PROPOSAL OF A NEW METHOD OF ECOLOGICAL EVALUATION OF VEGETATION: THE CASE STUDY OF THE VEGETATION OF THE VENICE LAGOON LANDSCAPE AND OF ITS SALT MARSHES

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ABSTRACT - In frequent case studies, the heterogeneity of vegetation formations is very high, because of the frequency of both natural and human disturbances. Consequently, the phytosociological approach and the auto-ecological one are not completely adequate for the evaluation of the ecological state of this vegetation in a landscape.

So, this evaluation needs the integration with a landscape ecological method of vegetation survey through schedules, as indicated by Ingegnoli (2002). Each type of schedule has been designed to check the organisation level and to estimate the metastability of a tessera of a certain type of vegetation, considering both general ecological and landscape ecological characters: (A) Landscape element characters (e.g. tessera, corridor), (B) Plant biomass above ground, (C) Ecocoenotope parameters, (D) Relation among the elements and their landscape parameters. There are four evaluation classes, the weights per class depending on an evaluation model designed as shown later on.

The principal aim of this research is to design a new schedule, available for the main coenosis of salt marshes vegetation, which allows to complete a preliminary study on the Venice lagoon landscape dynamics, based on its vegetation. The landscape of the Venice lagoon is very complex and articulated. Its main vegetation formations are the following: Underwater, Salt marshes, Littoral, Reclamation colonisations, Wet areas, Wooded patches and corridors, Agricultural cultivations, Urban green. The most important type of vegetation is represented by salt marshes prairies called "barene", especially by *Limonietum venetum* (Pignatti, 1966). This association can be divided into three sub-associations, the first with three facies: but the reality presents a large quantity of tesserae in intermediate or ecotonal states, even mixed with other associations (e.g. *Spartinetum maritimae*). The design and control of the schedule, the first measure of the community plant biomasses are a part of this study, the results of which will be discussed in this work.

KEY WORDS - Landscape Ecology, Evaluation of Vegetation, Venice Lagoon Landscape, Salt Marshes (Barene).

CRUCIAL IMPORTANCE OF VEGETATION IN THE EVALUATION OF THE ECOLOGICAL STATE OF A LANDSCAPE

To study the amount of the transformation of a landscape it is useful to focus on the main landscape apparatuses. The definition of landscape apparatus (Ingegnoli 2002) concerns functional systems of tesserae and ecotopes which form specific configurations in the complex mosaic (i.e. ecotissue) of a landscape. A tessera is the smallest homogeneus unit visible at the spatial scale of a landscape, multifunctional but tridimensional: it corresponds to the old definition of ecotope as the sum of physiotope and biotope, while an ecotope is the smallest landscape unitary multidimensional element that presents all the structural and functional characters of the concerned landscape: it is the minimum system of interdependent tesserae (Ingegnoli 2002). These apparatuses are distinguished by a specific landscape function (and/or its range of sub-functions), not only by many local characters.

A first well known, general but important, landscape function is demonstrated by the survey of human habitat (HH) versus natural and semi-natural habitat (NH). The HH can be defined as areas where human populations live or manage permanently, limiting or strongly influencing the self-regulation capability of natural systems. The NH are the natural ecotopes and landscape units, with dominance of natural components and biological processes, without direct human influence and capable of normal self-regulation. Note that even near-natural ecosystems (i.e. little changed after human abandonment) are NH. Remember that, in landscape ecology, the management role of human populations, if not directed against nature, may be considered as semi-natural. Following the ecotissue model (Ingegnoli, 2002), the sum HH+NH>1.

The ecotissue is a complex multidimensional structure represented by a basic mosaic and a hierarchic succession of correlated mosaics and attributes: it represents the structural model of a landscape. The basic mosaic is generally formed by the vegetational coenosis because the control of the flux of energy and matter and the capacity to create the proper environment pertain to it. This fact is in accordance with non-equilibrium thermodynamics. Whereas an energy concentration (i.e. photosynthetic plants) produces structure and organisation in a landscape matrix with increasing entropy, the order through fluctuation process creates a patch, which acquires a specific landscape role. This may be the principal way by which ecological systems become heterogeneous (Ingegnoli 1980, 1999; Forman & Moore 1991).

Consequently, a correct evaluation of the ecological state of a landscape is impossible without the evaluation of its vegetational components. But this evaluation have to be in accordance with landscape ecological principles. First of all, the definition of vegetation must be: the "complex of the plants" of a landscape element, considered in their aggregation capacities and in their relations with environmental factors. In this view, a coltivated tessera is to be considered as vegetation not only for its weeds (e.g. *Secalinetea, Chenopodietea*), but even for the cultivation itself (e.g. *Triticum aestivum, Hordeum vulgare*), without which the weeds does not succeed and the tessera does not become the habitat for many natural species (e.g. *Coturnix coturnix, Alauda arvensis*), besides to be a crucial ecological component for human population.

As enhanced before, the importance of vegetation evaluation in landscape ecology is extremely high, but it needs a proper methodology. In fact, for the landscape ecological principles it is not acceptable to reduce all the information regarding vegetation to the phytosociological criteria (Walter 1984; Naveh and Lieberman 1984, Pignatti 1996; Ingegnoli 1999, 2002). It must be clear that we appreciate the discipline of phytosociology, but this is not enough.

One of the useful form in which vegetational characters can be related to landscape ecology is through a survey schedule, a proper one for each type of vegetation, for the evaluation of a vegetated tessera. The schedule (TABLE 1) 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 parameters for each A, B, C, D groups range from 2 to 12, thereby reaching the number of about 26-32. The evaluation classes are four, the weights per class depending on an evaluation model. Remembering the well known relationships among gross productivity, net productivity and respiration in vegetation ecosystems (Odum 1971, Duvigneaud 1977), the development of a vegetation community may be synthesised in: (1) the growing phases from young-adult to maturity, expressed by an exponential process; (2) the growing phase from maturity toward old age, expressed by a logarithmic process.

