# LOCAL MODELS OF LAND USE & LAND COVER CHANGE ANALYSIS. THE CASE OF RIDAURA SESSILE OAK FORESTLAND (NATURAL PARK OF MONTSENY. BARCELONA)

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**Introduction: Perception of environmental changes and the Global Environmental Science**

Relations between humans and environment had been characterized since the origins of mankind by the transformation, especially since the Neolithic period and the first agrarian works[1]; other authors located the origin of marked environmental changes in the connection between Europe and America[2]. Nevertheless, the historic episode identified like the beginning of deep environmental changes linked to human activity was the Industrial Revolution. In this period biophysical factors' importance decreased in relation to socioeconomic elements (demographic trends, technological changes, etc.) like key elements in global change processes.

Since consumption model's generalization and consolidation initiated by the Industrial Revolution thinking currents that reported first environmental alterations signs arose; an example was Rachel Carson's "*Silent Spring*" (1962), one critic to development model in force from the analysis of pesticide hazard. In this scenario of global environmental crisis, where humans have exceeded their environmental transformation capacity (an underlying critic since thirties that reached its climax during 1973 and 1974s energy crisis), the Negative Anthropocentric point of view of understanding society and environment relations, where technocratic (Positive Anthropocentrism) arguments were considered erroneous and humans were pointed out like planet's problems reason, became important. The denunciation of *Exceptionalist Paradigm's* (called *Human Exemptionalist Paradigm* later) fragility, where humans controlled environmental elements, supposed the replace of the three classic approaches and the transition to the *New Ecological Paradigm*[3], where humans, considered as an exceptional specie, were dependents of a global system, produced environmental consequences and kept landscapes beyond their carrying capacity.

Related to this change of paradigm, ethic positions that emphasize value of nature per se and ecological laws of human rights and morals arose too. Some examples were the *Egocentric Environmentalism*[4] and other points of view where humans, like industrial society actors, were the cause of environmental disorders and without them new natural and harmonic orders could be possible, like Deep Ecology ideas[5]. The validity of this image of virgin landscapes (*Wilderness*) and without humans has been criticized by some authors and called *The Green*

[1] González Bernáldez, in Turner II *et al*.1995
[2] Gómez Sal, in Turner II *et al*.1995
[3] Catton & Dunlap, 1978
[4] Eckersley, 1992
[5] Devall & Sessions, 1985; Naess, 1989; Sessions, 1995

*Fantasy*[6]. Usually, in the basis of these nature-without-humans visions, some classic ecology theories based on balance like the "*superorganism*" stability (Clements) or the *Gaia* theory (Lovelock) can be found. Sometimes, these approaches has stepped out certain topics that have influenced in the conception of landscape by the society. Nevertheless, this "untouched" environmental scenario is an invalid postulate, rather idealized. In fact, the limit between cultural complex and ecological systems is one of the human knowledge limitations. Classic visions of balance and lineal order have been replaced by complex approaches, like net models (i.e. Bruno Latour's Actor-Network theory, 1996) and interdisciplinary focusing (i.e. Victor Toledo's Hybrid Disciplines, 1998). Actually, we can't separate nature and society; for this reason, nowadays the study of environmental changes requires the integration of ecological and social criteria so as to unravel landscape dynamics complexity.
Global Environmental Change science represents an interdisciplinary referent in the study of landscape changes by human societies, synergies and historic trends, actual status and future scenarios, from local to global scale.

**Methodology**

The methodology applied was based on the analysis of social-economic and biophysical driving forces, similar to IGBP-IHDP's LUCC project (*Land Use and Land Cover Change*). This balance through XXth century, especially since second half, determined land use and land cover changes, key indicators to understand past and present landscape changes and possible future scenarios. For to analyze these temporal stages, there has been posed a diachronic model and a synchronic model.
The diachronic study analyzes changes in agrarian and forestland surface and changes occurred in the floristic composition of cold-temperate forestland in the last 50 years. It integrates documental sources of information (cartography analyzed with GIS and botanical checklists) and oral sources of information too, that have taken an outstanding role for to reconstruct the environmental history and track it changes; interviews were administrated to social actors, such as actual and former landowners, forest workers and merchants, and Natural Park land managers.
The synchronic study monitors sessile oaks and holm oaks (*Quercus ilex*) mass' ecological dynamics in experimental plots measuring ecological variables such as size, age and mortality of adult trees and recruitment.

