THE STUDY OF VEGETATION FOR A DIAGNOSTICAL EVALUATION OF AGRICULTURAL LANDSCAPES. SOME EXAMPLES FROM LOMBARDY

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ABSTRACT - Considering that a landscape is much more than a set of spatial characters, I tried to focus its ecological elements and processes, proposing (a) new concepts (e.g. ecocenotope, ecotissue), (b) new functions (e.g. biological and territorial aspects of vegetation) (c) new applications (e.g. evaluation of vegetation, etc.). To verify these applications, a study on the landscape agricultural units of the hinterland of Milan (about 45° 26'N - 09° 17E, 100 m osl) is in process in these years. The characters of some forested tesserae along a transect between the Adda river and the Ticino river (East to West, passing through Milan) have been expressed, using the biological integrated method of vegetation survey proposed by Ingegnoli (2002). An example of how to use the ecological characters of all the different types of vegetation existing within a landscape unit is given by the study of corridors and crop fields. A comparison among 3 landscape units has been done, to demonstrate the diagnostic evaluation method, after a parametric analysis based on landscape ecological indexes.

KEY WORDS - agricultural landscape, vegetation, landscape ecology, landscape diagnosis, Landscape Biological Survey of Vegetation.

INTRODUCTION: WHY DOES LANDSCAPE ECOLOGY STUDY VEGETATION?

The theory of landscape ecology has to relocate its different approaches in a deeper biological vision. The comprehension of the landscape and of its main component -the vegetation mosaic- needs to underline that both of them are biological systems (Ingegnoli, 2002). Therefore a landscape is a living entity. We have revised landscape ecology according to new scientific paradigms (Ingegnoli, 1993; Pignatti et al. 2002) ranging from the Principle of Emerging Properties to the System Theory to the 'order through fluctuation' processes (Prigogine, 1996). Considering that a landscape is much more than a set of spatial characters, we tried to focus its ecological elements and processes, proposing

– new concepts (e.g. ecocenotope, ecotissue),
– new functions (e.g. biological and territorial aspects of vegetation)
– new applications (e.g. evaluation of vegetation, etc.).

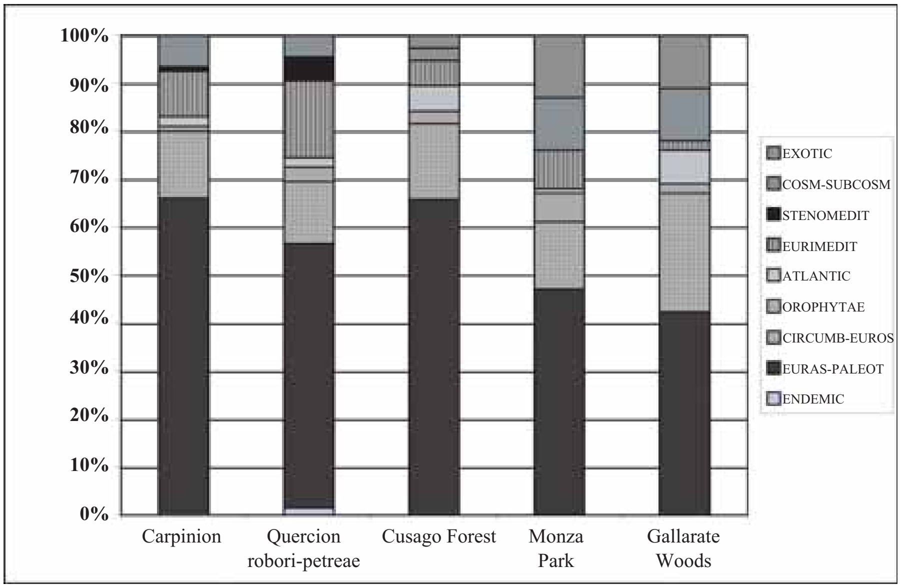

FIGURE 1 - Comparison among the chorological spectra of some woods in Lombardy, near Milan and the two phytosociological alliances of *Carpinion* and *Quercion robori-petraee* (Biondi & Baldoni, 1994). Note the Carpinion chorological spectrum vs the Cusago forest tessera: it is a good ecological status, confirmed by phytosociological relevées.