It was possible to design a credible model and to calculate, for each one of the main types of vegetation ecosystems, an exponential-logarithmic curve of development (FIGURE 1) having an adapt temporal dimension. Each curve presents in the transition phase (1-2) its own BTC values (see later), defined after a control through the field study of critical points referred for instance to plant biomass relations, structural and ecological parameters. The behaviour of each curve has been subdivided in four intervals of the same breadth, corresponding to four evaluation classes. Thus the derived values are the weight (scores) to be coupled to the A, B, C, D ranks of parameters, which represent the self-organisation level and the metabolic potentiality related to a system of ecosystem (Ingegnoli 2002).

In considering a set of vegetated tesserae, this schedule is very useful to check and compare the ecological state of each group of parameters (A, B, C, D), to verify a level of quality (Q) of each tessera and to estimate the biological territorial capacity of the vegetation (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). This function is proportional to the metastability of the vegetated tesserae, thus the BTC indexes allow the recognition of regional thresholds of landscape replacement (i.e. metastability thresholds) during time, and especially the transformation modalities controlling landscape changes, through vegetation changes.

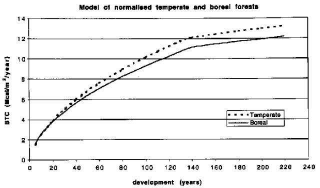

FIGURE 1 - Model of the development of normalised temperate and boreal forest. Note that their change in BTC follows an exponential growth equation passing to a logarithmic one in the late adult age, toward maturity. After a control phase on many natural forest case studies, this model (Ingegnoli 1999, 2002) allowed the proposal of a new methodology on vegetation evaluation based on landscape ecological principles.

At present, this research is extended to temperate and boreal forests, shrub-lands, green-lands, vegetated corridors, agricultural fields, gardens and urban arboreous green, schlerophyll forests and reed thickets.

STUDYING THE LANDSCAPE OF THE VENICE LAGOON

The formation, after the last glacial period, of longshore bars with some tidal delta in contrast with fluvial delta along the eastern side (just above the 45^{th} parallel) of the North Italian Plain, and local bradyseism, created typical lagoon landscapes, from the Po to the Isonzo rivers.

This usually transient ecological system, in the Venice lagoon of about 1100 km^2, was stabilised by Venetian people during the last 13 centuries (about 600-1900). In the last century, big changes were made in the Venice lagoon, as the dam barrages in the littoral sea, the Marghera Harbor, the large industrial zone near the harbor itself, the Canale Petroli (big oil canal for oil ships), the urbanisation of Mestre, Lido etc, the increasing boat and fish disturbances. This brought toward a degradation of the entire landscape.

The results of the transformations are reported in TABLE 2; they are normalised to the unity for comparison reasons. The changes expressed are very impressive: during only 100 years, the human habitat increased 142% while the natural habitat decreased 15,3%. The parameters of landscape ecology indicate a transformation of the entire landscape from rural to suburban, because HH=38% (in a landscape only 55% terrestrial) is equivalent to HH=69% of a totally terrestrial one.

In their whole, the landscape vegetated elements of the Venice lagoon changed sometime drastically, as shown in TABLE 3: the vegetated area decreased about 20% in the last century.

The most natural and typical vegetation, the salt marsh prairie, the presence of which was 28,1% in 1900, is today about 2/3 reduced, measuring only 12,2% of present vegetation (FIGURE 2). As shown in TABLE 3, the main types of vegetation form a truly heterogeneous system, within which today the natural vegetation is limited to about 30% of the entire surface. Thus, the human vegetation has to be inevitably evaluated, in order to study the landscape dynamics.

THE STUDY OF THE VEGETATION OF THE VENICE LAGOON LANDSCAPE

In TABLE 4 the results of the application of the above synthesized method of landscape ecology to evaluate the vegetation on the Venice landscape are expressed. The most typical samples from seven groups of vegetation are presented, with their mean quality and BTC values. The level of these vegetated tesserae is quite low, especially the most human dependent, but even the few remnant patches of forest are not in a good condition. In this table there are no data concerning the important vegetation of salt marshes, because the proper schedule was not yet elaborated. Consequently, the necessity to design an available schedule became imperative. The study started with an elaboration of theoretical data on the main plant association of the salt marsh vegetation in this landscape: the *Limonietum venetum* (Pignatti 1966).

The most significant characters of the *Limonietum*, are exposed in TABLE 5. Elaborated from recent scientific literature, these data present a community above ground biomass ranging from about 0,4 to 0,6 kg/m^2 of dry matter; consequently, the BTC ranges from 0,27 to 0,51 Mcal/m^2/year.

The study of the real tesserae on the field gave sometimes different results, due to frequent mixed associations, with higher percentage of *Spartina*, *Arthrocnemum* and other plants heavier than *Limonium*, or to very mature coenosis. These data ranges from about 0,5 to 1,3 kg/m^2 and the BTC from 0,30 to 0,75 Mcal/m^2/year. In both the cases, using biomass data from literature or from the field, note that BTC was calculated strictly following the theory (Ingegnoli, 2002).

The study of the vegetation on the field, summarized in TABLES 6 and 7, concerned the choice of the main ecological characters of (A) Tessera parameters, (B) Vegetational biomass above ground, (C) Ecocoenotope parameters, (D) Landscape unit context. About 60 phytosociological relevées were made on 30 tesserae of "barene" (salt marsh prairies in Venetian language), mainly (2/3) in the North Lagoon, which is the best conserved. Some tesserae were artificial and other also in a degraded state; all type of tesserae were considered in this study. The research was completed with the survey and drawing of many transects, some of which are presented in FIGURES 4 and 5.

The construction of a model [BTC-community development] with the passage between adult and mature stage at about 12 years (controlled on new natural and artificial salt marshes tesserae) followed. These communities have to fight against heavy disturbances (tide, wind, waves) thus their strategy of development is quite fast, even if the maturity stage can be very long. The contorted lignified stem of a *Limonium serotina* can reach more than 15-20 cm (height, 4/5 underground) with about 3 cm (diameter) before its expansion in a rosette of leafs and branches.

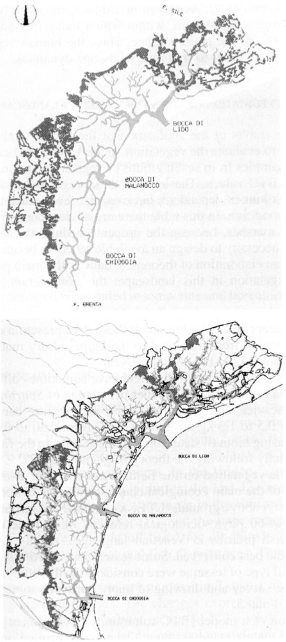

FIGURE 2 - Synthetic maps of the Venice lagoon showing the distribution and the extension of the salt marsh prairies (green), called "barene". Note the sharp difference between 1930 and 1998 (plots from CVN-2003).

