Landscape Bionomics: a systemic approach to understand and govern territorial development

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Abstract: The increasing importance of environmental studies brings even biology to a change in the scientific paradigm. That means a passage from reductionism to a systemic approach and shows the limits of many branches of biology, mainly genetics, ecology and medicine. New disciplines arose to upgrade these limits, as Epigenetics, Psycho-Neuro-Endocrine-Immunology and recently Bionomics. The discipline of Ecology or *"Speech on our House"* is necessary, but not sufficient: we need also Bionomics or "*Doctrine of the Laws of Life Organisation on the Earth*". The Landscape Bionomics (LB) concerns the space-time-information territorial scale, recognising landscape as a peculiar biological level, so a living entity. Therefore, new perspectives appear in vegetation science, in agroecology, in territorial planning and nature conservation. Moreover, LB is able to indicate a human health risk factor due to bionomic alterations (even without pollution). So, a new figure of man-environmental physician emerges as *Ecoiatra*.

Key Words: scientific paradigm, ecology, bionomics, landscape, vegetation science, agroecology, territorial planning, human health

1 Introduction

The old scientific paradigm was mainly reductionist, anchored to reversible processes, to the Darwinian struggle for existence, leaving few space to multidisciplinarity. The new one derives from the necessity to upgrade the dichotomy between nature and culture, limiting the reductionism and studying complex systems. Holism, symbiosis and cooperation, irreversible processes and trans-disciplinarity characterise this new paradigm.

While Physics started to change the scientific paradigm in the first half of past century, after the works of Pauli and Einstein on Quantum Mechanics and General Relativity, Biology has been remaining blocked since the end of the century, due to the "dogma of biology", imposed after the discover of DNA [1] and to the dominion of Neo-Darwinism. This delay to follow the new paradigm brought biology towards many limits, from micro to macro scale.

Some examples: (a) the surprising result of the human genome study, as expressed by the Nobel David Baltimore: "It is clear that we do not gain our undoubted complexity over worms and plants by using more genes" [2]; (b) the dogma of hematic-encephalic barrier and the fixity of brain tissue, recently destroyed by the demonstration of hormone and immune cells circulation in brain; (c) the ambiguity of the concept of ecosystem, as expressed by O'Neil [3] recognising the disruption between the biotic Vs. functional view, so that ecosystem and community analysis can not be integrated; (d) the failing of "green revolution" paradigm, not able to save the natural resources because of an excess of simplification of agricultural landscapes.

Pioneers scientists tried to anticipate the change of the paradigm, but often without success: we may remember Camillo Golgi [4] who insisted on the crucial function of neuronal network; Hans Selye [5] who discovered the "General Adaptation Syndrome" and the importance of the stress in etiopatholoy; Conrad H. Waddington [6] who started to study epigenetics; Richard Forman and Zev Naveh [7, 8] who started to study landscape ecology; Stephen R. Gliessman [9], who wrote the first important book on agroecology.

The new discipline of Bionomics derived from pioneer studies of Ingegnoli [10,11,12] and discussions together with Forman and Naveh, within which the landscape was recognized as living entity in the field of "Biological-Integrated Landscape Ecology" [13] recently re-named as "Landscape Bionomics" [14, 15]. It refers to the theory of complex systems, which can renew all the biological disciplines. The attempt to understand the behaviour of a landscape elaborating its thematic components meta-data (i.e. species, soils, human activities, hydrology, geomorphology, etc.), even with the help of GIS mapping and statistic controls, is without hope. The Principle of Emergent Properties [16] demonstrated the necessity of a top-down criterion of observation to enlighten and preserve the new acquired systemic properties. C.H. Waddington [6], wrote: "If we want to understand complex problems, that are controlled by causal networks and by web of causal networks, we must have from the beginnings a general idea of the functioning of the entire system, before examining it in detail".

This new vision, carried by Landscape Bionomics, inevitably leads to significant changes in how to assess and manage the environment. So, after a synthesis on the principles and methods of Landscape Bionomics (LB), we may review the new perspectives in Agroecology, Health/Environment and Territorial Planning.

2 Theory and Methods

2.1 Main concepts of Bionomics

Life is a complex self-organising self-transcendent dynamic metastable system [8], able to perceive, to process and transfer information, to follow rules of correspondence among independent worlds (coding), to reach a target, to reproduce itself, to have an history and to participate in the process of evolution [13,15]. Life on the Earth is organised as a space-time-information hierarchical system.