We will present an example: the study of Agricultural Landscape Units (LU) near Milan. A comparison among the chorological spectra of some woods in this territory and the two phytosociological alliances of *Carpinion* and *Quercion robori-petreae* (Biondi & Baldoni, 1994) are exposed in Fig. 1. Note the Carpinion chorological spectrum vs the Cusago forest tessera: it is a good ecological status, confirmed by phytosociological relevées.

Anyway, many questions arise:

– how to consider the contribution of this tessera to the metastability of the LU ?
– how to compare the data of the forest patch with those of other vegetation elements in this landscape unit (LU)?
– how to use the ecological characters of all the different types of vegetation existing within a LU to arrive to a diagnostic evaluation of the entire landscape?
– how to integrate the other main ecological parameters of the LU , like HH (human habitat) or SH/SH* (carring capacity)... ?
– what might be the role of this tessera within an ecological network?

So, I need to introduce at least (i) a new ecological function (BTC) and (ii) a new survey method in a clinical-diagnostic methodology context.

A NEW ECOLOGICAL FUNCTION: THE BIOLOGICAL TERRITORIAL CAPACITY (BTC)

The Biological Territorial Capacity, or BTC (Ingegnoli 1991, 2002), is a synthetic function, referred to the vegetation of an ecocoenotope, i.e. the ecological system, composed of the community (biotic view), the ecosystem (functional view) and the microchore (*sensu* Zonneveld 1995). It express the flux of energy a system must dissipate during a year to maintain its degree of organization and metastability. It is based on: (1) the concept of resistance stability (Odum, 1971); (2) the principal types of ecosystems of the ecosphere (Whittaker, 1975); (3) their metabolic data (biomass, gross primary production, respiration, R/PG, R/B) (Duvigneaud 1977, Piussi 1994, Pignatti 1995).

Two coefficients are present within this function:

$$a_i = (R/GP)i / (R/GP)\max \qquad b_i = (dS/S)\min/(dS/S)i$$

– where: *R* is the respiration, *GP* is the gross production, *dS/S* is equal to *R/B* and is the maintenance/structure ratio (or a thermodynamic order function; Odum 1971, 1983) and *i* are the principal ecosystems of the ecosphere.

The factor a_i measures the degree of the relative metabolic capacity of the principal ecosystems; b_i measures the degree of the relative antithermic (i.e. order) maintenance of the principal ecosystems. We know that the degree of homeostatic capacity of an ecocenotope is proportional to its respiration (Odum 1971, 1983). So through the a_i and b_i coefficients, even related in the simplest way, we can have a measure which is a function of this capacity:

$$BTC_i = (a_i + b_i)R_i w \qquad (\text{Mcal/m}^2\text{/y})$$

A new survey method

The method proposed here (Ingegnoli, 2002; Ingegnoli and Giglio, 2005) can be named as "landscape biological integrated survey of vegetation" or LaBISV. It is able to integrate three different criteria (a biotic one, an environmental one and a configurational one) with different temporal and spatial scales.

It uses a *parametric standard form* (a proper one for each type of vegetation) for the analysis and evaluation of a vegetated tessera. It helps in the definition of the so called "*normal state*" for each specific type of tessera.

The standard form (or schedule) has been designed to check the organisation level and to estimate the metastability of a tessera considering both general ecological and landscape ecological characters: A = landscape element characters (e.g. tessera, corridor); B = plant biomass above ground; C = ecocoenotope parameters (i.e. integration of community, ecosystem and microchore); D = relation among the elements and their landscape parameters.

The evaluation classes are four, the weights per class depending on an evaluation model, one for each of the main types of vegetation ecosystems (Ingegnoli, 2005). It is possible to evaluate the quality of vegetation per parametric set of data. The degree of metastability of vegetation can be estimated through BTC equations, calibrated per vegetation type. Results may be represented through ecograms.

TABLE 1 - Transect from Adda to Ticino rivers, surveying forest et tessera as remnants in Agricultural Landscapes and/or in Regional Parks near Milan.