The design of the schedule (TABLE 8) needed an iterative approach, with frequent control on the field. The verification of the schedule was made considering a significant set of samples on which the BTC was calculated through its theoretical approach, and compared with the values resulted from the application of the schedule itself. As it is reasonable to consider a similar level of uncertainty, it is possible to compare the measure made on the same group of samples of the BTC derived from the schedule with the BTC calculated on theoretical data (B, NP, R/GP and the BTC formula). The correlation (R^2=0,81) is sufficiently good.

EVALUATION OF THE VEGETATION OF THE SALT MARSHES

Even if this study was still a preliminary one, having the aim to demonstrate the validity of the new landscape ecological methodology proposed by Ingegnoli in an uncommon landscape type like the lagoon of Venice, the results seem to be very interesting.

After 50 years of the very good work of Pignatti (1966), the comparison between the species composition of the *Limonietum venetum* (FIGURE 3) seems to express some significant changes in the sub-associations I (1L) and II: the dominant species being less dominant, favoring especially *Spartina maritima*. A larger presence of *Spartina* seems to be confirmed also by the presence of many mixed formations (*Limonietum-Spartinetum*).

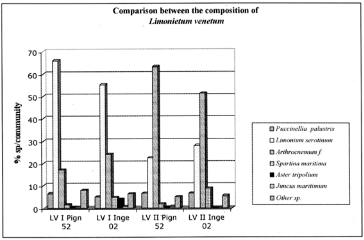

FIGURE 3 - Comparison among the species composition of *Limonietum venetum* I (1L) and II studied by Pignatti about 50 years ago (1952) versus the same associations studied by Ingegnoli 2002. Note that in 2002 the dominant species are less dominant, favoring especially *Spartina maritima* and *Arthrocnemum fruticosum*.

Some considerations on transects help to better understand the present state of these "barene". Here two figures are reported, referred on two cases needing strong actions of restoration ecology (FIGURE 4) and referred on two cases presenting a normale ecological state (FIGURE 5). The transects are identified in the way reported in the summary TABLES 6 and 7.

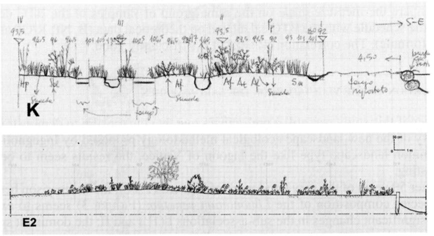

FIGURE 4 - Transects on two types of "barene" which needed strong actions of restoration ecology. The above figure (K) is referred to Canal Passaora (Ts. XXIII), clearly eroded, but with 9 sp/Ts.: its quality is quite low (42%) and its BTC is only 0.35 Mcal/m²/year. The figure below (E2) is referred to a tessera South of Chioggia, artificially rebuilt about 10 years ago (Ts. X) with 11 sp/Ts.: its quality is 50, and the BTC=0.43 Mcal/m²/year. For more data see TABLES 6 and 7. The scale is the same in all the four transects.

The erosion on the edge of the barene is common, sometimes even to the best vegetated, but the degradation of the barene presents two main typologies: (a) the first is like the transect K, in which the erosion is clearly evident, but vegetation is quite good, (b) the second is a more diffuse erosion over all the central surface, with a simplified and scarce vegetation. New artificial barene, built where some old isle were cancelled by erosion, are soon colonised by vegetation, in the way that we can see in transect E2: this profile seems to be not correct (especially the heigh distribution) allowing a very mixed vegetation.

The transect H1-H2 (FIGURE 5) shows the difference with E2. This is a natural condition, in which two tesserae are well defined both in geomorphic and vegetation characters. Landscape ecology underlines the importance of heterogeneity: not so much at species scale, but among different patches indeed, some of which must have good borders. The transect F1-F2 shows a similar condition, in which a minor salt content in soil allows the presence of an Agropyretum. An organic soil at the foot of the higher margin (F2) hosts an Atriplicetum.

The values of the ecological parameter of the tesserae resulting after this research were collected in three groups of comparable data: the worst cases, the best cases, the mean one. As exposed in FIGURE 6, the maximum value being 12, it is easy to make a proportion to see the different conditions of the studied vegetation.

Deriving from the non-linear classes of score in the schedule, the values present the following classes of evaluation: (i) high level (9-12), (ii) normal one (4.5-9), (iii) scarce one (2-4.5) and (iv) negative one (<2).

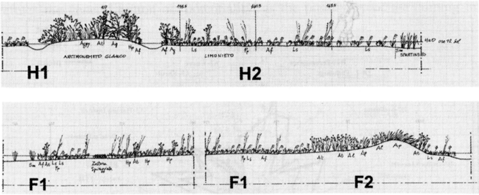

FIGURE 5 - Transects on two types of "barene" which present a normal ecological state. The above figure (H1-H2) is referred to Canal Tresso (Ts. XVI-XVII): H1 was evaluated with a schedule for shrub formation, H2 presents a quality of 51% and a BTC=0.42. The figure below (F1-F2) is referred to Val de la Dolce (Ts. XI-XII): F1 has a quality of 61% and a BTC=0.57, very similar to F2. For more data see TABLES 6 and 7.

The mean cases show 3 parameters of high level (B2, litter layers presence; C8, absence of alloctonous species; C9, absence of threatened plants), versus 5 of scarce (A4, low structural differentiation; C3, low diversity of species; C6, very low vertical stratification; D3, no source toward surroundings; D7, very few sedimentation) and 1 negative: A3, shrubs presence. The 5 scarce parameters (17.9%) may indicate a state of diffuse, even if not severe, degrading pressures. The negative one is linked with the tendency in changing the species composition of the *Limonietum*, mainly due to the 2 mm/year of soil lowering. In fact, the presence of *Artemisia coerulescens* is today rare, because of the height reduction of the typical margins of the barene. Note that the scarcity of the shrub presence is the only low parameter also in the best cases, and is reinforced by the scarcity of the sedimentation, mainly due to the sea dams at the tidal mouths, and to the insufficient suspension in fluvial waters.