Processes allowing the definition of life are *exportable* characters: each specific biological level expresses a process in a *proper* way, depending on its scale, structure, functions and amount of information. Each system which presents *proper* characters is an *entity*, and we can find *emergent* properties characterizing cell, organism, population, ecocoenotope, landscape, ecoregion, ecosphere.

Studying the real environment at different scales one must remember that *each ecological system* includes both a biological element and its environment. Conversely, it is easy to note (Tab.1) the existence of four parallel hierarchies, respectively based on the biotic viewpoint, on the functional viewpoint, on the spatial (configuration) viewpoint and on the cultural/economic viewpoint. So, to understand real living entities these criteria have to be integrated (Tab.1- last right column).

2.2 Synthesis of Landscape Bionomics

Landscape Bionomics (a) recognizes 'ecological units' of the territory as living entities composed by a complex integration of natural and human systems and (b) studies its physiology and pathology through a quali-quantitative clinical-diagnostic approach.

In summary, we have to underline that:

a) the landscape *is a proper biological system*, as a level of hierarchical organisation of life on Earth*;* thus,
b) the landscape *is a complex, adaptive, dynamic, self-organising, hierarchical system*;
c) its complex structural model can be based on the concept of tissue, thus being named *ecotissue* [13] (related concept ecocoenotope);
d) landscape bionomics has to be considered as *a discipline like medicine*, biologically based and trans-disciplinary.
e) a landscape scientist, whom we call "*ecoiatra*", can be properly compared with a physician of a wider and more complex level of life. Note that we have to study the *landscape pathologies*, but also their *influence on human health*, which may be dangerous *even in absence of pollution;*
f) cultural changes of landscapes, in many cases, express natural needs, as we may demonstrate;
g) territorial planning becomes a *project for surgical operations*, even in the case of "aesthetic surgery", and process of strategic environmental assessment as the *related indispensable check-up*, necessary to verify contingent therapy and the capability of the involved subject to survive to the operations without damage.

Being the landscape a biological level, *it is the physiology/pathology ratio which permits a clinical diagnosis of the landscape*, after a good analysis and anamnesis. No doubt that landscape bionomics has its own predictive theory, nevertheless, it is necessary to develop this discipline not as a simple predictive science, but also as a *prescriptive* one – again just like medicine.

The main theoretical chapters of Landscape Bionomics may be summarized as follows:

(a) anatomy and physiology of the landscape, i.e. its structure, functions and classification;
(b) transformations and pathologies of the landscape, focused on the normality-alteration ratio;
(c) analysis of the vegetation cover of the landscape unit (L.U.), based on LaBiSV (Landscape

Bionomics Survey of Vegetation, *sensu* Ingegnoli e Pignatti [17];

(d) analysis of the relations between animal populations and the landscape, based on LaBiSF (Landscape Bionomics Survey of Fauna) [15];

(e) analysis of the relations between human population and the landscape from an ecological point of view, following the LaBiSHH (Landscape Bionomics Survey of Human Habitat [15];

(f) general and bionomic landscape analysis, which propose peculiar landscape indexes of structure and dynamics;

(g) historical evaluation of the landscape, indispensable after the possible ways of development (e.g. " bifurcations") due to non-equilibrium thermodynamics;

(h) diagnostic evaluation of the landscape, in the sense of a "physician approach" to a l andscape unit (LU), arriving to indicate therapeutic rehabilitation criteria and projects;

(i) landscape evaluation, design and planning applications;

(j) applications in agroecology and in the relation between human health and environmental alteration.

For more details we suggest to refer to the book of "*Landscape Bionomics, Biological-Integrated Landscape Ecology*" [15] with the foreword of Sandro Pignatti. Anyway, we synthetically propose some significant systemic functions.

2.3 Basilar systemic functions

At present-day, the two main components acting and interacting within a landscape are the autotrophic one (vegetation) and the heterotrophic one (human population). Focusing on t hem, two main systemic functions arise (the *BTC* and the *Human Habitat*) and may be observed in their relation (*HH/BTC model).*

The biologic territorial capacity of vegetation (BTC)

$$BTC_i = (a_i + b_i)\, R_i\ w$$

is a function of vegetation, expressed as a flux of dissipative energy (*Mcal/m²/year)*, linked to:

1) the principal *types of vegetation communities;*

2) their *metabolic data* (biomass, gross primary production, respiration, B, R/GP, R/B), elaborating the coefficient $a_i = (R/GP)_i / (R/GP)_{max}$ which measures the degree of the relative metabolic capacity of principal vegetation communities [13]:

3) the *metastability* of vegetation [8, 18], based on the concept of resistance stability [19, 20], through the coefficient $b_i = (dS/S)_{min}/(dS/S)_i$ which measures the degree of the relative antithermic (i.e. order) maintenance of the same main vegetation communities.