**Study site**

The Montseny Mountain, declared Natural Park (1977) and UNESCO's Biosphere Reserve (1978), present outstanding socio-environmental elements for Global Change process monitoring.
Firstly, the presence of three biogeographical regions determines the appearance of ecotonic borders between several chorological elements which are especially sensitive to environmental changes. Secondly, socio-economical historical changes associated with energy consumption and primary sector activities and rural exodus have occurred during the second half of the 20th century.
The study site is located in the SE sector of the massif, an area of sessile oak (*Quercus petraea*) forestland called *Ridaura sessile oak forestland*. The place name is related to the *mas de Ridaura* where it is included the forestland (the mas is the name of the traditional catalan countryside unity conformed by different primary sector activities linked to a household). The

[6] Stavrakakis, 1999

study area integrates public ownership (County Council) and private ownership. The effective protection of the area doesn't exclude traditional primary sector activities.

**Diachronic analysis of Land Use Changes processes**

***Agriculture and farming activity***

In XXth century, agrarian works were actives in Ridaura up to the end of the decade of 1980s.
Nowadays, these abandoned agrarian structures are still visible, especially stonewalls; the general characteristic of these vestiges is the presence of vegetation poured out onto terraces and stonewalls.
Documented farming activity of the *mas* was less significant than agrarian works. It consisted in few cows devoted to produce milk and other small farm animals devoted to self-consumption. Farming finished at the same time than agriculture. Related to neighbours' farming activity linked to Ridaura, only goat flocks (varying through the years during the second half of XXth century) occasionally grazed part of the sessile oak forested area until the beginning of 1980s. Nowadays, Can Ridaura hasn't farm activity but landowners hand over remaining meadows to neighbour's herd on summer.

***Forestry***

Forestry in Ridaura included wood (of sessile oak, mainly) and firewood (of holm oak) extraction. Oldest oral references of sessile oak wood extraction in Ridaura explained the use of this material for railways construction works at the beginning of XXth century; nevertheless, this use surely was former, because the railway expansion in Barcelona began at the half of XVIIIth century and the development was very fast: at 1860 railway arrived until Sant Celoni and Riells i Viabrea, two villages of Baix Montseny. Even, the cultural footprint of this work had been gathered in Baix Montseny's language background like a reprimand to children ("*We'll send you to Ridaura to make crosspieces!*"). Too, sessile oak wood was used to produce joists (until year 1940, approximately), pieces of furniture and cartwheels, product that underwent an outstanding demand peak during First World War (1914-18).
Holm oak extraction destined to firewood remained active until the second half of the decade of 1980s, with less recurrent intervention shifts than in the first half of the century, when were approximately every five years. After the end of firewood extraction in Ridaura there weren't any interventions over sessile oaks and holm oaks forest masses.
Another destination of Ridaura sessile oak forestland biomass was the elaboration of charcoal, especially active since the end of XIXth and the first half of XXth century. During the decades of 1950s and 1960s, charcoal's demand dropped, an effect linked to the spread of fossil fuels; this fact conditioned the crisis of charcoal and firewood and the progressive abandon of these forest works; in Ridaura they ended at the beginning of the decade of 1970s.
"*Carbonet*" (catalan name, this kind of charcoal is called and in spanish, "*cisco*") was the less quality charcoal elaborated in Ridaura sessile oak forestland from vegetable rests of forest clean and cut down activity and destined to domestic tasks like cooking and heating. The most productive period of this product was the decade of 1950s, when emigrants came to the massif of Montseny to work in charcoal activity (the origin of these workers was Almería, Andalucía, South of Spain). Activity decreased since the decade of 1960s and ended at the half of the decade of 1970s.
Nowadays, there are some vestiges of charcoal activity through Ridaura sessile oak forestland that indicate this former land use. One outstanding group of these vestiges are the old waves; still remain 21 vestige charcoal waves (sometimes with little charcoal pieces scattered at the bottom of the wave and mixed with leaves and humus)

**Analysis of Land Cover Changes processes**

***Biogeographic context***

Human intervention over ecosystem's dynamics recently made that scientist reconsider the role of biotope transition areas in land cover processes until to recognize their indicator capacity in front of environmental changes. For this fact, *ecotonic borders* as a transition areas are outstanding study targets for their dynamic character[7] and their global change processes indicator capacity[8] in terms of sensibility to structural, dominance or flora composition changes (*land cover changes*).