TEMPERATE FOREST TESSERA	Q.T (%)	Q.F (%)	Q.E (%)	Q.U (%)	BTC (Mcal/m²/yr)	BTC/BTC$_s$ (%)**	H (m)	vFM (m³/ha)
Survey								
Q. Carpinetum + Robinia p. Capriate, P. Adda N.	27,3	68,2	36,4	52	**4,21**	**41,2**	12	140
Old Oak Remnant Forest Parco di Monza	62,1	54,6	46,8	57,6	**6,23**	**61,0**	27,2	556
Ts5, *Q. Carpinetum + Q. rubra*, P. Monza	40,9	43,9	35	39,9	**3,93**	**38,5**	24	207
Ts.6 *Q. Carpinetum + Acer platanoides*, Parco di Monza	53,8	53	37,7	36,4	**4,53**	**43,2**	20,5	290
Ts.3 *Querco-Carpinetum* Bosco Cusago	64,4	54,5	68,2	71,2	**7,44**	**72,8**	26	520
Ts.1 *Robinietum* Bosco Riazzolo, Cisliano	18,9	53	35	47	**3,48**	**34,1**	9,5	120
Ts.1 *Q. Carpinetum* Parco Ticino, Robecco	61,4	54,6	58,6	57,6	**6,41**	**62,7**	23,4	439
Ts.2 *Q. Carpinetum* Parco Ticino, Robecco	46,2	43,9	47,3	47	**4,95**	**48,4**	19,6	315
Ts.4 *Querco-Carpinetum* B. Fasolo, P. Ticino	72	69,7	75	64,7	**7,42**	**72,6**	24	428
Mean values of the transect	49,7	55	48,9	52,6	**5,40 ±1 ,42**	**52,8**	20,7	335
Comparison								
ABR2 *Q. cerris & Abies alba* Rosello, Abruzzo	79,5	54,9	77,5	81,3	**8,00**	**79,8**	18,4	353
Ts3, *Querco-Tilietum* P. Bialowieza,	100	84,9	81,8	94,6	**10,34**	**101,2**	29,4	768

Q.T = quality of the landscape element; Q.F = quality of the plant biomass; Q.E = quality of the ecocoenotope parameters; Q.U = quality of the relation among the elements and their landscape parameters; as indicated by Ingegnoli (Landscape Ecology: A Widening Foundation, Springer, 2002).
(*) BTC$_s$ = threshold of mature forest (i.e. fluctuation, *sensu* Falinski), deduced from the model of Ingegnoli.
H = heigh of the canopy.
vFM = plant biomass volume (measured with the "spiegel relaskope").

THE CASE STUDY OF SOME AGRICULTURAL LANDSCAPE UNITS NEAR MILAN

When I need to apply the method to our case study, what can I gather now concerning forested remnant tesserae? First of all: (i) a total quality for the considered tessera, (ii) partial qualities related to the 4 groups of parameters, (iii) a BTC estimated value. Let us see, for instance Table 1, in which are summarized the characters of some forested tesserae along a transect between the Adda river and the Ticino river (East to West, passing through Milan).

These tesserae are remnants in the agricultural landscape and their fittest vegetation (*sensu* Ingegnoli, 2002, 2005) pertains to the alliances shown in Fig.1, even if often invaded by *Robinia pseudoacacia*, *Quercus rubra*, and *Prunus serotina*. The values of the BTC function are medium-low, from 3.48 to 7.44 Mcal/m^2/year.

The mean values of the transect presents a BTC = 5.40, that means a medium quality of vegetation of about 53%, not dissimilar from the other qualities of the parameters of tessera (QT), plant biomass (QF), ecocoenotope (QE), and landscape unit (QU). The mean of the heigh of the canopy (20.7 m) and the volume of plant biomass (335 m^3/ha) are not a reason able to justify the medium-low quality standard of these remnant forests: the comparison with a good example of Oak-Spruce forest demonstrates that – in similar condition of heigh and volume- it is possible to reach about 80% of the threshold of maturity.