The HH, human habitat function, evaluates in a proper bionomic way the set of areas:

(a) where human population lives,

(b) which is managed permanently,

(c) in which subsidiary energy is added

(d) limiting the self-regulation capacity of natural systems (NH).

As shown in Figure 2, the function of correlation *HH/BTC*

$$y = 0.0007x^2\ 0.1518x + 8.85 \quad [R^2= 0.95]$$

derived from the correlation HH/BTC of 45 landscape units in North Italy and Central EU can be used as a model and allows us to define the most frequent thresholds of characterisation of the main types of landscape. In this figure, from the left we see: agricultural landscape, suburban-rural, urban-open, urban-dense.

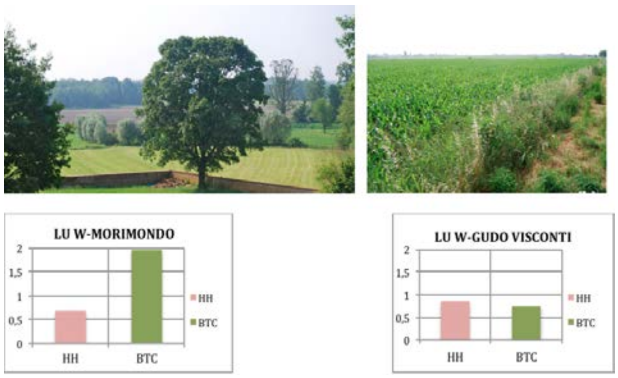

Fig. 1. *Agricultural landscapes: (a) in Morimondo with an acceptable beauty value, as confirmed by the good level of its BTC; (b) in Gudo Visconti with a scarce beauty value, worst level of its BTC (agricultural land mean BTC value in Lombardy is 1.1-1.3 Mcal/m²/yr); HH= human habitat (% of Land Unit LU).*

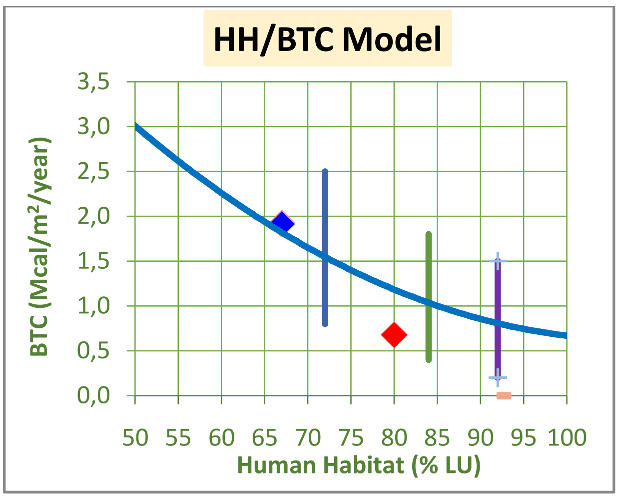

Fig. 2. *The HH/BTC model for Temperate Belt. Points*

are referred to Fig. 1 (a, b).

The prevalent importance of vegetation components in a landscape has been emphasized by many scientists, which underlined the necessity to renew vegetation science, because of the limitations in studying a complex system using old geobotanical concepts [21]. The LaBiSV methodology (Landscape Bionomics Survey of Vegetation) has been proposed to respond to these assertions. Other new systemic functions and indexes, such as the CBSt (the Efficiency of Vegetation Index) and the bQ (the Bionomic Quality), have been elaborated. The LaBiSV method [13, 15, 22, 23, 17] may be synthetized in a *frame protocol*, articulated in 12 main phases and linked to a model like Fig. 3 per each phytocoenosis type.

