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The impact of agroforestry networks on scenic beauty estimation The role of a landscape ecological network on a socio-cultural process

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Abstract

The reintroduction of agroforestry networks (via a GIS-supported design procedure) is one of a number of strategies that some authorities of the lagoon of Venice drainage basin (in Italy) are planning to use in order to control lagoon pollution and to achieve landscape amelioration. While attention is paid to the conservation implications and environmental effects of an ecological network, socio-cultural impacts are not generally given the same consideration. The aims of this paper were (1) to assess the impacts of agroforestry network planning outputs on the perception of landscape in terms of scenic beauty (SB) estimation, (2) to analyze the influence of socio-economic variables on the agroforestry role in SB, (3) to analyze the relationships between SB and landscape variables as measured on the local and landscape scales, and (4) to assess the strength of an *expert rating* SB empirical procedure utilized in the GIS system. The outcomes of the GIS planning procedure application were found to have a positive impact on the perceptive evaluation of landscape, but landscape sites preference did not appear to be significantly different between socio-economic groups: in all cases, sites with an optimized agroforestry network were preferred to the same sites without. A strong explanatory relationship was found to exist between citizens' scenic beauty estimation (SBE) and the landscape metrics. The *representative* empirical procedure gave sound qualitative results for this kind of landscape, but can be efficiently substituted by the regression model tested at the "local" scale. At the "landscape" scale it appears that (1) the explanatory power of the landscape pattern metrics selected for the GIS procedure is high, even for the mean "social" SBE, (2) the main explanatory power among network metrics is expressed by connectivity and circuitry, and (3) it is reasonable to expect that the impact of an agroforestry network on citizens' SBE could be predicted with the empirical models that were tested.

Keywords: Landscape; GIS; Agroforestry; Networks; Scenic beauty (SB); Aesthetics; Spatial pattern analyses; Landscape preferences

1. Introduction

Countries within and outside the European Union are promoting agroforestry policies to preserve rural landscapes (EU Rule 1257/99), and some authorities of the lagoon of Venice drainage basin (in Italy) are aiming to control lagoon pollution by developing

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strategies that include the planning of agroforestry networks (Progetto Siepi©) reintroduced by means of a design procedure supported by a geographic information system (GIS) (PLANLAND®©; Franco, 1997).

Great attention is given to the conservation and environmental implications of an ecological network (e.g. Hudson, 1991; Forman, 1995), but socio-cultural impacts (Burel and Baudry, 1995) are not generally given the same level of consideration. But we need to consider the values that individuals and society place on the non-market aspects of landscape, like "beauty", in order to maximize the efficiency of the resource allocation in landscape management.

In dealing with agroforestry networks, we can consider the impact of socio-cultural or socio-economic processes on the landscape in terms of landscape functions connected to landscape structures in a landscape ecology perspective (see Burel and Baudry, 1999; Forman, 1995, for a wide discussion about this concept).

There are two main reasons for this.

The *first reason* is that human culture, even from an aesthetic and mythological perspective, influences landscape changes and these changes, conversely, influence culture (Arler, 2000; Soriani et al., 1996; Turco and Zanetto, 1992). These relationships lead to some consequences expressed by two principles (Nassauer, 1995): (1) human perception, cognition and evaluation directly influence and are influenced by landscape structures and functions; (2) cultural processes influence both built and "natural" landscapes.

Landscape functions are defined as fluxes of energy and matter, and perception, cognition and valuation of landscape can influence the transformation of landscape structure, for this reason this process can modify the fluxes of energy and matter in a landscape. Going on we believe that if we extend the "natural landscape" idea from a cultural perspective (see Shama, 1995, for a wide discussion about this topic) to the landscape ecology perspective of "landscape" (sensu. Forman and Godron, 1986) we can treat the cultural process linked to the human perception as an ecological function: there is no difference, from the ecological point of view, between humans modifying a dense understory because it does not have a perceptive cultural value (Nassauer, 1995), or beavers modifying the hydraulic asset of entire watersheds.

