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LANDSCAPE BIODIVERSITY CHANGES IN FOREST VEGETATION AND THE CASE STUDY OF THE LAVAZÉ PASS (TRENTINO, ITALY)

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Abstract - The Italian Conecofor programme of forest monitoring inserted in 2004 the study of "landscape biodiversity" because a forest is not only an ecosystem, it is –first of all- a landscape. The Biological Integrated School of Landscape Ecology, widening the concept of landscape, is able to elaborate a new methodology of vegetation survey (LaBISV) based on ecological parameters. This methodology allows to study the changes in forest vegetation referred both to landscape structure and function and landscape biodiversity. As an example of application here is presented in extreme synthesis the case study of the landscape unit of the Lavazé Pass (Trentino- Alto Adige). Traditional methods of forest evaluation did not find any ecological problem in the landscape forest of Lavazé. On the contrary, it was possible to demonstrate that this forest landscape unit was altered in few years (1998-2004) because of the tourist pressure and ski rides.

Key Words - Landscape ecology, forest changes, vegetation survey.

INTRODUCTION

If we want to answer the apparently simple question: what a forest is, ecologically speaking? we have to underline that a forest is not only an ecosystem *sensu* Odum: "system of community" (Odum, 1971, 1983), it is also a landscape *sensu* Forman: "system of ecosystems" (Forman & Godron, 1986; Forman, 1995). This widening definition should be crucial also in the main international research strategies as, for instance, the ICP Forests monitoring "Forest Focus". It concerned:

- tree vitality (Level I) and
- ecosystem parameters on selected plots (Level II).

The Forest Focus strategy has been of undoubted importance, but the comprehension of the ecological state of forests necessitates more investigation, because the study of a forest limited to trees and plots is not able to reach their landscape characters and behaviours.

On the other hand, the concept of biodiversity, defined by U.S. Office of Technological Assessment (Massa & Ingegnoli, 1999), is referred to the different types of objects forming a living system and to their organisation within and among these systems. Therefore, biodiversity depends on two aspects (Fig. 1):

- the diversity of the components of ecological systems and
- the diversity of their relations in the organisation of these systems (2 aspects: local and context).

Biodiversity is also an attribute of an entire ecological system. Therefore, to reach a better under-

Fig. 1- (a) Specific biodiversity in a prairie; (b) tesserae biodiversity within an ecotope and ecotope biodiversity within a landscape unit.

standing of the ecological state of a forest, we have to check:

- species diversity (α, β and γ) and landscape elements diversity (ψ, τ);
- ecosystem-community diversity (e.g. tesserae) and landscape diversity (e.g. landscape unit), measuring the states of their ecological organisation.

That is why the Italian CONECOFOR programme of forest monitoring (integrated with ICP Forest) inserted the study of "landscape biodiversity" on 12 permanent plots (b1) and for one of these plot (TRE1) extending the research to the entire context, or Landscape Unit (LU), following the principles of Landscape Ecology.

NEW LANDSCAPE ECOLOGICAL CRITERIA

The discipline of landscape ecology needs a revision according to the new scientific paradigms. That is why Ingegnoli (2002) tried to better focalize landscape ecological elements and processes, studied to widen the foundation of landscape ecology as expressed through the foundation of the Biological Integrated School (Ingegnoli, 2002). In facts, to advance landscape ecological theory, a widening foundation is needed able to relocate in a deeper biological vision the different approaches, first of all those by Naveh (1984) and Forman (1986). This school proposes:

(a) a new landscape structural model (related concepts: ecocenotope, ecotissue),
(b) a new complex integrated function (e.g. biological and territorial capacity of vegetation),
(c) a new method and applications (e.g. new evaluation of vegetation, etc.).

(a) ecocoenotope and ecotissue

The concept of biodiversity confirms the identification of the landscape as a living entity. The *ecocoenotope* was defined as an ecological system, composed by the community (biotic view), the ecosystem (functional view) and the microchore (spatial contiguity characters), while the *ecotissue* concept (or ecological tissue) represents the complex multidimensional structure built up by a main mosaic (generally formed by the vegetation coenosis) and a hierarchic set of correlated and integrated mosaics and information of different temporal and spatial scales, constituting the landscape structural model. The basic landscape mosaic is formed by the vegetation coenosis because the control of the flux of energy and matter and the capacity to create the proper environment pertains to vegetation. But the complex system structure of a landscape is the ecotissue.