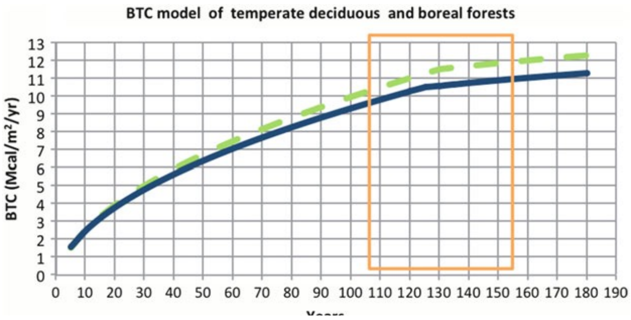

Fig. 3. *Model of the development of temperate (green broken line) and boreal (blue) forests. Theoretical and field studies on these types of vegetation show these two exponential-logarithmic curves of development. The threshold between adult-mature and m ature-old phases is respectively 10.5 or 11.5 Mcal/m^2/year.*

Similarly, very interesting models arise relating HH to the Standard Habitat per capita (SH) function and the concept of Landscape Apparatuses or with the Living System Carrying Capacity (σ) and the g-LM (General Landscape Metastability) (see [13,15]).

2.4 The screening of the bionomic state of a LU

Being the landscape units recognized as living entities, the main landscape syndrome categories are shown in Tab. 2.

Tab.2. Main landscape syndromes categories and sub-categories

Main landscape syndrome categories	Sub-categories of syndromes
A- Structural alterations	A1- Landscape element anomalies A2- Spatial configuration problems A3- Functional configuration problems A4- Multiple structural degradation
B- Functional alterations	B1- Geobiological alterations B2- Structurally dependent dysfunctions B3- Delimitation problems B4- Movement and flux dysfunctions B5- Information anomalies B6- Reproduction problems B7- Multiple dysfunctions
C- Transformation syndromes	C1- Stability problems C2- Changing process dysfunctions C3- Anomalies in transformation modalities C4- Complex transformation syndrome
D- Catastrophic perturbations	D1- Natural disasters D2- Human-made destruction
E- Pollution degradations	E1- Direct pollution E2- Indirect pollution
F- Complex multiple syndromes	F1- Acute F2- Chronic

Following a clinical-diagnostic method, explicated and discussed in [15], thus referring to the concept of normality ranges for each bionomic and ecological parameter, and relating them trough a hierarchical trans-disciplinary approach, it is possible to put in evidence the *bionomic states* of the examined landscape units and to quantitatively estimate it through a Diagnostic Index. As shown in Fig. 4, this methodology permits us to evaluate and compare different future scenarios too.

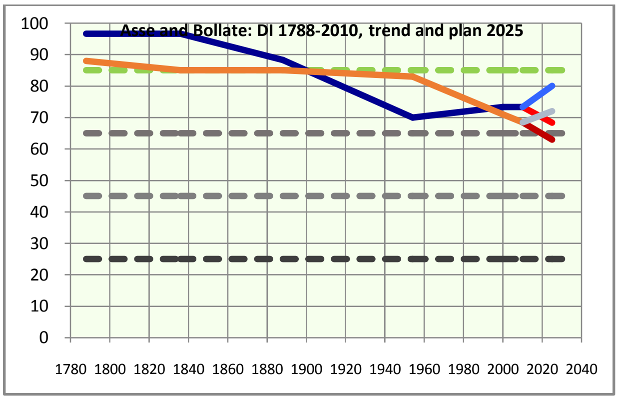

Fig. 4. *The dynamics of DI (Diagnostic Index) applied to the LU of Asse (Belgium) in orange and Bollate (Lombardy) in dark-blue, since 1780. The five belts represent the diagnostic evaluations (from the bottom: extinction, severe dysfunction, dysfunction, alteration, normality).*

3 Understand and Govern Territorial Development

3.1 Agroecology

This recent discipline is based on the ecological knowledge applied to the governance of agricultural systems, trying to minimize external inputs. In facts, from the interactions among vegetation, fauna and bacteria at different space-temporal scales it is possible to avoid a wide input of fertilisers and pesticides. Moreover, agroecology promotes family farms, local supply chains, product quality and knowledge 'tacit'. So, it promotes fully sustainable food and agricultural systems in environmental, economic and social way. The recent association 'Agroecology Europe' wants to reinforce the interactions among various agents in relation to the research, to the application and to social movements which sustain agroecology. As written by Stefano Bocchi [25] about the innovation strategies, agroecology must be trans-disciplinary and have to consider the entire complex system of its territory, following landscape bionomics principles.

The problem is that, today, agroecology is linked to conventional ecology and following this vision it is impossible to evaluate the bionomics state of an agricultural landscape. We would have to pass from the old concept of ecosystem to the new one of *ecotissue*, from the concept of 'stability through constancy' to '*stability through change*', from reductionist parameters (e.g. LAI) to systemic one (e.g. BTC), from health defence only related to pollution to a *defence related to bionomics dysfunction*, etc.