An example of how to use the ecological characters of all the different types of vegetation existing within a landscape unit is given by the study of corridors and crop fields, always in agricultural landscapes near Milan, as shown in Fig. 2 and 3. Note that the main measures are: (a) the mean total quality (Q) of vegetation tesserae (Cfr. the mentioned method) and (b) the ratio BTC/BTC_S, being BTC_S the value at the maturity threshold. In Figure 2 we compare 4 case studies in which the characters of vegetation corridors are quite low: the only acceptable situation is in the municipality of Cusago, due to the presence of semi-natural fountains canals (*aste di fontanile*). In Figure 3, the evaluation of the fields of mais are compared in 5 case studies. As in Fig. 2, it is possible to note different situations presenting a very heterogeneous ecological quality.

The possibility to analyze and to evaluate forested tesserae and other ecological elements, like corridors or crop fields are in any case very important, because they allow a true diagnosis of the ecological state of different landscape units.

An ecological diagnosis of a complex living system like a landscape depends on the comparison between the conditions of the examined system and the conditions of the state or behavior considered as a normal one for this type of ecosystem. This is a clinical-diagnostic method.

TABLE 2 - Comparison among some agricultural landscapes of the hinterland of Milan.

Parameters	**Besate**	**Cusago**	**Adda Nord**
Area (ha)	*1.260,70*	*1.157,40*	*3.906,40*
Inhabitants (n)	*1.729*	*3.046*	*40.173*
Human Habitat HH (%)	84,6	90,2	85,2
Carrying capacity σ = SH/SH*	4,09	2,51	0,68
Productive subsystem PRD (%)	77,4	76,5	58,3
Agricultural ratio PRD/HH	0,91	0,85	0,68
BTC ($Mcal/m^2/yr$)	1,4	0,95	0,63
Landscape Metastability LM	7,2	4,1	2,3
BTC standard classes	4	3	2
Crop quality Q (%)	65	48	29
Veget. corridors connection ($\alpha+\gamma$)	0,67	0,59	0,12
Exotic floristic species (%)	10,7	5,4	14,3
Protective subsystem PRT (%)	2,30	2,64	1,44
Forest cover (%)	1,42	2,65	5,57
Forest metastability BTC ($Mcal/m^2/yr$)	6,21	5,84	3,74
Habitat capacity evaluation HCE=(BTC/HH)*	6,77	2,64	0,50

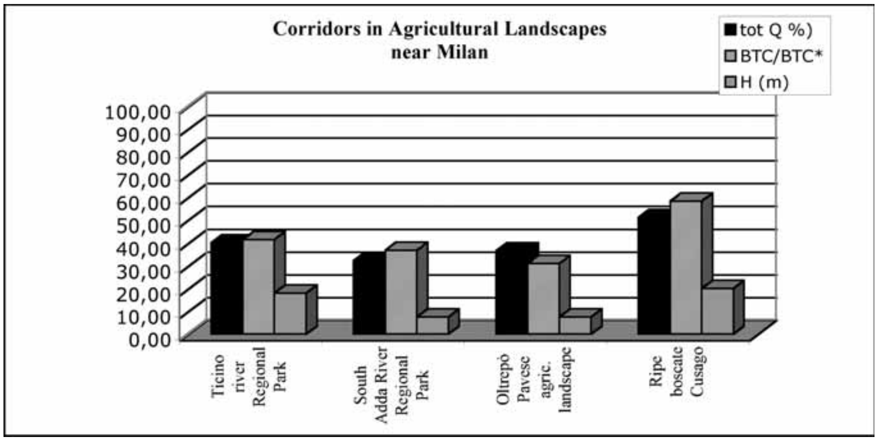

FIGURE 2 - Comparison among 4 case studies of vegetated corridorsin agricultural landscape units near Milan. Only in Cusago the vegetation quality is over 50%. Note that the main measures are: (a) the mean total quality (Q) of vegetation tesserae (Cfr. the mentioned method) and (b) the ratio BTC/BTC *, being BTC * the value at the maturity threshold.