(b) complex integrated function: BTC

The *biological territorial capacity* or BTC (Ingegnoli 1991,1999,2002; Ingegnoli & Giglio 1999), is a synthetic function referred to a vegetational ecocoenotope and based on: (1) the concept of resistance stability ; (2) the principal types of ecosystems of the ecosphere; (3) their metabolic data (biomass, gross primary production, respiration, R/PG, R/B). These data are elaborated to measure the degree of the relative metabolic capacity and the degree of the relative antithermic maintenance of the principal ecosystems.

This function, measured in Mcal/m^2/year, can represent the state (the order) of an ecological system and it is proportional to the metastability of the vegetated tesserae. Thus the BTC indexes allow the recognition:

(i) of regional thresholds of landscape replacement (i.e. metastability thresholds) during time;
(ii) especially of the transformation modalities controlling *landscape* changes, through vegetation changes;
(iii) but also of the second aspect of biodiversity, which concerns the organisation level of an ecological system.

(c) evaluation of vegetation

This method is named: Landscape biological integrated survey of vegetation or LaBISV. The main theoretical bases of the methodology (Ingegnoli, 2002, 2005; Ingegnoi & Giglio, 2005; Ingegnoli & Pignatti, 2007) are:

A. Vegetation as the main landscape forming biosystem,

B. Concepts of ecotissue and ecocenotope as multidimensional structures of the landscape,
C. Biological territorial capacity of vegetation or BTC as the main landscape integrative function,
D. Vegetation development model (Time/BTC) based on a proper exponential-logarithmic curve,
E. Comparability between natural and human vegetation characters,
F. Possibility to determine normal (optimal) parametric values in surveying vegetation,
G. Availability to measure the second (b) concept of biodiversity.

MAIN PHASES OF THE LaBISV METHOD

I Phase: Identification of the landscape elements

The elements composing the forest landscape unit (LU), following the Biological Integrated School of Landscape Ecology, have to be recognised, first of all the LU boundaries and their ecotopes. Then, we have to choose the vegetation tesserae (Ts) and to identify their vegetation types, analysing their ecological (structural/functional) subdivisions and the perimeter of the different tesserae. Remember that permanent plot generally do not coincide with their tesserae.

II Phase: Study of geographical and historical characters

The character of the study system (i.e. the LU) needs a collection of geographical data, site and local data, e.g. climate, substrate, morphology, etc. The behaviour of the LU requires also the collection and elaboration of historical and human data, old maps and books data, main human land uses, main historical changes. Historical methods cover deep importance in the reconstruction of the LU, and also in the differentiation of the phytocoenosis.

III Phase: Survey of tessera, biomass, ecocoenotope and landscape parameters

In a forest survey of Tessera characters (TS) normally 6 parameters are collected: vegetation height, canopy cover, structure, edge ratio, management, permanence. The survey of Plant Biomass requires 3 parameters: dead plant biomass, litter depth, biomass volume. [Above ground biomass]. The survey of ecocoenotope needs 10 parameters: dominant sp, species richness, key sp presence, alloctonous sp, infesting plants, threatened pl, biological forms, vertical stratification, renew capacity, dynamic state. [A Phytosociological frame can be used]. The survey of the main relations Ts/LU requires 9 parameters: contiguity, source/sink, functional role, disturbance incorporation, geophysical instability, fauna interest, transformation modalities, landscape pathology, permanence.

IV Phase: Ordination and Evaluation of main landscape vegetation parameters

After the analysis of the above mentioned vegetation parameters their ordination in four classes in a standard form is needed, as shown in Tab. 2. This schedule allows an evaluation per column, scores depending on different models related to different vegetation types. It is possible to evaluate the vegetation qualities (Q); evaluation (measured/optimal) per group of parameters and/or the entire Ts. It is also possible the estimation of BTC, through equations linked with the development models and BTC theory.