The *second reason* is that the several theories produced on this topic (mostly "information processing", Kaplan and Kaplan, 1982; "biological", Appleton, 1975; Bourassa, 1991) have some foundations in common: (1) there are some elements—such enclosures or distant vistas (open/closed spaces composition), fresh and clean water (e.g. Gregory and Davis, 1993), and canopy features (e.g. Lamb and Purcell, 1990)—which strongly influence the appreciation/non-appreciation of a landscape, with an importance that varies according to the observer's life history, his or her own elaboration capacity and information availability (e.g. Brunson and Reiter, 1996), and the cultural heritage of his or her social group (e.g. Purcel, 1992); (2) these theories (biological, information processing, and the correlated ones) support the validity of the links between the preference ⇔ the human behavior ⇔ the landscape change (i.e. the two principles defined above) and are compatible with the analytical and descriptive patch-corridor-matrix model utilized in landscape ecology (Bell, 1995, 1999; Nassauer, 1995), if visually considered.

If these socio-cultural processes can be analyzed with a landscape ecology approach, then—to correctly support an agroforestry network design—the planners need to assess how these landscape structures affect the aesthetics of the landscape. We need, therefore, to verify if and how the results of agroforestry network planning has an influence on "social" landscape appreciation in order to understand if it would be possible to obtain optimum trade-off scenarios from the ecological, agronomic and aesthetic perspectives. This could be a democratic means of efficiently taking this social process into account in a landscape planning approach (Arler, 2000).

If there is this influence, the procedure that landscape planners should utilize would have to be simple, rapid (automatic) and reliable for large areas (Bishop and Hulse, 1994). The rapidity of the evaluation procedure it is an economic constrain, mostly in the case of large evaluated areas, that is to say, when the procedure has to be used many times.

Two types of approaches for estimating landscape appreciation are described in the literature: the *perception based approach* and the *expert based approach* (Daniel, 2001).

The first approach is based on regression models between scenic beauty (SB) estimations and explanatory landscape variables (*representative* models), and second approach is based on empirical weighting criteria of landscape appreciation descriptors to be valued by experts (*expert ratings* models). Neither of these approaches, however, have the required characteristics stated above.

Dealing with *representative* models and following the analyses of Hunziker and Kienast (1999) we decided to compare SB (treated as a dependent variable, Daniel and Boster, 1976) with some landscape descriptors treated as independent variables. The use of SB as a statistical variable permitted us to develop statistical comparisons between each real (not planned) and each simulated (planned) site, and to have a first estimate of whether there is a role of the agroforestry network planning outputs in the SB values of the whole sample, that is, the mean "social" landscape beauty valuation.

Doing that and, more, to develop the regression models, we had to determine how the structural composition of the society sample influenced the sample ("the society") scenic beauty estimation (SBE): the more variance of SB can be explained by socio-economic variables, the less the SB used for comparison represents the whole community SBE and/or the less reliable the regression model based on landscape-variables are.

After that, landscape (independent) variables were measured at two different scales of perception, to evaluate the influence of scale on the landscape structure *vs.* function (e.g. agroforestry network per SB perception) relationship.

At the "local" scale (the human-natural perception scale, at the ground level) we did not use variables that were "objectively measurable" in the terrain (e.g. the basal area, the dominant height, . . .) because of the intrinsic difficulty of eliminating the subjectivity of the expert view with regard to the variables chosen, and because of the possibility that there may not be a relationship between the measurable characteristic and the informative contents of the *perceived* image. We preferred to examine this content directly, by means of the abundance ratio of the perceived landscape elements (like buildings, hedgerow, fields, . . .), together with some indices of their composition (see Section 2 for explanations). While this is less correct statistically, it is more directly meaningful to estimate the actually *perceived* role of the agroforestry network role in citizens' landscape beauty appreciation, and more directly comparable to the *perceived* composition of the patches (like fields) and corridors (like hedgerow).

At the "landscape" scale (the non-human-natural perception scale, from aerial photographs), we used "measured formal landscape criteria", (Hunziker and Kienast, 1999) in this case landscape pattern indices, because agricultural changes connected to agroforestry implementations (see Franco, 2000, for review) affect the formal content of landscape (that is, the pattern).