The distribution of the ecological parameters is not always proportional among best, mean and worst cases. For instance, human disturbances are heavier in the best cases than in worst ones. This does not mean that disturbances help the vegetation in the best cases, but that today human disturbances on the barene are not so degrading.

On the opposite, a comparison among the synthetic sets of the ecological parameters of vegetation leads to a more proportional vision. In facts, in FIGURE 7 the best, mean and worst cases show similar plots: only the worst single tessera (VIII, Ravagio) is different, being a new artificial barena. The evaluation classes are the same of the previous figure. The mean cases do not present high class set of parameters, and their BTC is scarce. Even considering the worst case, the only set in a normal state is the same that in the best cases arrive to the top class: the ecocoenotope parameters (C). Thus, the ecocoenotope parameters result as the most positive, on the contrary of the BTC.

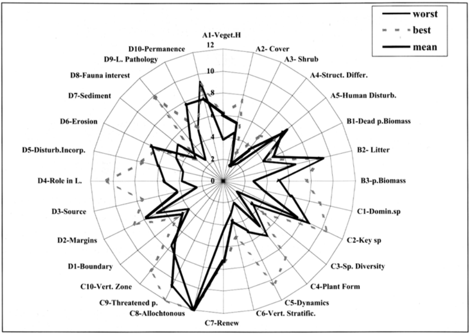

FIGURE 6 - Detailed values of vegetation parameters measured with the proposed schedule on the salt marsh. The set of results of this research was divided in worst, best and mean cases (tesserae, Ts). The maximum value being 12, it is easy to make a proportion to see the different conditions of the studied vegetation. Note that only 10 parameters reach a belt of maximum value (9-12) and only in the best cases.

Note that if only the more traditional ecological parameters are well studied, and they result quite normal, the evaluation of the vegetation could be untrue. This fact reinforces the necessity to insert the landscape ecological parameters in studying the vegetation.

The condition of the characters of the tessera are not so good. They result just normal only in the best cases.

CONCLUSIONS

The presented methodology shows its interesting possibilities both in theoretical and practical aspects. In facts, the above reported evaluation on the vegetation allowed to complete the study, the control and diagnosis of the lagoon landscape dynamics, therefore to design the therapeutic criteria of ecological rehabilitation.

The changing environment of the lagoon landscape seems to influence in very short times the vegetation composition, so that the concept of "potential vegetation" is impossible to be applied. This observation confirms the necessity to abandon the concept of potential vegetation in studying a landscape, and to substitute it with the concept of "fittest vegetation" (Ingegnoli, 2002). This new concept refutes the general notion of 'potentiality' as the possibility of the coming into

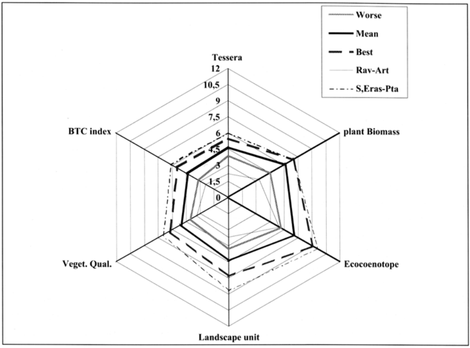

FIGURE 7 - Sinthetic values of the vegetation set of parameters, measured with the proposed schedule. The worst vegetated tessera (Rav-Art, Ts. VIII) and the best tessera (S.Eras-Pta, Ts. XXVI) are plotted toghether with the best, mean and worst cases. Note that the ecocoenotope parameters result as the most positive, on the contrary of the BTC. This fact reinforces the necessity to insert the landscape ecological parameters in studying the vegetation.

existence, in the absence of man and for large territories, of a deterministic, a priori fixed vegetation type and interpreted as the best condition for a place, independent of all the other environmental and human factors and of time. Moreover, no potential homogeneity can be a model for the develpoment of a landscape. On the contrary, the concept of "fittest vegetation" indicates the most suitable or suited vegetation to: the specific climate and geomorphic conditions of a certain limited period of time in a certain defined place; the main range of incorporable disturbances (including man's); natural or not natural conditions. This could be a great change of perspective.

In TABLE 9 some of the most significant ecological parameters are summarised, available to express the ecological state of the Venice lagoon landscape, and their re-balance targets, derived from a preliminary research made by Ingegnoli in 2002-2003 for the Magistrato alle Acque di Venezia (Water Magistrate of Venice) through CVN (Consorzio Venezia Nuova).

We observe that in this table four parameters on six are directly dependant from vegetation evaluation, and the other two have linkages with vegetation. Note that to elaborate the re-balance targets is essential to use the proposed methodology on vegetation evaluation, in an iterative process of design and control.

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TABLE 1 - Schedule for the evaluation of vegetated corridors, available also for the estimation of their biological territorial capacity (from Ingegnoli 2002).