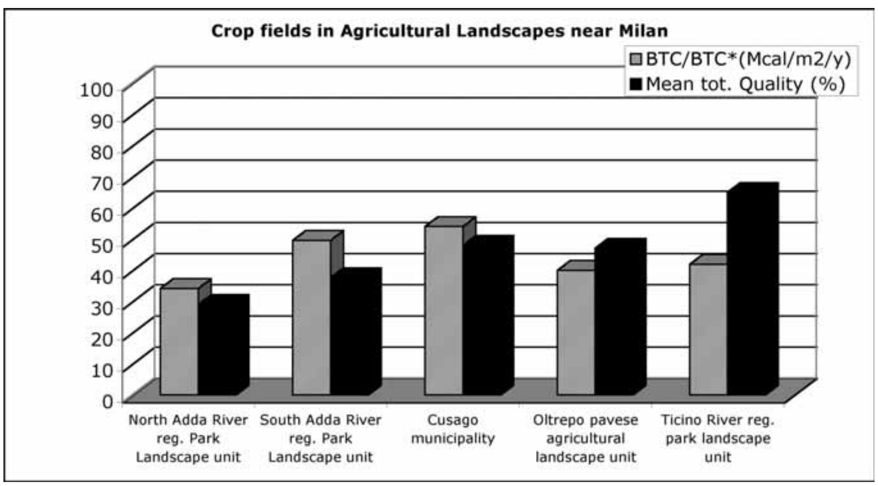

FIGURE 3 - Comparison among 5 case studies of cropfields in agricultural landscape units near Milan. Note that the main measures are: (a) the mean total quality (Q) of vegetation tesserae (Cfr. the mentioned method) and (b) the ratio BTC/BTC*, being BTC* the value at the maturity threshold.

An other example on how to compare the data of the forest patch with those of other vegetation elements in a landscape unit (LU) and to integrate the other main ecological parameters of the LU, like HH (human habitat) or SH/SH* (carring capacity) can be given by the study of a transect among the agricultural, rural-suburban, and urban landscapes from the Center of Milan towards the West, arriving near the Ticino river (Fig. 4). This assessment needs the integration of local and species parameters and of new functions: the new method presented in this paper enhances the diagnostic evaluation of the ecological state of the examined systems.

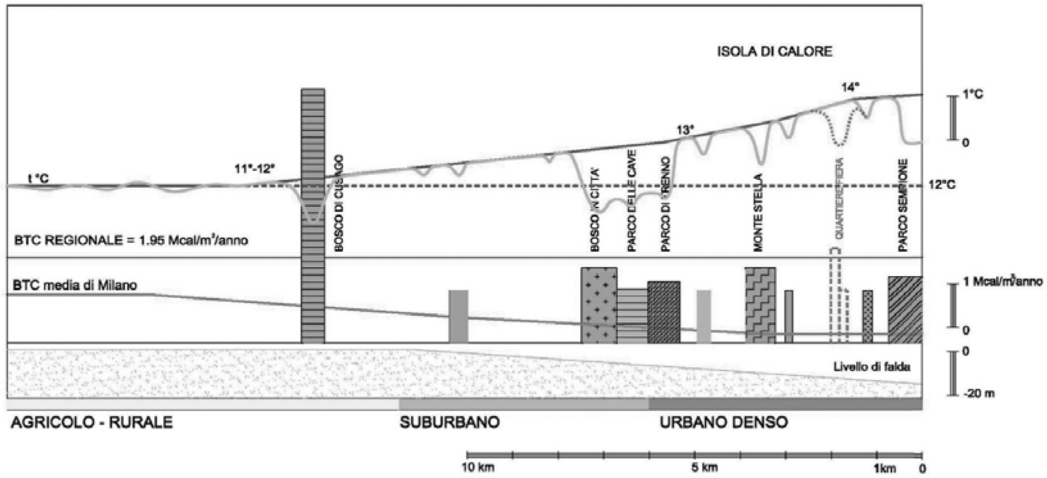

FIGURE 4 - Note the sharp difference between the remnant patch of natural forest in Cusago and other vegetation patches representing the urban parks in Milan. Other differences between the agricultural-rural landscape and the suburban-urban one is done by the decrease of the BTC values and the increase of the temperature over the town, with some breaks for the presence of vegetation patches (from Ingegnoli and Giglio, 2005).