Regarding the *experts ratings* models, they try to synthesize the visual quality of a site by (1) an estimate of visual aspects of a picture by an expert, who assigns scores to some landscape descriptors of perceptive appreciation and refuse (selected from the literature or by means of specific researches), and (2) a successive weighted aggregation of the scores (e.g. Brouwer, 1996; Scrinzi et al., 1996). The *experts ratings* empirical procedure that was utilized in PLANLAND®© (visual quality condition (VQC) Franco, 1997) operates in a similar way (as detailed under Section 2). This procedure, however, is very time-consuming for large areas, is not theoretically as robust as *representative* models, and needs at least a qualitative test of its reliability. This study belongs within a wider framework of research evaluating the agroforestry network impact on the social, cultural and economic processes in the Venetian landscape. The other research aims were:

- to evaluate social awareness of non-point source pollution and of the agroforestry network roles (Mannino et al., 2001);
- to estimate the contingent value of the agroforestry network, and to evaluate the correlation of the existing policy (with its benefits for agroforestry plantation) with farmers' expectations (Franco et al., 2001).

In this paper, we are reporting on the results of our research into the impact of agroforestry networks on SB valuation of landscapes, and addressing the planning consequences of the impact that was found.

Our aims in this paper are

1. to analyze the influence of socio-economic variables and of the effect of agroforestry on the landscape SBE;
2. to assess the impact of landscape amelioration planning output (which employs an optimized

agroforestry network analysis and GIS design procedure) on the SB of the landscape;

3. to analyze the relationships between SB and landscape descriptors at the “local” (ground level) and at the “landscape” (aerial photographs) scale, in order to gain empirical knowledge about the influence of agroforestry planning on SB, and to find out if SB is sensitive to some measurable characteristics of landscape (that are sensitive to agroforestry network implementation);
4. firstly to assess the strength of the SB evaluation approach utilized in the GIS PLANLAND®© (an *expert ratings* empirical procedure, VQC; Franco, 1997) by means of a qualitative comparison, in each of the pictures examined, between the “social” (statistical) SB values and the experts’ beauty-weighted index. Secondly to compare in the same experimental system (the analyzed landscape) two of the most widespread SBE approaches used in the planning assessment and linked to two different ways of thinking (see for discussion Daniel, 2001).

2. Methods

2.1. Respondents

A stratified random sample of farmers, Venetian (lagoon) citizens and Venetian drainage basin citizens (non-lagoon citizen), was chosen from telephone listings. The sample consisted of 320 families and 60 university students (architecture course of urbanism and planning; environmental science). The number of respondents was 196. The “socio-economic variables” (categories) and their representation in the sample are reported further.

Surveys were mailed and every person per family was contacted afterwards by phone to clarify the scientific aims of the research, or directly given to the university students.

2.2. Procedure

The SBE was carried out using 12 images (16 cm × 12 cm, taken in the county rural landscape) which were rated using a 10 point scale. The number of images, the number of respondents and the kind of representation to be used were based on literature review (e.g. Stamps, 2000). A scoring method on photographs has been used, because it gives the same results as comparison methods and it is easier to use in this type of survey (Hunziker and Kienast, 1999).

Six of the images were real, taken with a 35 mm lens and 100 ASA slide. All of the images were taken in the same season (October 1998) to reduce uncertainty in the interpretation of results (Fig. 2). All of the images were geocoded in the GIS that was utilized for the agroforestry network planning (Fig. 1).

Six of the images were obtained by modifying the slides by simulating as exactly as possible the planned agroforestry systems as thy would appear in the 8th year after plantation. The perspective and dimension of the plantation were obtained first by a simulation software (ACURENDER®©, PLANLAND®©) and then reproduced by photo-composition. Images were well mixed and printed on different pages to prevent people from recognizing the same sites with and without planting (Fig. 2). The images were tested by a group of 10 people (four professional designers and six university students) before mailing: nobody recognized

Socio-economic variables	Classes
Sex	Males 67%, females 33%
Age	1: 0–25 years 18%; 2: 25–40 years 25%; 3: 40–60 years 36%; 4: >60 years 21%
Educational status	1: primary school 37%; 2: high school 50%; 3: graduate 12%
Job	1: farmers 23%; 2: students 22%; 3: employees and professionals 21%; 4: retired workers and housewives 29%; 5: other (unemployed) 5%
Family	1: 1–2 persons 32%; 2: 3 persons 27%; 3: 4 persons 50%; 4: >4 persons 17%
Income	(In this case, only 60% of respondents answered) 1: 0–12.970, 34%; 2: 12.9700–23.348, 42%; 3: >23.348, 24%
Residence location	1: Venice and islands 21%; 2: Mestre and suburbs 40%; 3: inland-farmlands 39%