The Ridaura sessile oak forestland, located in the SE sector of the massif is an Atlantic influenced zone between 800 and 1000 meters of altitude and represents an example of ecotonic border transition from *Mediterranean* to *Eurosiberian* region.

***Land cover diachronic analysis***

Diachronic analysis model based on the comparison between aerial photograph of 1956 and orthophotomap of 2003 by GIS tools showed quantitative and qualitative land cover changes. These processes were identified like an outstanding increase of forestland cover and a decrease of agriculture and farming land covers.

Related to forestland, land cover has increased and modification processes have occurred. In 1956 sessile oak forestland areas were only two isolated strips and a little zone near the home, with an extension of 2.0 hectares, approximately. At the same time, the rest of the study area, excluding agrarian and farming land covers, presented a typical morphology of scrubland. The cartography of the year 2003 showed a continuous forest land cover of 4,5 hectares up to the road line and 6,0 hectares down the road line.

The conversion of all the agrarian land cover and the partial modification of farming area have occurred; since 1956 until 2003, 0.4 hectares of farming land cover have been turned into scrubland, 1.1 hectares have been turned into forestland and 0.4 hectares have been fragmented in three pieces of 0.2, 0.1 and 0.1 hectares but still remained active like meadows.

In this form, land cover changes between 1956 and 2003 can be resumed in an outstanding modification (increase) of forestland covers (800% up and 300% down to the road) and the totally conversion of one piece and the decrease of the rest of agrarian and farming land cover.

Changes observed between flora checklists of 1966 and 2005 showed two kinds of land cover changes. Firstly, in terms of vegetation structure, the main trend was the reduction of open spaces and the increase of vertical barked biomass, in the line of the quantitative forestland area increase observed by the GIS analysis. Secondly, in terms of community composition, the relative abundance of eurosiberian chorology taxons like *Teucrium scorodonia* remained similar, but an increase near to 5% of characteristic mediterranean chorology taxons like *Arbutus unedo* has been documented; at the same time, in open spaces between 1966's checklist and 2005's checklist eurosiberian species have been replaced by mediterranean and pluriregional species.

***Land cover synchronic analysis***

For the synchronic model 12 experimental plots (10x10 m) were distributed at different altitudes (between 800 and 1000 meters) into sessile oak forestland area; 6 plots were located into areas that presented sessile oak forestland cover in 1957 and 6 outside them. In each plot, number and diameter (at 1.3 meters) of sessile oak and holm oak (live and dead trees) and number and age of seedlings of both species were measured. Too a flora checklist and the estimation of diversity index (*Shannon-Weaver*) by 3 random 10 m. transects in each plot had been realized.

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[7] Fagan *et al*., 2003

[8] Hansen & Di Castri, 1992; Peñuelas & Boada, 2003; Boada & Saurí, 2002, Peñuelas *et al*. 2005

In terms of adult trees density, holm oaks were more abundant than sessile oaks, approximately in 2:1 ratio, and in terms of basal area (total amount of trunks' wood circular area measured at 1.30 meters) the predominance was by sessile oaks, maybe for the presence of some thick trees (diameter>30 cm.)

In the case of sessile oaks diameters, there weren't statistical meaningful differences between areas covered by sessile oak forestland in 1956 and didn't ones, but in the case of holm oaks there were statistical meaningful differences: holm oaks located in 1956's not-forested areas presented wide diameters than holm oaks located in 1956's forested ones.

Related to mortality, sessile oaks had higher rate than holm oaks, especially in young trees. This situation could be linked to competition relations (for resources like water, light, space, nutrients) between holm oaks and sessile oaks, and between sessile oaks themselves. In fact, competition relations are one of the cited determining factors in flora communities' alteration (species composition, phenology changes, etc.)[9]. There weren't statistical meaningful tree mortality differences between areas covered by sessile oak forestland in 1956 and didn't ones.

In the case of seedlings, number of sessile oak seedlings per hectare was higher than holm oak seedlings, approximately in 14:1 ratio. Nevertheless, survival rate of these seedlings was lower than holm oak seedling survival rate (0,700 *versus* 0,374). In the case of sprouting, this strategy was more observed in holm oaks (1.75 feet/genotype) than in oaks (1.09 feet/genotype). On the assumption that it could be differences between plots forested and not forested in 1956 by sessile oak forestland and sessile oak and holm oak seedlings, statistical analysis didn't show meaningful differences.

