotones as territorial interfaces, that is as *reprogrammable, three-dimensional territorial membranes* implies the possibility and capacity to be able to intentionally modify or adapt their functioning and structure (momentarily or long-term) to suit accordingly the set goals and desired effect envisioned in each case. Examples of such programmable urban interfaces have historically appeared and been utilized in traditional top-down planning to achieve segregation and separation of urban fabrics, configuring them as limits or selective barriers, and ultimately producing fragmented and disassociated urban fabrics. Nevertheless traditional settlements also took advantage and modified to their benefit these areas in a diversity of cultural contexts. The updated contemporary understanding of cities and ecology of cities in general (comprehending the autopoetic properties and organic complexity of the territory), gives an added value to urban ecotones, given the fact that they can interact with and control a wide range of urban flows ranging from natural to antrhopogenic (*selective permeability*), and in this way be presented with the potential to mend territorial misconfigurations / conflicts or evenmore enhance urban complexity and interaction between the urban artefact and the natural regional backdrop (*biophysical matrix*), and between apparently heterogeneous urban fabrics, increasing the overall organization level of the territory and respectively territorial efficiency. They can accordingly control urban energy dissipation, especially along urban-natural edges, minimizing negative impacts and producing threshold situations that can synergitically work with natural systems. In this way, ecotones emerge as powerful analysis and planning tools that when viewed in the territorial context can efficiently and integrally reconfigure / reprogramme the obsolete, latent or conflictive urban fabrics. At the same time their potential joint consideration as a regional structure, a region-wide network of interconnected and interrelated interfaces, can have a positive effect not only on their individual function but also the entirety of the urban region (function + structure).

RQ5. At what spatial and temporal scales are research results most useful for decision-making and management purposes? Is there a predictable pattern to dynamic change / shift in ecotones? Under natural / anthropogenic conditions ? What are the characteristics and processes of ecotones that are sensitive to changes in the global environment? Can we make reference to certain types of ecotones intrinsically linked to mediterranean cities & processes?

When considering the question of scale in relation with anthropogenic ecotones, the importance of the *sliding between scales* methodology is made imperative especially when taking into consideration the *scaling* properties of cities and thus respectively of ecotonal areas. A potentially interesting future research perspective could investigate the relation between the scaling properties of cities (in terms of size, metabolism, characteristics etc) and the emergence of urban ecotones. Accordingly, urban ecotones should be analysed and planned in a multi-scalar manner, including in the considerations a wide spectrum of spatial and time scales. The amplitude of this spectrum should extend to include all elements that are relevant to the design goals as well as socio-ecological sensibilities of each territorial context and project in question. The more detailed the lecture of these ecotonal areas, the richer respectively the complexity features that can be identified and thus the conclusions and results that

can be produced. Indeed after more than a century of development of a theoretical body of the so called city-science, there are certain predictable growth patterns (urban morphologies, typologies), that have been identified and categorized, that can appear along urban ecotones or city edges and can help foretell the future dynamics and changes taking place, utilizing principally morphological criteria. And since ecotones are the areas where these changes principally take place, or at least are manifested more pronounced, they can serve as valuable spatial indicators for identifying signs of urban explosion, implosion, misfunction or other respective phenomena. This concept as seen can be applicable both to anthropogenic or natural ecotones, always taking into account the special and intrinsic characteristics of each system. The appearance / disappearance of certain building typologies, change or introduction of new uses, social fabric re-configuration, stress signs or in more general terms an increase in energy dissipation or intensity of activity can all be signs of upcoming or concurrent changes / dynamics. The way that these dynamics can affect specific components of the ecotone or its overall structure and function depends greatly on the character, intensity and duration of the perturbation.

In the context of the mediterranean city paradigm, there are certain types of urban ecotonal situations that are characteristically repeated all throughout the mediterranean basin. The city walls of the fortified city, the industrial city fringe with the introduction of new activities and building typologies, the exploded city in contrast with the agro-mosaic backdrop, the coastline and the port-city relation among others. The shared historical and cultural traits developed over milenias as well as the contemporary forces of liberalization and economic rule, have accordingly shaped the mediterranean cities and respective cultures, marking a common co-walked path that when looked individually (in each case-study) or in the mediterranean context (as a shared cultural trait) offer us updated and revisited knowledge for enriching and comprehending in more depth the meditterranean city as a paradigm through the changes and transformations experienced over history and space.