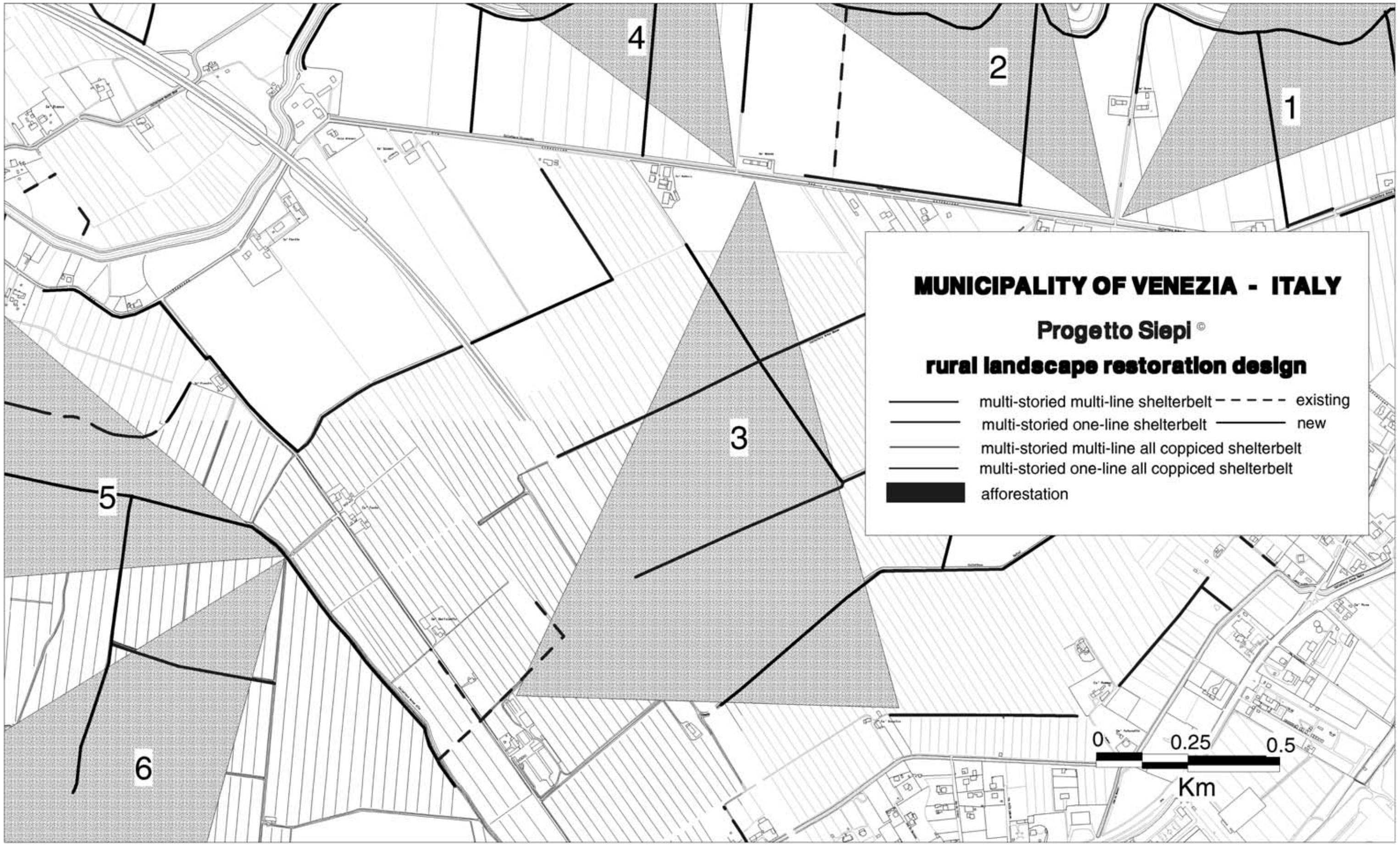

Fig. 1. A simplified representation of the studied area and of the six analyzed visual fields.