Remember that cultivations are linked with food and health; diet is, in reverse, linked with the environment too. Therefore, to recognize the health state of an agricultural landscape could be very important, e.g. the comparison between conventional and biological agriculture in term of landscape unit functions.

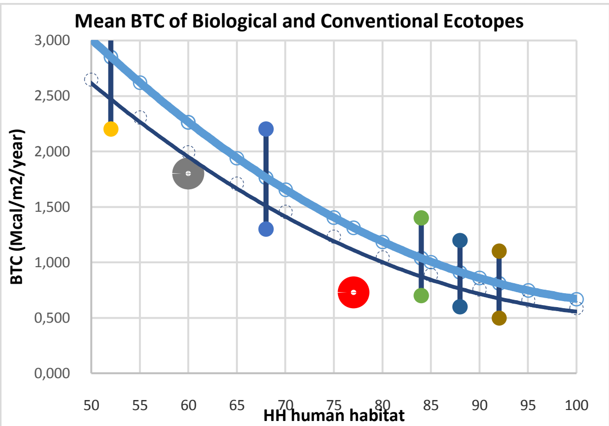

Fig. 5*. Comparison between the BTC and H H parameters of Conventional (red) and Biological (grey) Agro-Ecotopes in Albairate (Milan). Note the distance from the dotted line of tolerance.*

In Fig. 5 we expose the differences between the biological and conventional (red) agro-ecotopes in Albairate (Milan). Note the different BF (Bionomics Functionality): the first is BF = 0.86 (near the tolerance) while the second is BF = 0.65 (out).

3.2 Health/Environment

W.H.O. reports consider pollution, occupational risks, food alteration and built areas as environmental factors influencing our health. Few studies address Landscape dysfunction and human health: their results are uncertain because of the insufficient evaluations of landscape disorders. The growing importance of risk factors in medicine and the new ecological advancements in landscape diagnosis impose to deepen these studies.

As we asserted before, Landscape Bionomics recognizes 'land units' (LU) as living entities, studying their physiology, (e.g. metastability, biologic functions) and pathology (e.g. diagnostic index) and renewing vegetation science, allowing to express systemic estimations, therefore valid correlation, with other basilar landscape elements. Therefore, the simple surface ratio "green space/urbanisation" [29], can be substituted with systemic models e.g. HH/BTC. Following this method, we investigated the ecologic parameters of 72 municipalities near Milan forming a gradient from the dense urban landscape to the agricultural one, all with similar pollution intensity. The correlation bionomic degradation vs. mortality rates was investigated.

A clear increase of mortality rate MR [x 1000] is correlated (Fig. 6) with the increase of landscape dysfunction: we pass from MR = 7.64 in non altered landscapes (BF = 1.0) to MR = 9.5 in landscape with a deprivation of 50% (BF = 0.50) of the normal state. Even the population age (PA) is growing with the degradation of the LU, but the increase of MR is more than 4 times the increase of PA. The raise of MR with Landscape degradation is mainly due to other physiologic processes.

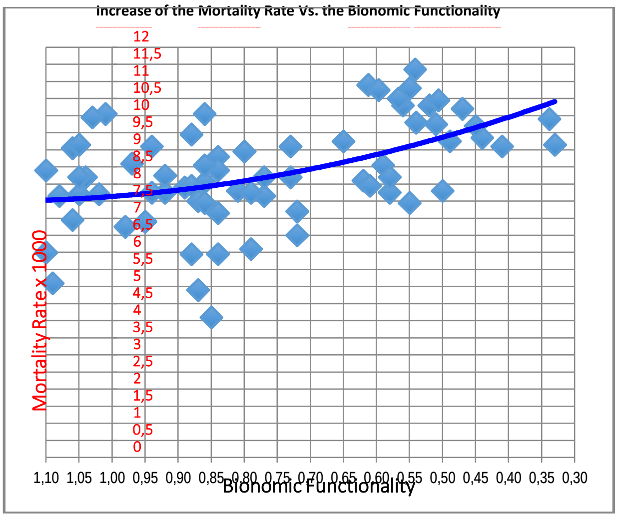

Fig. 6. *Correlation MR = f (BF) in 72 LU of the Milano-Monza (MI-MB) Area. The Pearson Coefficient is twice the minimum values of significance.*

Bionomics theory has previewed a process like this [13]. A basilar ethological alarm process registers all the environmental alterations producing stress. So, landscape dysfunctions, even in absence of pollution, may attempt our health bringing to an excess of cortisol, which reduces our hormonal, immune and nervous system defences [26, 27, 28]. This may enlarge the W.H.O. estimation of the environmental MR and the importance of applications impose a true effort in landscape rehabilitation.