In Figure 4 we can see the sharp difference between the remnant patch of natural forest in Cusago and other vegetation patches representing the urban parks in Milan. Other differences between the agricultural-rural landscape and the suburban-urban one is done by the decrease of the BTC values and the increase of the temperature over the town, with some breaks for the presence of vegetation patches. In the same transect, it is possible to show an example of how to use the chorological aspects of all the different types of vegetation existing within a LU to contribute to a diagnostic evaluation of the entire landscape. Figure 5 presents the changing in allochthonous species presence within the remnant wood patches and urban parks from the countryside toward the city.

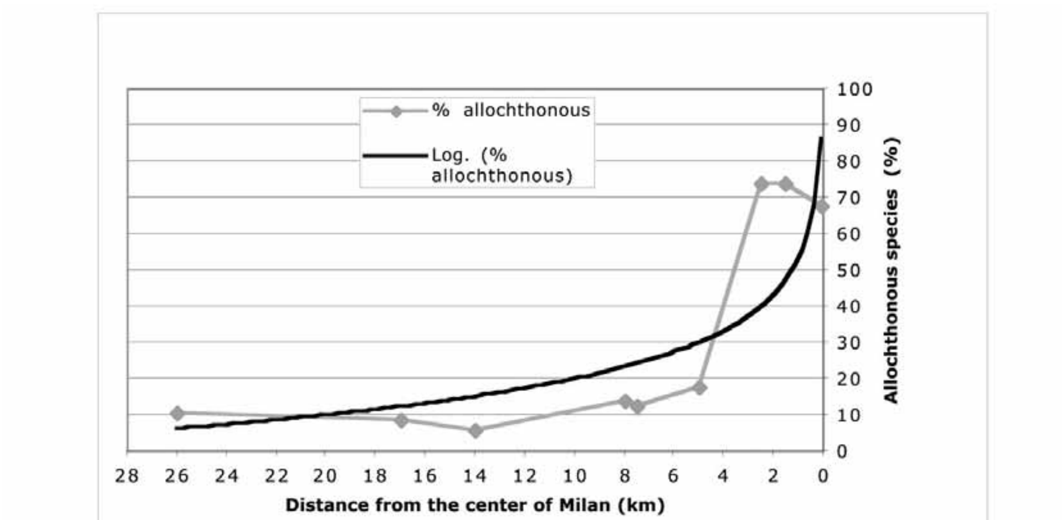

FIGURE 5 - Transect among the agricultural, rural-suburban, and urban landscapes from the Center of Milan towards the West, arriving near the Ticino river. Allochthonous species are measured, and acorrelation curve is plotted. The increase of exotic species stars from the Milan border.

In the Ticino river Regional Park forests it is possible to register about 10% of allochthonous species; in the countryside between the Ticino river and Milan in some cases this percent can decrease (7.9 % in the Cusago municipality); in the sub-urban belt (e.g. Parco delle Cave) the exotic species reach about 15-20%; then in the urban parks the level of allochthonous specie is extremely high, from 65 to 75%.

THE DIAGNOSTIC EVALUATION OF SOME AGRICULTURAL LANDSCAPE UNITS

The study of vegetation for an ecological characterisation of different types of agricultural landscapes can be made through many ecological parameters (Ingegnoli e Giglio 2005). In this paper, Table 3 shows a comparison among 3 typical agricultural landscape units of the hinterland of Milan: Besate (near the Ticino river, south to Abbiategrasso), Cusago (near the West side of the suburban ring of Milan) and Adda Nord (near the Adda river, North to Trezzo).

These parameters, as exposed in Table 3, are: (1) Productive subsystem PRD (%) of the examinedterritories; (2) Agricultural ratio PRD/HH, (3) Biological territorial capacity of vegetation BTC (Mcal/m^2/yr); (4) Landscape Metastability (LM = τ * BTC); (5) BTC standard classes; (6) Crop quality Q (%) (*sensu* Ingegnoli 2002); (7) Vegetation corridors connection (α+γ) (*sensu* Forman 1995); (8) Exotic floristic species (%); (9) Protective subsystem PRT (%); (10) Forest cover (%); (11) Forest metastability BTC (Mcal/m^2/yr). The landscape heterogeneity is low in all the case studies, being the BTC standard classes only 4.3 and 2 respectively.