V Phase: Examination of parameter/landscape problems and normal values choice

Referring to the previous studies, it is now possible to observe any diagnostic aspects useful to check the ecological state of the LU (and of their elements). The altered parameters must be underlined and compared with normal conditions. Therefore, the choice of normal values per set of parameters and/or per specific parameter becomes crucial. Very useful could be the plotting of ecograms exposing normal values per set of parameters. The integration with other ecological indicators concerning the examined system may complete the diagnostic results.

EXAMPLE OF APPLICATION OF THE LaBISV METHOD: THE LAVAZÉ LANDSCAPE FOREST UNIT:

Identification of the landscape element

The Lavazé Pass forest landscape has been identified as shown in Fig. 2. This LU measures about 175 ha at an altitude of about 1.800 m asl and it is covered of Spruce forests (*Homogyno-Piceetum*, Zukrigl 1973), with the dominance of *Picea abies* and the presence of *Pinus cembra*. The presence of this pine becomes dominant at the west border of the LU, but outside the Lavazé Pass. The examined LU is composed by 4 ecotopes one of which (n°1) is a pasturage, characterised by *Nardus stricta* formations and the presence of some shrub patches (*Juniperus*

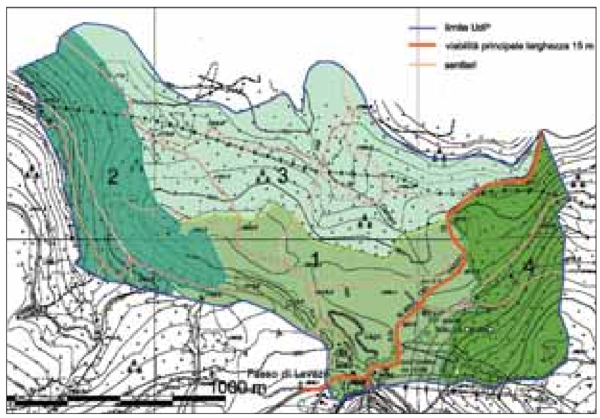

Fig. 2 -The landscape unit of the Lavazè Pass and its four ecotopes (see also tab. 1).

Table 1. Main characters of the ecotopes composing the landscape unit of the Lavazé Pass

Ecotope	Area (ha)	% LU	Land	HH/NH	Slopes (%)
1. Lavazé Pass plan	44,78	25,9	prairie	1,1-1,2	< 25
2. West slope, near the creek	33,93	19,7	Forest (spruce)	0,15-0,20	40-60
3. North belt, with bogs	63,21	36,6	Forest (spruce)	0,15-0,20	15-45
4. East slope	30,69	17,8	Forest (spruce)	0,15-0,20	20-40
Total landscape unit (LU)	172,63	100,0	forest	0,35-0,40	15-60

LEGEND: HH= Human habitat; NH= Natural Habitat *communis*).

Study of geographical and historical characters

The examined LU represents a mountain pass between the Fiemme valley and Ega valley. Its geological structure is quite mixed, due to the presence of the nearby dolomite and porphyritic rocks. The presence of man is ancient but limited to the wood and pasture activities, with very few rural buildings; but today the sport and tourist pressure is increasing and could became dangerous. In this LU some forest patches (tesserae) were not managed since at least 120-150 years, e.g. the TRE.1 permanent plot of CONECOFOR (Petriccione, 2002). The transformation of the LU in the last few years (1998-2004) shows a strong increase of forest patches destroyed by storms and/or clearcuts (from 0.3 to 3.4%) and ski rides (from 0.6 to 3.5%); but this resulted in a limited change of the forest area, from 67.9 to 63.7% that means a decrease of 6.18%, as deduced from table 2. A very small destruction of the forest, as declared by local Autority (Trento Province).

Survey of tessera, biomass, ecocenotope and landscape parameters

Ten forested tesserae of the LU have been analysed (about 1/3 of the forest area), following the LaBISV method. Table 3 shows an example of the vegetation survey: the tessera A of the Lavazé Pass Forest, which presents a quality of only 59%. The main results of the survey on the mentioned tesserae are exposed in table 4.