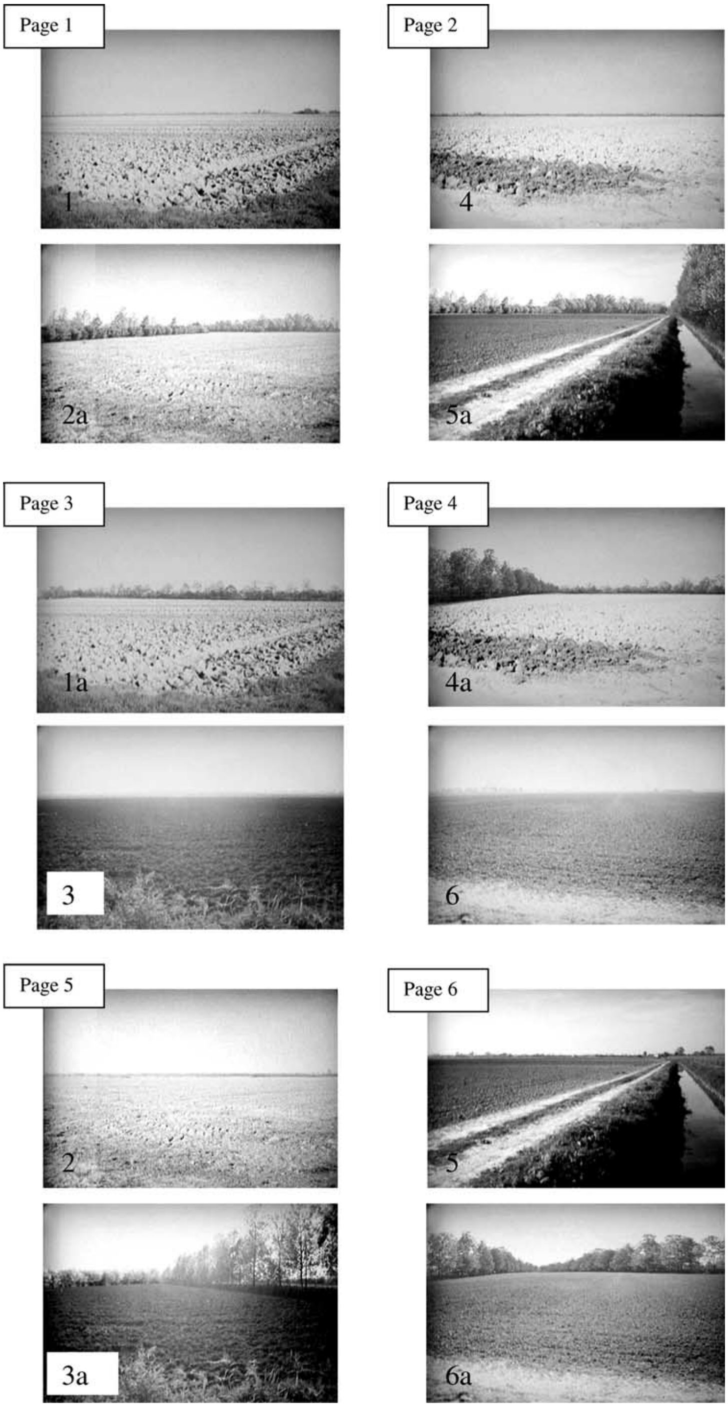

Fig. 2. Results of the six sites really photographed and the same six sites after the agro-forestation planning simulation, as presented to the respondents (from the first to last page). Here are reported, too, the sites' codes: the simulated images are indicated with an "a" after the arabic code of the real sites images.

the same sites with and without the planned agroforestry systems.

To reduce the subjectivity of ratings for SB scaling, an origin-adjusted rating scaling procedure was chosen due to its simplicity and robustness when compared to other more complex procedures, given the statistical representativeness of the sample. The *i* value given by the *j* respondent was substitute by the difference between the mean value of respondent *j* and the value of *i*. Other scaling procedures were tested (e.g. full *Z* score), but, as expected (Stamps, 2001), no differences were detected.

Statistical comparisons have been made with a parametric ANOVA. Parametric assumptions were estimated with visual and numerical methods and non-parametric Kruskal–Wallis ANOVA was used when violation of the parametric assumption were detected, given that scoring methods rely on an ordinal scale. When no differences were detected in parametric and non parametric ANOVA results, the Duncan test was utilized to detect homogeneous groups and/or significant differences. Correlation was calculated with Spearman coefficients and with Pearson product moments, to detect differences.