TABLE 3 - Diagnostic evaluation of the examined agricultural landscapes.

Parameters	Normal values*	Δ (%) Besate	Δ (%) Cusago	Δ (%) Adda Nord
Human Habitat HH (%)	65-85	ok	6,1	ok
Carrying capacity σ = SH/SH*	2-10	ok	ok	66
Productive subsystem PRD (%)	60-80	ok	ok	2,8
Agricultural ratio PRD/HH	0,85-0,95	ok	ok	**19,5**
BTC (Mcal/m^2/yr)	1,00-1,95	ok	0,5	**37**
Landscape Metastability LM	5-16	ok	**18**	**54**
BTC standard classes	4-6	ok	**25**	**50**
Crop quality Q (%)	60-100	ok	**20**	**51,7**
Veget. corridors connection (α+γ)	0,7-1,1	4,3	**15,7**	82,8
Exotic floristic species (%)	0-4	267,5	**35**	279,7
Protective subsystem PRT (%)	3-5	**23,3**	**12**	**52**
Forest cover (%)	5-15	71,6	**47**	ok
Forest metastability BTC (Mcal/m^2/yr)	7,00-8,50	**11,3**	**17**	**46,6**
Habitat capacity evaluation HCE=(BTC/HH)*SH	2,3-30	ok	ok	78,3
Diagnostic INDEX	85-100	**78,6**	**67,9**	**35,7**

NOTE:
Distance (%) Evaluation Scores: 0-10 =2; **10-30 = 1**; **30-60 = 0,5**; > 60 = 0.
(*)Normal values: according to a Productive Agricultural Landscape (in Central Eu Plan)

TABLE 4 - Diagnostic evaluation of an agricultural landscapes in a central European plan.

Class	Diagnostic Index	Diagnostic Evaluation	Physio-pathological notes	Ecological Health & Interventions
I	0,85-1,00	Normal	Homeostatic plateau	Quite good health, only prevention
II	0,60-0,85	Alteration	Compensation needed	Instable health, some therapies
III	0,35-0,60	Disfunction	Some physiological damages	Disfunction, intervention needed
IV	0,15-0,35	High disfunction	Harmful effects	High disfunctions, difficult intervention
V	< 0,15	Extinction	Irreversible damages	Degenerative transformations

The forest cover is proportionally higher in the most crowded unit (Adda Nord), while lower in Besana: 5.57% Vs 1.42%; but the forest BTC runs on the contrary at the opposite, and similar is the decrease of crop quality and LM.

To arrive to a true diagnostic evaluation of the examined agricultural landscapes it is necessary to consider the normal values of each parameter. The ranges of normal values are exposed in Table 4, according to a Productive Agricultural landscape (of Central Europe).

For each case studies has been measured the distances (%) from the normal values, evaluating these percentages with the following scores: 0-10 = 2; 10-30 = 1; 30-60 = 0.5; > 60 = 0.

The sum of the scores gives the value of the diagnostic index. Note that only 2 parameters are good: the HH and the PRD. As shown in Table 4, all the results are out of the normal ecological state, being these agricultural landscape units in alterate conditions. The clinical-diagnostic methodology needs also to link the diagnostic index with physio-pathological notes, ranking the landscape health in at least five classes of diagnosis: (i) normal, (ii) alteration, (iii) disfunction, (iv) high disfunction, (v) extinction.

The diagnostic index of Besana is in the II class, indicating an alterated condition, thus a need of compensation; similar is the condition of Cusago. The diagnostic index of Adda Nord landscape unit indicating a disfunction, needs interventions.

CONCLUSION

The necessity to preserve agricultural landscapes is increasingly important, especially in very urbanized territories, in Europe. For instance, in only 33 years (1969-2002) the hinterland of Milan (about 2,150 km^2) reduced its agricultural landscape units from 45.2% to 13.5%, while the urbanized landscape grown from 45.3% to 78%. First of all it is necessary to integrate the traditional methods of vegetation survey (e.g. phytosociology) with other new methods; in this case with the landscape biological integrated one (proposed by Ingegnoli). Moreover, it is essential to reach a diagnostic evaluation of the landscape units.

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