Diversity index obtained by Shannon for sessile oak forestland was $1.92 \pm 0.38$ bits $\cdot$ point$^{-1}$ and mean number of species was $6 \pm 2$. There weren't statistical meaningful differences between diversity of areas covered by sessile oak forestland in 1956 and didn't ones.

**Discussion and conclusions**

Related to field work and analysis of documental and oral sources of information can be considered the existence of environmental change processes in the Ridaura sessile oak forestland. Actual landscape is the result of the evolution and balance through the years of socioeconomic and biophysical driving forces that can't be interpreted by only one disciplinary point of view.

Related to this study case, three key driving forces that are linked among themselves has been identified: *demographic trends, politic decisions and economic dynamics.*

Demographic and ownership changes can be translated into changes of social actors and their wishes and needs: the transition from rural traditional way of life, based on primary sector activities oriented to self-consumption and land custody by catalan traditional rent lifestyle (*masoveria*), to a model based only in residential land use (usually second households) carried out by the landowners (a trend similar to other Alt Montseny's villages and *masos* that were uninhabited during second half of XXth century)

The political decision of to declare the massif of Montseny like a protected area and the existence of public ownership surface determined landscape management in Ridaura; although traditional primary sector activities are allowed there aren't interventions over land use or land cover (forest plans, raw materials extraction, etc.).

In this scenario of no-activity abandon of primary sector activities was a key factor in Ridaura's vegetation dynamics. Regional and global agrarian and farming dynamics, especially since the decade of 1960s, cornered to subsistence primary economies in terms of activities' cost-benefit. These dynamics, combined with other circumstances like hilly orography or modest familiar economies that difficult the access to items like mechanization, forced the decrease of agrarian

[9] Bazzaz, 1996

and farming works. In similar circumstances, forestry and charcoal activity went into crisis as a result of fossil fuels expansion during the decade of 1960s. Barcelona's influence area reduced the demand and forced the abandon of these activities in the massif of Montseny, including Ridaura, main supplier of these raw materials. This land use change, characterized by the abandon of primary sector activities and the replacement by residential use, represented the transition from an agrarian model (characterized by self-consumption agrarian and farming works and firewood and charcoal use) to a post-industrial model (characterized by third-sector society); in this study case, the transition between global change general clusters was direct and without signs of the industrial model, considered intermediate to two cited ones, and characterized by the increase of primary sector activity inputs (chemistry and technology) and fossil fuel use.

The reduction of human activity that determined in the past a clearer landscape structure than actual land cover facilitated that these areas were settled by vegetation, a process called *second succession*[10]. As a result there were land cover changes based on the increase of forestland surface by the afforestation of scrublands and, mainly, of agrarian and farming areas, and on the increase of vertical barked biomass.

Related to biophysical driving forces, the most influential effects were related to climate change and specifically to the increase of temperature. In the Montseny this change had been determined in 1.2-1.4ºC during the second half of XXth century[11]. More than only the temperature increase the importance of climate change factor is related to the absence of meaningful rainfall regime's changes that determine an arider climate scenario, fact that favour esclerophyl species in front of atlantic species, biome replacement phenomenon called *mediterranization*. One mechanism supposed linked to it is the flora taxons' shift to favourable environmental conditions, a situation called effect already documented in the massif of Montseny[12].

Following data obtained in this study case is difficult to infer changes in adult holm oaks and sessile oaks and recruitment dynamics. Maybe the complex nature of change process, determined by a broad group of biotic (predation, pests, etc.) and abiotic conditions (light, temperatures, etc.) that couldn't be 100% monitored at the same concision level, make difficult to concrete absolute trends of change.

Even so, results obtained like the increase of mediterranean chorology taxons between 1966 and 2005 and the survival troubles observed in young sessile oak trees and seedlings suggested some uncertainties for the future: at mid-term and long term it could be possible a scenario where young sessile oaks low fitness linked to competence (with holm oaks and with themselves), the death of old sessile oaks, the decrease of sessile oak seedlings and the increase of mediterranean taxons (including holm oak seedlings) definitely determine the biome replacement process and the land cover shift.

[10] Bazzaz, 1996
[11] Peñuelas & Boada, 2003
[12] Peñuelas & Boada, 2003