Ordination and Evaluation of main landscape vegetation parameters

The most characterized forested tesserae (Ts), exposed in table 4, present a certain heterogeneity, resulting in a range of BTC values from 5.67 (Ts L)

Table 2. Measure of the landscape elements forming the LU of Lavazè Pass in 1998 and in 2004

	1998		2004	
Landscape element	**Area (ha)**	**LU%**	**Area (ha)**	**LU%**
Forests	117.26	67.9	109.95	63.7
Destroied patches or clearcuts	0,5	0.3	5.94	3.4
Ski rides	1	0.6	6	3.5
Paths	4	2.3	2	1.2
Bogs	3.66	2.1	3.66	2.1
Grass patches	3.5	2.0	2.37	1.4
Forest areas	***129.92***	***75.3***	***129.92***	***75.3***
Prairie	27.56	16.0	26.08	15.1
Shrub patches	4.5	2.6	4.5	2.6
Ski rides	2	1.2	2.9	1.7
Paths	2	1.2	2.1	1.2
Lake	1.75	1.0	1.75	1.0
Prairie areas	***37.81***	***21.9***	***37.35***	***21.6***
Built tesserae	2.9	1.7	3.31	1.9
Roads and parkings	2	1.2	2.05	1.2
Built areas	***4.9***	***2.8***	***5.36***	***3.1***
Landscape unit	**172.63**	**100.0**	**172.63**	**100.0**

Table 2 - Measure of the landscape elements forming the LU of Lavazè Pass in 1998 and in 2004

Tessera A - *Piceion abietis*, ha 2,25 elevation 1880 m - (Lavazè Pass, TRENTO)
Vegetation Survey by Ingegnoli e Giglio, August 2004

BOREAL FOREST	1	5	14	25	evaluation
T. TESSERA CHARACTERS (Ts)					
T1 – Vegetation height (m)	< 9	9.1-18	18.1-29	> 29.1	Canopy
T2 – Cover of the canopy	< 30	> 90	31-60	61-90	% Ts surface
T3 – Structural differentiation	low	medium	good	high	Age, space groups, etc.
T4- Interior/edge (%)	none	< 30	31-89	> 90	(% Ts)
T5 - Management	simple coppice	coppice	wood	natural forest	Or similar
T6 – Permanence (years)	< 80	81-160	161-240	> 240	Oldest trees
F. VEGETATIONAL BIOMASS (ABOVE GROUND)					
F1- Dead plant biomass	near 0	> 10	1-5	5-10	% of living biomass
F2- Litter depth	near 0	< 1.5	1.6-3.5	> 3.5	cm
F3 – Biomass volume (m^3/ha)	< 200	201-500	501-950	> 950	pB = 606 m^3/ha
E. ECOCENOTOPE PARAMETERS					
E1- Dominant species (n°)	> 3	3	2	1	As pB volume
E2- Species richness	< 15	16-30	31-40	> 40	n° sp./Tessera
E3- Key species presence (%)	< 5	6-40	41-80	> 80	Phytosociological
E4- Alloctonous species (%)	> 10	10-4	< 4	0	From other ecoregions
E5- Infesting plants %	near all	> 25	< 25	0	Coverage on Ts
E6- Threatened plants	evident	suspect	risk	0	Even acid rain damage
E7- Biological forms (n°)	< 3	4-5	6-7	> 7	Cfr. Box 1987, mod.
E8- Vertical stratification	2	3	4	> 4	traditional
E9- renew capacity	none	intense	sporadic	normal	Dominant species
E10- Dynamic state	degradation	recreation	regeneration	fluctuation	Cfr. Ingegnoli 2002
U. LANDSCAPE UNIT (LU) PARAMETERS					
U1- Similar veg. contiguity	0	< 25	26-75	> 76	% of perimeter
U2- Source or sink	sink	neutral	Partial	source	Species & resources
U3- Functional role in LU	reduced	minor	evident	important	Context & typology
U4- Disturbances incorporation	insufficient	scarce	normal	high	Local disturbances
U5- Geophisical instabilities	evident	partial	risk	none	On the phisiotope
U6- Permeant fauna interest	low	medium	good	attraction	Key species
U7- Tranformation modalities of the Ts	strong distubances	gradual changes	temporal instabilities	fluctuation	Today + tendency
U8- Landscape pathology interference	serious	near chronicle	easy to incorporate	none	From landscape
U9- Permanance of analogous vegetation	< 100	100-300	300-1200	> 1200	Historical presence (years)
RESULTS OF THE SURVEY					
Total score Y (= h+j+k+w)	h = 1	J = 6	K = 13	w = 8	Y = 413
Quality of the Ts [%]	Q = Y / 700				**Q = 59**
Estimation of the BTC [Mcal/m^2/year]	BTC (b) = 0,01339 (y-28) + 0,12 (pB / 70)				**BTC = 6,19**