Vegetated corridor	1	7	17	33	score
A. CORRIDOR (C) CHARACTERS					
A1- Corridor width (W)	< 2.5	2.6 -10	10.1 -20	> 20.1	meters
A2- Vegetation high (h) (mt)	< 3	3.1 -12	12.1 -24	> 24.1	weighed avr,
A3- Presence of water (w)	none	1 canal	2 canals	river	w < W
A4- Interruptions (> h)	> 4	3-4	1-2	0	n° in 10 h
A5- Management works	cutting	pruning	marginal	0	
A6- Tree cover (%)	< 30	31-60	61-90	> 90	medium
A7- Permanence (years)	< 60	61-120	121-180	> 180	real age of C
A8- Linearity	rectilinear	semi-rect.	mixed	irregular	entire tract
A9- Presence of road (r)	traffic r.	paved r.	rural road	no or path	r < W
B. VEGETATIONAL BIOMASS (ABOVE GROUND)					
B1- Dead plant biomass in C	near 0	exceeding	near norm	normal	wood
B2- Litter depth of the C	near 0	< 1.5	1.6-3.5	>3.5	cm
B3- Plant biomass volume	< 100	101-300	301-600	> 600	m^3/ha
C. ECOCENOTOPE PARAMETERS					
C1- Dominant species	1	1-2	2-3	> 3	studied tract
C2- Key species presence (%)	< 5	6-20	21-80	> 80	botanical
C3- Diversity	< 15	16-30	31-44	> 45	n° sp/stud. tr
C4- Plant forms (n°)	< 3	4-5	6-8	> 8	cf. Table 7.3
C5- Dynamic state	degradat.	recreation	regener.	fluctuat.	cf. Sect. 5.1.3
C6- Vertical stratification	1	2	3	≥4	cf. Fig. 7.7
C7- Renew capacity	none	sporadic	normal	intense	domin. sp.
C8- Allochthonous sp. (%)	> 10	10-4	< 4	0	not region.
C9- Infesting species	many	few	sporadic	0	even local
C10- Threatened plants	evident	suspect	risk	0	even acid r.
D. LANDSCAPE UNIT (LU) PARAMETERS					
D1- Source (vs. surroundings)	sink	neutral	partial	effective	
D2- Connections of the C	0	1	2	>2	nodes
D3- Interior species in the C	0	sporadic	few	many	forest sp.
D4- Network participation	not	neutral	potential	effective	
D5- Disturbance incorporation	0	scarce	normal	high	local disturb.
D6- Technologic interferences	≥2 crosses	1 cross	very near	far/or no	
D7- Faunal exchange	poor	low	normal	high	vs. matrix
D8- Lichens presence on trees	0	1-15	16-35	>36	n° species
D9- Type of matrix	urban	suburban	rural	s-natural	matrix
E. RESULTS OF THE SURVEY					
E1- Total score Y (= a+b+c+d)	a=	b=	c=	d=	Y=
E2- Quality of the corridor	Q = Y / 1023				
E3- Quality of parameter sets	A/A_{max}, B/B_{max}, C/C_{max}, D/D_{max}				
E4- BTC estimation	BTC = 0.00766 (y-31) + 0.1 (pB/75) [Mcal/m^2/year]				

A1, projection of the width of leafage on the ground; *A2*, weighed average of canopy trees (h); *A3*, canal and riverbed width smaller than W; *A4*, n° of interruptions in a tract 10 times (h) long; *A9*, road width smaller than W; *B3*, pB is plant biomass volume: cf. 7.3.3; C1, tree/s sp. the biomass volume of which clearly exceed the equitability (eq) of the total canopy pB. If no species exceed, sign the fourth column (d); *C2*, presence compared with phytosociological association/s or phytocoenosis of reference; *C8*, presence of species not autochthonous of the ecoregion; *C9*, even character species (not dominant) but with a too massive covering; *C10*, present situation; *D6*, by technological network; *D8*, following Nimis (1990)

TABLE 2 - Main changes (%) in the landscape components of the Venice Lagoon (~1,100 km^2) in the last century, Note the transformation of this landscape from rural to suburban.

Landscape apparatuses		Main components	1900	1950	2000
Human Habitat (HH)	Residential (RSD)	Built	0.6	3.3	4.9
	Subsidiary (SBS)	Industrial, canal, road, airport	3.35	5.44	7.15
	Productive (PRD)	Agricultural field, orchard, fish pond	22.9	28.0	23.7
	Protective (PRT)	Urban green, edgerows, etc.	0.1	0.7	2.4
		TOT. HH	*26.95*	*37.44*	*38.15*
Natural Habitat (NH)	Resistant (RNT)	Forested patch and reclamation veg.	0.8	0.3	1
	Stabilising (STB)	Salt marshes, under-water prairie	18.7	14.1	10.3
	Ecotonal (ETN)	Swamp, vegetated belt	4.6	0.03	0.02
	Resilient (RSL)	Shrub, prairie	0.3	0.2	0.2
	Connective (CON)	Edgerow, wooded corridor	1.2	0.9	0.4
	Excretory (EXR)	Channel, reed	3.25	3.06	3.1
	Geomorphic (GEO)	Lagoon, sea littoral, beach	44.2	44	46.83
		TOT. NH	*73.05*	*62.56*	*61.85*

Note: the values of this table does not correspond with final values of the landscape apparatuses, that need further calculation due to the concept of ecotissue (Cf. Ingegnoli 2002). These values indicates only the dominant functions of the apparatuses.

TABLE 3 - Main changes (%) in the landscape vegetated elements of the Venice Lagoon in the last century. The lost of 20% of vegetated areas in only 100 years is put in evidence.

Landscape elements	Vegetation types	1900	1950	2000
Littoral	Sand vegetation	(0.2)	(0.1)	0.1
Lagoon and channel	Underwater prairies	(5.5)	(5.5)	5.0
	Salt marshes vegetation	13.20	8.55	4.60
Wet area	Reeds and wet prairies	(3.40)	(0.75)	0.50
Reclamation	Mixed vegetation	1.2	1.0	1.4
Terrestrial margins, littoral strips and lagoon islands	Wooded patches	0.6	0.2	0.2
	Cultivated fields	13.3	19.9	23.0
	Wooded cultiv./orchards	9.4	7.8	0.4
Urbanized areas	Urban green	0.2	0.7	2.4
LANDSCAPE	**Vegetated areas**	**47.0**	**44.5**	**37.6**

(...) error of estimation greater than in other types of vegetation

TABLE 4 - Sample survey of the most characteristic vegetated tesserae of the landscape of the Venice Lagoon, following the landscape ecological methodology proposed by Ingegnoli.