HY. An urban ecotone is the transition area between at least two distinct urban biomes / biotopes of differentiated characteristics (morphological, socio-economic, typological etc), where this ecotonal space is characterized by a pronounced edge effect, in terms of intensity and diversity of activity, a set of defined spatial (length, shape) and time (rhythm, history) characteristics restricted to the ecotonal area but ultimately linked to the adjacent patches´ internal dynamics. The ecotone thus lies on a critical / inflection point of intersection between different fields or levels of social organization, and along which the social discontinuities based upon discrepancies in values, interests, knowledge and power, are most likely to be located and manifested.

The concept of the urban ecotone, updated and enriched in terms of definition and understanding through the theoretical and case-study analysis, is now understood as a four-dimensional manifestation of urban and territorial dynamics. A conceptual, invisible membrane that can enhance as well as inhibit territorial efficiency based on the handling and management of corresponding flows that drive the socio-ecological differentiation of adjacent patches. The co-relation between efficiency in the societal use of energy, land-use management and the environmental quality of ecosystem functioning of the land matrix creates a three-way relationship, with a critical environmento-historical perspective. In the contemporary mosaic city there is an evergrowing number of information carriers and interactions taking place, that when viewed in their totality, reveal an enriched territorial complexity, that often passes unperceived when focusing on homogeneous urban patches. or when projecting monofunctional areas / zones. The added implied complexity utilized for describing these concepts permits to open ground for conceptual advancements in urban and territorial theory and thinking. At the same time aids in establishing criteria for identifying the driving forces and dynamics behind city growth and respectively ecotone behaviour, thus offering tips and projectual logics for a more sustainable land-use planning and growth management. Above all it can open up the debate on the inhibited potential of contemporary cities.

The extrapolation of the results of the case study of Thessaloniki to further case studies, both on a mediterranean as well as international level, and their respective comparison can help to further test the formentioned results / conclusions and enrich the overall understanding on urban ecotones and ecotones in general. Thus a compilation of a database of respective analyses & experiences of ecotones in different urban contexts is highly recommendable as a future direction for further research advancement. Nevertheless, the recognition and understanding of the ecotones as products of the socio-ecological metabolism of a territory adds to the concept of mosaic heterogeneity an added value, at least as far as our perception of the territorial processes goes. The concept of the territorial mosaic city as a city of interfaces or better said a ***city-network of interfaces***, emerges as an adequate model for interpreting contemporary urban mosaic dynamics and for comfortably embracing the concept of complexity within the city-science body of theory. A lot of arguments can be made in favour or against the assumptions and conclusions set forth by this paper, but one that can be undeniably accepted is the fact that the ecotonal analysis and thus the comparative analysis of heterogeneous patches, can highlight an increased complexity not perceived / appreciated when looking exclusively homogeneous structures / systems. This implied and suggested complexity that ecotone analysis can make emerge is also probably one of the key contribution in the advancement of the theoretical discourse of urban complexity and ecology of cities.

Epilogue
On the city as a collective work of art

"It is perhaps safe to say that the modern practice of town-planning ... would have been a much simpler thing if it had not been for Geddes. There was a time when it seemed only necessary to shake up in a bottle the German town-extension plan, the Parisian Boulevard and Vista, and the English Garden Village, to produce a mechanical mixture which might be applied... to every town in the country; thus it would be "town-planned" according to the most up-to-date notions. Pleasing dream! First shattered by Geddes as he emerged from his Outlook Tower in the frozen north, to produce that nightmare of complexity, the Edinburgh Room at the great Town Planning Exhibition of 1910."

Patrick Abercrombie

Indeed the city, as a human artefact, has been compared to many different and apparently resembling systems such as ecosystems, machines, brains, archipelagos or even constellation of stars; that is to say, utilizing either a mechanistic or an organic simile, or a combination of the two in many cases, to describe relevant to each case processes. All attempts valid, as attempts of interpretation, but not necessarily as attempts for a systematization of knowledge. The advancement and refinement of system theory sciences and the resulting increase of interest in complexity and complex systems in general, was naturally expected to touch the urban realm and processes sooner or later. Ecological systems, biological or ecosystemical, were the first to looked at in a systematic way, taking on with the pace a more spatial approach and attention to the territorial context. If we are to appreciate, or even start by comprehending cities as complex systems we need to be aware of the special characteristics of what makes a city.

Indeed a city can demonstrate many of the characteristics mentioned earlier, that is to say ecosystemic, mechanic or electromagnetic behaviours present in other systems, but what renders it completely different from others is the socio-economic vector/-s intrinsically present in its functioning. This results in the superposition / juxtaposition of an increased complexity and organisational system on top of the existing systems of the biophysical matrix of the territory. Apart from the higher (internal) organization that they convey, cities are also energy dissipative systems, releasing varying amounts of energy in their surroundings, which accordingly can create new structures, or provoke the respective collapse of others. The intermediate perturbation hypothesis is an appropriate starting point for reconsidering contemporary cities in terms of efficiency and of integrating the socio-economic systemic functions to the biophysical matrix and its respective carrying capacity, always considering the multiplicity of scales, layers and situations present in such cases.