Table 3 - The standard form proper of boreal forest showing results of the surveyed tessera A.

to 9.09 (Ts F) Mcal/m^2/year. Note that the tessera (L) shows a plant biomass volume more elevated than Ts H (525 vs 443 m^3/ha), but its biological territorial capacity (BTC) was estimated only 5.67 vs 6.65 Mcal/m^2/year of the same Ts H. This result underline the limitations of traditional parameters in evaluating the ecological condition of forest patches.

Surveyed Tesserae	*area*	*Q.T*	*Q.F*	*Q.E*	*Q.U*	**BTC**	*BTC/BTC$_s$*	*H*	*vFM*
A. Forested Ts	*ha*	*%*	*%*	*%*	*%*	*Mcal/m^2/yr*	*%*	*m*	*m^3/ha*
Z, Ts (containingTre1)	4,01	70,7	56	95,6	80,4	8,50	90,0	29,5	739
A, East, q 1880 m	2,25	50	58,7	64,8	58,7	6,19	65,0	24,8	606
B, East, q, 1800 m	4,25	50	32	74,4	71,6	6,15	65,0	26,1	320
C, North-East, q 1780 m	4,40	64,7	56	73,6	67,6	7,48	79,1	25,7	872
D, West di Z, q 1790m	4,18	56	56	74,4	71,6	7,04	74,4	25,6	629
E, North, q 1770 m	4,41	56	56	70,8	62,7	6,93	73,3	25,8	793
F, West, q 1800 m	4,31	78	70,7	82,4	85,3	9,09	96,1	32	1086
G, South, q 1790 m	2,83	57,3	56	78,8	57,8	6,94	73,4	26,7	713
H, South-West, q 1750 m	3,73	57,3	44	78,8	67,6	6,65	70,3	20,7	443
L, West of D, q 1800 m	2,74	44	44	66,4	52,9	5,67	59,9	26,6	525
Forested Ts (average)	*37,11*	*59,4*	*53*	*76,6*	*68,9*	*7,17*	*75,8*	*26,5*	*686*

LEGEND: the ratio BTC/ BTC$_s$ indicates the present BTC level related to the threshold of maturity BTC (BTC$_s$). BTC$_s$ = 0,85 BTC$_F$ (where BTC$_F$ is the BTC value proper of the transition phase between adult forest and forest maturity (see the model in Ingegnoli, 2002);
QT= Ts parameters (Quality), QF= plant Biomass parameters (Quality), QE= ecocoenotope parameters (Quality), QU= LU parameters (Quality); H= High of the canopy, FM= plant biomass (spiegel relaskope)

Table 4 - The most characteristic forested tesserae (Ts) at the Lavazé Pass. Their survey utilised the LaBISV method studied by Ingegnoli.

Surveyed Ts	*area*	*Q.T*	*Q.F*	*Q.E*	*Q.U*	**BTC**	*BTC/BTC$_s$*	*H*	*vFM*
B. Other vegetation	*ha*	*%*	*%*	*%*	*%*	*Mcal/m^2/yr*	*%*	*m*	*Kg/m^2*
a- *Juniperus* shrubs	1,2	45,5	36,9	78,6	69,8	1,44	65,1	0,7	1,9
b- *Nardus stricta* grasses	1,6	21,9	12,5	52,8	51,4	0,58	47,5	0,4	0,8
c- Alpine bogs	1,5	62	51	94	72,9	1,22	85,6	0,2-1	1,5
	4,30					*1,04*			

See table 4 for legend.

Table 5 - Other types of vegetation in the Lavazé Pass, surveyed with the LaBISV method.

The few other types of vegetation of the landscape unit are exposed in table 5, which presents the low BTC level of *Nardus stricta* grasses (disturbed by overgrazing) and *Juniperus* shrubs (quite poor and irregular) vs normal values of the alpine bogs.