Explorative multiple linear regression models (standard and forward stepwise) were calculated for the comprehension of the functional relation of the considered variables. Ridge regression was utilized to reduce the problems due to variables collinearity.

Intrinsic not linear models (piecewise linear regression models) were tested to value the strength of possible design tools. Both correlation and regression models were calculated with mean SB values weighted by the SB standard error.

Because of a mailing error, the sites 2 and 3a (Fig. 2) lacked in judgements and for this reason were rejected in some sites versus socio-economic variables interaction analyses (when the number of observations were statistically not significant).

Commercial software packages were applied (STATISTICA©, EXCELL©, SYSTAT©, STATGRAPHICS©, PHOTOSHOP©).

2.3. Landscape descriptors

SBE results were related to landscape variables, of both “local” (human-natural perception scale) and “landscape” (aerial photographs) types.

2.3.1. “Local” scale

In the first group, the perceptive impacts of landscape structures were estimated by means of (1) the measure of the visible sky and of the different visible patches and corridors present in each slide (expressed as percentage of the slide surface), (2) the measure of the perceived, (3) the Shannon–Wiener diversity of enclosures different ecotopes (*measured in step* 1).

Based on the theories outlined in the Section 1 and the literature review (e.g. Stamps, 2000, 2001; Lange and Bishop, 2001) these variables are relevant to the local spatial scale and are related to the natural-human perception scale (at the ground level).

The visible landscape elements perceived were: open bare field, open maize field, water courses, tracks, hedgerows, banks, field grassed margins, buildings and sky.

The enclosures, for their importance in environment perception and preference, were estimated by means of the ratio between the percent of the perceived open space (ground plane excluded sky) versus the percent of the landscape blocking features (vertical structures like hedgerows, buildings, banks) (Stamps, 2001). Shannon–Wiener visual diversity was computed considering the well known formulation

$$H = \sum_{i=1}^{n} P_i \ln P_i$$

where *P* is the percent abundance of the *i* visible element and *n* is the number of visible elements.

These two indices were utilized to synthesize some of the “*preference framework elements*” as complexity (the richness or diversity of perceived landscape features), legibility and prospect (related to the balance between open spaces and enclosures). Based on the information processing approach (Kaplan and Kaplan, 1982) these elements, with coherence and legibility, build up the basic informational needs (involvement and the making sense) that drive the environmental preference.

2.3.2. “Landscape” scale

On the “landscape” scale, for the reasons already explained in the Section 1, the *formal landscape content* of the images that were to be related to human preference for landscapes (e.g. the images) was measured by circuitry, connectivity and density of real and planned agroforestry networks, and by Shannon–Wiener diversity of patches.

Landscape pattern metrics were calculated using PLANLAND®© GIS procedure for the same areas corresponding to the photographs' points of view (1 km × 130° radius area centered in the visual point). We defined a area for the indices calculation slightly wider than the visual field for technical problems, for example the needing to utilize the complete length of the observed hedgerow in the computation.

The description of landscape pattern by means of indices has been attempted both to quantify the characteristics or modification of landscape structures (supposing they influence on landscape functions) and to measure some landscape parameters like connectivity, heterogeneity, fragmentation (e.g. for review: Franco, 2000; Gustavson, 1998).

2.3.3. *Landscape pattern metrics meanings*

The indices calculated here are the spatial metrics utilized in the GIS procedure and have been already selected for strength of information and lack of redundancy in the planning of agroforestry networks.

The density of real and planned agroforestry plantings (m/ha) has a clear physical meaning.

Connectivity and circuitry are two indices that come from the graph theory and have been used in geography and in landscape ecology (Forman and Godron, 1986). They are based on the rate of the theoretical and existing nodes and links of the network, do not have any intrinsic ecological meaning and need a series of conventions to be applied to the real world, in this case to agroforestry networks in the rural landscape (e.g. Selman and Doar, 1992). This indices estimate an "intrinsic" topological characteristic of a network that neither exists in its individual structural components (corridors), nor is simply accounted for by the presence/absence of the single components. In relation to this kind of structure these parameters are theoretically supposed to be correlated to some landscape functions as biotic or hydrologic fluxes. Several field and simulation studies give empirical support to

Table 1
Visual quality criterion/descriptors elements of landscape images used in the VQC empirical procedure