It is becoming increasingly common to see the comparison of the city, in all its artificiality, to a living object, an organism. Recent advancement and studies on cities have highlighted a series of common traits, universal properties, present in all cities on an international level. Cities do metabolize energy and convert it to suitable forms and systems through an extensive and complex network infrastructure. And respectively cities follow certain rules of *physiology*; presenting an economy of scale in many of their aspects. Cities thus do scale - and so do many of their features, whether physiological or socioeconomical, indeed we can talk of an urban allometry property. What is important is to be able to comprehend how to scale complex organizational structures for cities in growth or accordingly in degrowth. An emerging city science trying to deal with the question of city in a holistic and systematic way thus needs to be accompanied by a coherent body of theory behind it and a series of testable hypotheses that demonstrate the shared structural and functional features of cities. Implicit in this consideration is also the perception and comprehension of the city as a socioeconomic reactor and attractor that create complex, apparently chaotic, relationships and resulting dynamics. The introduction of scaling arguments can lead to a deeper understanding of the dynamics of tipping points and phase transistions present in urban processes. The concept of the ecotone, translated in the urban context, is such an intent to read and comprehend these dynamics interrelating apparently heterogeneous systems. The intrinsic property of ecotones, of an increased diversity and intensity of edge activity, can thus be key in fostering interaction and even innovation in urban areas when managed properly. In this context, and in combination with a pro-active character (related with the planning practice and theory), emerges the conceptual shift of the ecotones as spatial interfaces.

The conceptual vehicle of the ecotone as a spatial interface is valuable because it implies a parallel shift from a mere consideration of spatial scales to the questions of relationships that appear between heterogeneous patches / structures, developing in this way a network of multiple and simultaneous peer-to-peer relations taking place within the regional mosaic. These relations, thus, do not necessarily correspond to strict morphological criteria but can also include non-physical structures and relationships of a phenomenological nature. Which brings up the question of the potential role that ecotonal areas can have as reprogrammable interfaces; what sort of urban model / ideal do they follow, and what can be their specific functions in order to achieve the desirable effect. Do they affect territorial efficiency? do the knit together a more complex fabric? do they present opportunities for restructuration, and meaningful planning interventions? Interventions that work with and in favour of the local fabric and its residents. This paper has tried to support all the above points without ignoring the open-endedness of the research topic in hand.

The city-science discipline has been revolutionized recently by the emergence of city-data systems with the respective open and big data information flows and the diverse visualization tools utilized for representing and ultimately interpreting and comprehending urban dynamics. Real time and dynamic data can benefit greatly research on ecotones, considering their intrinsic dynamic character, and help advance the current understanding on their function and structure. By demystifying complexity, decomposing it and giving it an added value now understood as knowledge and information we can indeed start to delve into real and significant dynamic analysis of contemporary urban regions. Accordingly our understanding of urban ecotones can benefit greatly from the utilization of these technologies and their respective rapid advancemnet. So thus, purposefully, this paper has not entered into qualitative analyses, with the respective development of indicators and measurements, but instead has opted for a more qualitative and phenomenological approach in its analyses. Analyses that consciously avoid the sectorial vision of the city and aim for an integral, complex and representative vision of urban reality. A quantitative analysis would need to be a separate effort alltogether, preferably with a comparative character of diverse urban experiences and contexts.

This paper has respectively aimed at a theoretical advancement on the concept of ecotones and their application in the urban context, ultimatelly aiming to enhance the contemporary perspective, science and vision for our cities as rich and complex systems. An enriched vision that can bestow a potentially higher level of organization for cities and respectively a higher structural resilience, set forth as an ultimate and pragmatic goal for cities worldwide. The quantitative confirmation of these theoretical models can today be tested adequately utilizing the prementioned city-data technologies that allow for a real time monitoring of processes and dynamics. When we collectively manage to merge a coherent theoretical body, with testeable hypotheses and with adequate predictive and computational models that collectively express societal goals and aspirations, all in conjuction with a efficient management, then we will be able to complement the traditional city science discipline from a vast theoretical field into a holistic and coherent science. Cities are social catalysts that foster social interaction and innovation, productivity but at the same time pollution, resource depletion and social unrest. There is a duality in the urgency to face the urban question. The city is simultaneously the problem and the solution. A historical standpoint marking a departure but also a destination, the understanding and expression of the city, paraphrasing Mumford, as a *collective work of art*.

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