3.3 Territorial Planning

Today, “urban and territorial planning” is the dominating discipline, which can be marginally implemented by economy and ecology. Hence, together with the SEA (Strategic Environmental Assessment), this planning is largely practised by architects and engineers, technicians not sufficiently skilled in biological disciplines.

At LU scale, the scheme is quite simple: a set of human and natural components is analysed at present (ex ante), its inputs contribute to the design of a preliminary plan. This draft plan is controlled through SEA methods, evaluating potential “ex post” impacts and upper scale plan adequacy. SEA results, correcting the draft plan, allow the design of the final plan and its monitoring. Thus, after the analysis of the existent situation of the landscape (territory), a preliminary plan is composed. The environmental aspects are considered, but they remain limited to pollution levels, recreational and ecosystem services and rare biotope preservation. Functions are, first of all, intended as socio-economics. No adaptive complex system and no one of its emergent properties are considered. Rarely (or not properly) is even evaluated the historical- ecological dynamics of the landscape system. Landscape ecology started to change the present vision [30, 31, 32].

Conversely, in a Landscape Bionomics vision [15], disciplinary and theoretical elaborations and practices derive from (a) Urban and Territorial Planning and (b) from Landscape Bionomics. Consequently, at least two professional figures have to cooperate: the “ecoiatra” and the urban planner. Note that the formation of the ecoiatra cannot be the same of the planner (architect or engineer), but it must be, first of all, based on advanced natural and agrarian sciences, biologically integrated. The main phases of the process, guided by LB, have to be dynamic, enlarging historical methodologies to the entire landscape system. Analysis and diagnosis are conceptually separated, but in fact they need iterative processes. The LU have to be delimited even in the same municipality, strictly following bionomic criteria. To better understand the planning processes, we need to focalise a list of arguments concerning (I) landscape analysis, (II) landscape diagnosis, (III) landscape planning and (IV) SEA.

As already underlined (see 2.1) we must remember that the first aim of planning is linked with the therapeutic functions which follow the diagnostic assessment of the LU. If you go to Fig.4. you can appreciate the crucial role of planning to change the trend of Diagnostic Index towards degradation, decreasing bionomic dysfunctions. All that changes also the concept of sustainability, because –first- we must heal the landscape syndromes before planning social-economics aspects, either wise we damage the human health dependent on bionomics dysfunctions; -second- we have always to remember that we, and sustainability, deal with territories as living systems, thus evolving ones.

4 Conclusion

The aims of this short work is only introductive, to underline the importance of the new discipline of Landscape Bionomics. This discipline, developed following the new scientific paradigm, brings many changes both in theory and application of bio-environmental studies, because of the systemic vision due to the recognition of the landscape units as living entities.

A lot of works should be done to widening the principles and methods of LB, especially trying to renew the main fields here only mentioned: first of all agroecology, health/environment relations, territorial planning, but also vegetation science and the relationships between ecology and economy.

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Tab. 1. Hierarchical levels of biological organisation on the Earth

SCALE	BIOTIC Viewpoint*	FUNCTIONAL Viewpoint**	SPATIAL CONFIGUR. Viewpoint***	ECONOMIC & CULTURAL Viewpoint****	**INTEGRATED** Viewpoint ***LIVING ENTITIES***
Singular	Organism	Organism niche	Living space	individual	Meta-organism
Stationary	Population	Population niche	Habitat	Cultural site	Meta-population
Local	Community	Ecosystem	Micro-chore	Historic or Economic	Ecocoenotope
Territorial	Set of communities	Set of ecosystems	Chore	Historic-cultural Economic L.	**Landscape**
Regional	Biome	Biogeographic system	Macro-chore	Historic-cultural regional economy	Ecoregion
Global	Biosphere	Ecosphere	Geosphere	Noosphere and Global economy	Ecobiogeosphere°

* biological & general-ecological criterium; ** traditional ecological criterium; ***not only a topographic, but also a systemic criterium (Cfr. Emergent Property Principle);****cultural as a synthesis of anthropic signs and elements; ° "Gaia Hypothesis"…