Problems examination of parameter/landscape and normal values choice

The results of vegetation survey and the elaboration of ecological parameters lead to compare the present situation of the landscape unit with its normal values. These values have to be reached among the characters of a sub-natural forest landscape. The experience in observing similar landscape units in a good ecological balance, the correlation between peculiar parameters and the application of ecological models allow to define these normal values, as shown in table 6.

Parameters	Normal values*	1935 surveyed	1935 Distance %	1998 surveyed	1998 Distance %	2004 surveyed	2004 Distance %
BTC (Mcal/m^2/yr)	**5,57-6,15**	5,18	**- 7**	5,05	**-9,3**	4,76	**-14,5**
HH (%)	**20-22**	20,6	**0**	21,4	**0**	26,7	**+21,4**
ψ = H (3+D)	**5,5-5,7**	4,63	**-15,8**	4,99	**-9,3**	5,29	**-3,8**
LM = τ *BTC	**29-31**	24,27	**-16,3**	24,16	**-16,7**	23,09	**-17,6**
C/F (%)	**80-90**	80,54	**0**	77,39	**-3,3**	64,55	**-19,3**
Allochthon plants (%)	**0-1**	0	**0**	0	**0**	0,1	**0**
Forest surface (%)	**65-80**	68,9	**0**	67,9	**0**	63,7	**- 2,0**
Agricultural surface (%)	**10-20**	18,7	**0**	16	**0**	15,1	**0**
σ = HS/HS*	**3-8**	2,9	**-3,3**	1	**-66,7**	0,92	**-69,3**
HCE = (BTC/HU)* σ	**70-580**	72,9	**0**	23,6	**-66,3**	16,4	**-76,6**
DIAGNOSTIC INDEX	***0,85-1***	***0,85***	***0***	***0,75***	***-11,8***	***0,60***	***-40***

LEGEND: HH= Human Habitat; ψ= structural landscape diversity; LM= landscape metastability; σ = HS/HS*= carrying capacity of a territory; HCE= Habitat Capacity Evaluation Index; C/F=core areas/forest surface
Distance (%) →Evaluation Scores: 0-10 →2; 10-30 →1; 30-60 → 0,5; > 60 →0.
DIAGNOSTIC INDEX: 0,85-1 = normal; 0,6-0,85 = alteration; 0,35-0,6 = dysfunction; 0,15-0,35 = complex dysfunction; < 0,15 near to extinction.
(*)Normal values: according to a sub-natural forest Landscape.

Table 6 - Synthesis of the ecological diagnostic evaluation of the LU of Passo di Lavazè. The ranges of normality (Normal values) are referred to the historical structure of the LU and to its potentiality of forested sub-natural landscape.

The comparison among the ecological parameters (measured or estimated in 1935, 1998 and 2004) with the normal values is expressed through the distance (%), that is the difference from a normal value of an ecological parameter and its survey per each period of time. Giving scores to these distance evaluation (0-10=2; 10-30 =1; 30-60=0.5; >60=0) it possible to calculate a diagnostic index (DI) with acquires the following meanings:

DI = 0.85-1, normal ecological state;

DI = 0.6-0.85, alteration;

DI = 0.35-0.6, dysfunction;

DI = 0.15-0.35, intense dysfunction;

DI = < 0.15, near to extinction.

In this case study we see from table 6 the progressive alteration of the ecological state of the landscape unit, which was particularly strong in the late short period (1998-2004), being the DI decreased from 0.75 to 0.60 in only 6 years! The reasons can be found in the enhanced tourist pressure, especially the enlargement of the ski rides (Fig. 3.)

CONCLUSION

Through this experience, the Italian CONECOFOR programme tried to demonstrate the necessity to study forests even with landscape ecological theory and applications. In doing this we think to bring a contribute to reach these goals:

(a) a better understanding of transformation processes of a forest landscape unit

Fig.3 - The new ski ride (on the right) recently created in one of the examined tessera. The resulting small patch between the two ski rides completely lost any interior ecological characteristic.

(b) a new capacity for landscape vegetation evaluation and diagnosis.
(c) better therapeutic possibilities of intervention in nature conservation,
(d) more coherent building of ecological models able to integrate vegetation with other landscape parameters.
(e) the possibility to measure biodiversity in a more complete way
(f) the diagnostic evaluation of a landscape forested unit.

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