Landscape elements		Schedule parameters					Results		
Sm. N°	Vegetation typology	scarce	poor	good	high	tot Y	Quality %	Biomass m^3/ha	BTC $Mcal/m^2/yr$
A	**Edgerows (vegetated corridors)**						***36.0***	m^3/ha	***2.94***
1	*Populus* 1 (Le Giare)	8	7	14	2	361	35,3	370,7	3,02
2	*Populus* 2 (Le Giare)	9	7	10	5	393	38,4	442,8	3,63
3	*Robinia* ((Portegrandi)	10	9	8	4	341	33,3	43,6	2,43
4	*Salix* (Jesolo)	8	4	14	5	439	42,9	370,7	3,62
5	*Fraxinus* (Lazzaretto)	9	9	9	4	357	34,9	304	2,90
6	*Acer, Robinia* (S. Erasmo)	8	14	8	1	275	26,9	113,8	2,02
7	*Tamarix* (v. Figheri)	8	8	9	6	415	40,6	38,27	2,99
B	**Forest patches**						***50.2***	m^3/ha	***5.37***
1	*Mesophylus* forest (Carpendo)	1	6	8	13	413	67,0	244,5	6,98
2	*Mesophylus-higrophilus* (Mestre)	6	5	9	8	315	51,1	65,5	4,94
3	Pine forest (Cà Savio)	2	7	11	8	345	56,0	417	6,25
4	Pine forest (Jesolo)	7	8	9	4	243	39,4	341,3	4,37
5	Pine forest (Alberini)	2	12	8	6	290	47,1	225,2	4,89
6	Pine forest (Cà Roman)	5	8	9	6	285	46,3	502	5,44
7	*Higrophilus* forest (v. Averto)	6	7	12	3	251	40,7	256	4,31
8	*Robinia* forest (v. Figheri)	5	7	6	10	332	53,9	312,2	5,79
C	**Meadows, prairies**						***37.8***	kg/m^2	***0.55***
1	*Ruderal* (Mestre)	7	8	8	6	335	36,1	1,20	0,58
2	Agricultural (Carpendo)	7	10	6	6	317	34,2	0,60	0,47
3	Moist-wet (Piave Vecchia)	2	6	10	11	508	54,7	0,50	0,71
4	*Molinietum* (S. Erasmo)	5	12	7	7	342	36,9	1,40	0,62
5	*Ammophyletum* (Cà Roman)	5	7	12	5	349	37,6	0,65	0,52
6	Planted *Ammophyl.* (Cà Savio)	11	9	5	4	240	25,9	0,60	0,37
7	Natural *Ammophyl.* (p. Sabbioni)	7	7	9	6	344	37,1	0,30	0,46
8	Ruderal (v. Figheri)	5	5	14	5	367	39,5	1,50	0,67
D	**Reeds**						***58.4***	kg/m^2	***1.25***
1	*Phragmit.-juncetum* (Alberoni)	2	6	12	9	575	53,6	1,10	1,40
2	*Phragmitetum* (Millecampi)	5	3	5	16	700	65,2	0,90	1,23
3	*Phragmitetum* (Figheri)	5	3	8	13	640	56,3	0,90	1,13
E	**Woody agrarian**						***28.0***	m^3/ha	***1.22***
1	Orchard (Jesolo)	7	8	11	3	748	32,6	47,4	1,43
2	Vineyard (Carpendo)	11	11	2	4	545	23,7	8,2	0,91
3	Vineyard (Malamocco)	7	15	4	3	566	24,7	10,8	0,96
4	Poplar grown (Carpendo)	7	12	7	4	715	31,1	96,4	1,58
F	**Sown fields**						***33.5***	kg/m^2	***0.60***
1	Maize (Fogolana)	16	4	3	3	174	21,6	1,90	0,45
2	Carrot (Brondolo)	7	9	7	3	250	31	2,20	0,63
3	Radicchio (Conche)	12	5	5	4	236	29,3	1,20	0,51
4	Radicchio (Malamocco)	10	7	5	4	244	30,3	1,20	0,53
5	Maize and tomatoe (S. Erasmo)	4	7	2	13	472	58,6	1,50	0,99
6	Soy (Piave Vecchia)	13	3	4	5	243	30,1	0,90	0,50
G	**Urban Green**						***27.7***	m^3/ha	***2,18***
1	Urban Park(Tessera)	11	9	9	1	293	24,2	80,0	1,56
2	Urban Park (Mestre)	6	16	6	2	316	26,1	142,2	1,82
3	Urban Park (S. Elena)	6	11	13	0	343	28,4	439,2	2,62
4	Pine Camping (Cà Savio)	3	6	5	6	389	32,2	369,0	2,71

TABLE 5 - Theoretical characters of the main association of the Venice lagoon salt marshes vegetation, and its divisions: (I) Sub-Association *Limonietum typicum*: 1.L L.v. var. *Limonium*, 1.P L.v. var *Puccinellia*, 1.A L.v. var *Aster tripolium*, (II) Sub-Ass. *Limonietum salicornietosum fruticosae*, (III) *Limonietum juncetosum maritimi*; (B) above-ground biomass; (NP) net production.

Limonietum venetum (L.v.) (Pignatti 1966)	**I (%)**			**II**	**III**	**B**	**NP**
	1.L	**1.P**	**1.A**	**%**	**%**		
Puccinellia palustris	6.5	**54.7**	8.5	6.7	7.6	513	416
Limonium serotinum	**65.9**	8.0	24.1	22.4	27.8	378	307
Arthrocnemum fruticosum (Salicornia fruticosa)	17.1	5.5	2.8	**63.2**	7.9	678	666
Spartina maritima	1.6	0	0	1.8	1.0	631	513
Aster tripolium	0.5	12.7	**54.4**	0.3	3.8	545	443
Juncus maritimum	0.5	0	4.3	0.6	**44.0**	345	279
Other species (*Halimione portulacoides, Salicornia sp, Inula crithmoides, Suaeda maritima*, etc)	7.9	9.1	5.9	5.0	7.9	720	580
Community Biomass (B)	470	483	507	599	433		
Community net production (NP)	401	398	415	559	360		
Respiration (R)	278	276	288	388	250		
Main range of BTC	0,32	0,30	0,31	0,41	0,27		
	0,40	0,37	0,39	0,51	0,34		

Note : the above ground biomass data (B , NP) for each species (g d.w./m^2) from Scarton F, Rismondo A, Nascimbeni P (2000), Scarton F, Rismondo A, Manzoni A (1999), Day J W, Rybczyk J, Scarton F, Rismondo A, Arc D, Cecconi G (1999); The respiration R derive from the assumption of R/GP = 0.41 (Whittaker and Likens 1975 and Kimmins in Piussi 1994): BTC (Ingegnoli 1991, Ingegnoli and Giglio 1999, Ingegnoli 2002) in Mcal m^2/year.

TABLE 6 - Synthesis of the surveys, phytosociological relevés, transects and landscape ecological schedules on the salt marshe vegetetation of the Venice Lagoon Landscape (2002-2003).

Site (Barena)	ex Salina 1		ex Salina 2		pal. Tralo		p.ta Cane			L. Ravagio		Sud Chioggia				V.le della Dolce				Can. Tresso 1			
Notes	*New form.*		*New. Form.*		*Old marine*		*Olld fluvial*			*Restored*		*Oldest artificial*				Terrestrial margin				*Old marine*			
Date	30.07.02		30,07,02		30.07.02		31.07.02			31.07.02		10.09.02				10.09.02				11.09.02			
Tessera	I		II		III	IV	V	VI		VII	VIII	IX		X		XI			XII	XIII	XIV	XV	
Relevé N°	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Plot area (m²)	4	4	4	4	4	4	4	4	4	4	4	6.2	6.2	6.2	6.2	4	4	6.2	16	4	4	4	4
Plant cover (%)	90	90	95	95	85	95	80	95	90	75	60	80	70	65	90	80	95	95	95	75	80	85	40
Puccinellia palustris	fr	+.1			+.1	+.1		2.2	1.2	2.2	1.1				+.1	1.2	1.2	**3.2**			+.1	+.1	1.1
Limonium serotinum	2.1	2.1			+.1	**4.4**		**3.2**	**4.2**	1.1	+.1	1.2		1.1	2.2	3.3	**3.3**	2.3	1.1	2.2	+.1	**5.5**	2.1
Arthrocnemum frutic	**3.2**	2.2			**2.2**	2.2	2.3	**3.3**	1.2	**3.3**	2.2		1.1		**4.3**	**4.3**	2.3	1.3		2.2	**3.4**	1.1	**3.2**
Spartinamaritima	2.2	**4.3**		**5.5**		+.1		1.2	3.3	1.2		**4.4**	**3.4**							**4.4**			
Aster tripolium					+.1	+.1											1.2	2.2	2.3		+.1		
Juncus maritimum																fr	fr			fr	**3.4**		
Limonium bellidifolium																							
Suaeda marittima	+.1				1.2		+.1										+.2	1.2	+.2		+.1		
Halimione portulac	+.1	+.1			**2.3**		**3.3**			+.1	+.1		2.3	**3.3**	+.2	+.1		2.3		+.1	+.2		
Inula crithmoides	1.1	+.1												1.2			+.1				+.2		
Salicornia spp	+.1	+.1	**5.5**			+.1	+.1	+.1		1.3	**3.2**	1.3					+.2						
Artemisia coerulesc																					fr		
Arthrocnemum glauc					1.2									fr							fr		
Agropyron pungens					+.1									2.2					1.3				
Phragmites comm													+.1		+.1								
Atriplex latifolia							**3.3**												4.4				
Tamarix gallica					fr									fr									
Salsola soda							+.2																
Juncus acutus					+.1										fr								
Cakile maritima							+.1																
Cfr.Stellaria														+.1									
Species N°	8		2		10	6	7	5		6	5	6		11		9			5	5	10	3	
Plant biomass (kg/m²)	2.26	2.27	1.70	2.48	5.93	2.69			1.52	2.16	0.71			3.10		6.07					3.96		
Dry pl. Biomass (kg/m²)	0.92	1.09	0.27	1.40	2.35	0.65			0.53	0.68	0.27			0.85		1.57					1.28		
Transect	A				B1	B2		C		D1	D2	E1		E2		F1			F2	G1	G2		
Lands. Ecol. Schedule	S1		S'		S'	S2	S'	S3		S4	S5	S6		S7		S8			S'	S'	S9	S10	
Veg. Quality (%)	50		57		54	45	43	47		49	34	50		50		61			60	43	57	42	
BTC (Mcal/m²/year)	0.44		0.53		1.44	0.36	1.13	0.38		0.41	0.24	0.40		0.43		0.57			0.58	0.36	0.47	0.34	

TABLE 7 - Synthesis of the surveys, phytosociological relevés, transects and landscape ecological schedules on the salt marshe vegetetation of the Venice Lagoon Landscape (2002-2003).

Site (Barena)	Can. Tresso 2			Can. Dese			Can Tresso p.ta N			Can. Passaora		Isola S. Erasmo						Can. Tresso-Passaora				
Notes	*Old marine*			*Old fluvial*			*Marine*			*Old eroded*		*Marins of the island*						*Old marine. Monitored after 50 yr*				
Date	11.09.02			11.09.02			18.09.02			18.09.02		01.08.02 and 17.09.02						29.07.03				
Tessera	XVI		XVII	XVIII	XIX	XX	XXI	XXII		XXIII		XXIV	XXV		XXVI		XXVI I	XXVIII				
Relevé N°	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Plot area (m^2)	10	10	4	4	4	4	1	4	4	4	4	4	4	6	4	5	4	4	4	4	4	4
Plant cover (%)	95	95	90	85	80	85	80	75	80	70	65	92	80	90	100	85	95	90	80	75	70	65
Puccinellia palustris			1.2	+.2	+.2			+.1	+.1	1.2	**2.1**	1.1	+.2	+.1				+.1			f.r	
Limonium serotinum	+.1		1.2	**3.3**	2.2			**4.3**	1.2	2.2	1.2	**4.4**	1.2	+.2	**2.2**	1.2		**3.3**	**4.3**	+.2	2.2	1.2
Arthrocnemum frutic			+.2	2.3	1.2		1.2	2.3	+.2	+.2	+.2	3.2	**3.3**	**3.3**	**2.3**	**2.3**		2.2	2.2	**4.3**	**3.3**	2.2
Spartinamaritima			**4.4**	1.2	**4.4**			f.r	**3.3**	+.1	1.3	fr						+.2			2.2	**4.3**
Aster tripolium	+.1	+.1		2.1		1.3	+.2			1.1	+.1	+.1			**2.1**	+.1						
Juncus maritimum				1.2											fr	**2.3**			f.r			
Limonium bellidifolium												fr	2.2	2.2		+.2						
Suaeda marittima	**3.4**	2.4				+.2	**2.3**	+.1	+.2	1.2	+.1	+.1		+.2		+.1						1.2
Halimione portulac	+.1	+.2								+.1	1.3	+.1	+.1	1.2	+.1	**2.2**		+.1				
Inula crithmoides		+.2								**3.3**	**2.3**				+.1			1.2				
Salicornia spp				fr				f.r				+.1								f.r		f.r
Artemisia coerulescens																		+.1				
Arthrocnemum glauc	2.2	**3.2**				1.2					2.1		fr	2.2	1.2			f.r				
Agropyron pungens		+.2				**3.4**										1.1	**5.5**					
Phragmites comm															1.1		+.1					
Atriplex latifolia	1.1	+.1				2.2																
Tamarix gallica																						
Salsola soda		+.1					+.1															
Juncuc acutus																						
Cakile maritima																						
Cfr.Stellaria																						
Species N°	9		4	7	4	5	4	6		9		9	7		11		2	11				
Plant biomass (kg/m^2)				4.10				2.06														
Dry pl. Biomass (kg/m^2)				0.92				0.65														
Lands. Ecol.Schedule	S'		S11	S12	S'	S'	.S'	S13		S14		S15	S'		S16		S'	S17				
Veget. Quality (%)	45		51	56	50	44	55	58		42		64	60		70		49	50				
BTC (Mcal/m^2/year)	1.34		0.42	0.48	0.42	0.41	0.45	0.48		0.35		0.55	0.52		0.61		0.44	0.41				

TABLE 8 - Schedule for the evaluation of salt marshes prairies tesserae, applicable also for the estimation of their biological territorial capacity (BTC).

Salt marshes prairies	1	3	6	12	
A. TESSERA (*Ts*) CHARACTERS					
A1- Vegetation height (m)	< 0.2	0.21-0.45	0.46-0.7	> 0.7	weighted av.
A2- Soil cover (%)	< 30	31-60	61-90	> 90	*Ts* surface
A3- Shrub presence (%)	0	<5	6-15	> 15	max 30%
A4- Structural differentiation	low	medium	good	high	groups, etc.
A5- Human disturbances	extended	marginal	sporadic	none	& artefacts
B. VEGETATIONAL BIOMASS (ABOVE GROUND)					
B1- Dead plant biomass %	> 20	20-10	10-5	<5	dried/green
B2- Litter layers presence	A	B	C	D	Cf. note
B3- Plant biomass	< 0.3	0.31-0.75	0.75-1.25	> 1.25	kg/m^2 (dry matter)
C. ECOCOENOTOPE PARAMETERS					
C1- Dominant species	not clear	1	2-3	> 3	cover
C2- Key species presence (%)	< 5	6-20	21-80	> 80	botanical
C3- Diversity	< 5	6-10	11-15	>15	n° sp./*Ts*
C4- Plant forms (n°)	1	2	3	> 3	p. form *sensu* Box
C5- Dynamic state	degrading	recreation	regener.	fluctuat.	*sensu* Falinski
C6- Vertical stratification	1	2	3	4	small herb to shrub
C7- Renew capacity	none	sporadic	normal	intense	of dominant sp.
C8- Allochthonous sp. (%)	> 5	5-2	< 2	0	not regional
C9- Threatened plants	evident	suspect	risk	0	even acid rain
C10- Vertical zones	outside	near out	near typ.	typical	*sensu* Pignatti
D. LANDSCAPE UNIT (*LU*) or ECOTOPE PARAMETERS					
D1- Boundary connections	0	< 20	21-80	> 80	% perimeter
D2- Margins	not clear	> 30	30-10	< 10	% area
D3- Source (vs surroundings)	sink	neutral	partial	effective	resource & sp.
D4- Role in the landscape unit	reduced	minor	evident	important	Ts/contest
D5- Disturbance incorporation	none	scarce	normal	high	local disturbances
D6- Erosion	evident	partial	risk	none	physiotope
D7- Sedimentation	none	low	good	high	mainly tidal
D8- Permeant fauna interest	none	medium	near good	attraction	*Ts*/key sp.
D9- Landscape pathology interference	extremely serious	near chronic	easy to recover	none	surrounding ecotopes
D10- Permanence (years)	<50	51-100	101-200	>200	age in *LU*
E. RESULTS OF THE SURVEY					
E1- Total score Y (= a+b+c+d)	a=	b=	c=	d=	**Y = ...**
E2- Quality of the Ts	Q = Y/336				
E3- BTC estimation	BTC = 0,0026 (Y- 28) + 0,1 (pB/1,4)				

A1, higher layer (h) weighted average; *A3*, % of covering. If the shrub cover exceeds 30%, use the schedule for shrubbery (Ingegnoli 2002); *A4*, presence of not coeval plants and of groups of the same species; *B2*, Litter layers: A almost without organic soil, B organic soil exceeding, C partial organic soil with undistinguished layers, D like C with distinct layers; *B3*, *pB* is plant biomass; *C1*, herb species the biomass of which clearly exceeds the equitability of the total *pB*. If no species exceed, sign the first column (a); *C2*, presence compared with the phytosociological association/s or the phytocoenosis of reference; C4, see Ingegnoli 2002; *C6*, do not consider an isolated tree; *C8*, not autochthonous of the region; *C9*, present situation; *C10*, referred to character species and their salt gradient (see Pignatti 1966); *D1*, connection with vegetation analogous to the Ts; *D2*, surface % of the *Ts* with edge characters: edge = from 5 to 10 h; *D3*, following the source-sink theory; *D4*, functional role of the tessera in the ecotope or in the entire landscape unit; *D10*, years of permanence of the ecotope as salt marshes prairie.

TABLE 9 - Synthesis of some of the most significant landscape ecological parameters referred to the preliminary study of the Venice lagoon landscape (Ingegnoli 2002-2003)

Main landscape ecological parameters	1900	1950	2000	re-balance targets
Habitat ratio, HH/NH (%)	36.9	59.8	61.7	60 ÷ 61
Metastability of vegetated components, BTC (Mcal/m^2/year)	0.51	0.35	0.29	0.38 ÷ 0.40
Salt marshes/tidal area	28.5	19.0	11.0	18 ÷ 20
Resistant landscape apparatus RNT (%)	1.99	1.40	1.76	4 ÷ 5
Ecotonal landscape apparatus ETN (%)	7.32	3.95	4.24	7 ÷ 8
Landscape functional diversity τ (bit Mcal/m^2/year)	3.83	3.51	2.95	3.3 ÷3.4

τ landscape ecological index considering both heterogeneity and information among classes of vegetated tesserae (Ingegnoli 2002)