1	Perceptive order: it is present a recognisable order in the visual elements of patches and corridors
2	Perceptive legibility: the open spaces and enclosure configuration allow to identified possible paths can be
3	Mystery: can be found refuge conditions and variable perspective
4	Are present single and/or isolated trees
5	There is a strong presence of *genius loci*
6	Contrast and diversity of the landscape
	There is a sense of unity among the landscape elements
	The grain and diversity of the landscape permits a visual absorption capability (Bell, 1995)
	The visual elements diversity creates interest (perceptive complexity)
	The ratio between the landscape elements and the empty/solid volumes ranges from 1/3 to 2/3
	The horizon line is interrupted: the relationship between the landscape element shapes outlines closed spaces
7	Presence of water
	The presence of water is visible
	The visible water is clear, fresh and natural
8	Naturality–artificiality
	The conflict between the visual forces of the landscape and the direction, shape and position of artificial elements generates tension
	The enclosures have simple geometrical forms of no interest and/or the margin zones are missing
	Watercourses are associated to vegetation
9	Character of vegetation
	Trees dimension
	Diversity
	Contrast
	Visibility
10	Identity and shapes of built
	In the visible buildings it is possible to recognise historical and/or architectural values

this hypothesis (Fahring and Merriam, 1985; Forman, 1995; Franco, 2002).

The classic Shannon–Wiener diversity index tries to synthesize information about the richness and evenness of landscape patches composition (e.g. Forman, 1995) where a high value represents a rich composition and even distribution.

2.4. *The VQC ex ante procedure*

The VQC is an empirical procedure (an *expert rating* model) used to obtain a relative SBE during the design development, and is presented as a video image (a CAD environment three-dimensional rendering image based on the GIS otput; e.g. Franco, 2000) to be valued by an expert by means of a questionnaire, where each question corresponds to an elementary descriptor (Table 1). The descriptors represent the biophysical landscape features assumed to be indicators of landscape scenic quality. The descriptors are derived from studies about the relationship of landscape human appreciation and about the landscape features influencing it (mostly Appleton, 1975; Bell, 1995, 1999; Bourassa, 1991; Lamb and Purcell, 1990; Kaplan and Kaplan, 1982; Kellomaki and Savolainen, 1984; Lamb, 1990; Schroeder, 1986; Silvennoinen et al., 2001), and from a literature review of similar empirical models (e.g. Scrinzi et al., 1996). This step allows for a judgment of a picture by breaking it down into common-value elements, followed by an analytical rebuilding. Every criterion/descriptor assumes a value between 1 (worst case) and 5 (best case). The weighted mean of the operative criteria/descriptors of any one picture gives a synthetic and geocoded index of aesthetic appreciation or rebuttal, which can be processed with other similar values. The aim is to support the design/planning process with relative estimations. All geocoded values are standardized within one index that has the same variation range as other indexes of the GIS procedure.

The reliability of the *expert rating* model was tested on four experts (professionals working on landscape planning and design, with two chosen from architecture studies, and two from ecological studies) who were asked to define each picture by using the empirical procedure scheme. Given the number of experts in the sample, the results were simply compared graphically with the SB of the surveyed sample, representing the "social" perceptive value of the same landscapes.

3. Results

3.1. *The influence of socio-economic variables on the citizens' scenic beauty estimation*

In general (1) young people give to SBE a lower value than other age classes (Fig. 3a), (2) respondents with high school degree and students (which actually overlap the "young" age class), and employees give a lower value than other classes (Fig. 3b and c); except for employees, all of these tendencies are statistically significant.

Considering the interaction of socio-economic variables it appears that, taking into account the age, the level of education influences the SB only in a secondary way. The education effect depress the SBE in the young people, but become positive in the elder classes (Fig. 3d). Finally it results that university students ("young" class) or employees with low level studies give lower values than others. Other influences detected were based on interactions of a variety of variables and for this reason did not give very reliable final statistical sample.

3.2. *The influence of agroforestry networks on citizens' scenic beauty estimation: site preferences*

All the sites with a planned agroforestry network were significantly preferred to the same sites without a planned agroforestry network (Fig. 4), as shown in the ANOVA and Duncan tests results (Table 2). Results of non parametric and parametric ANOVA were equivalent. The SB for each site was normally distributed (as theoretically expected), apart from the less (site 4) and most appreciated cases (site 5a), that showed some skewness. The use of the differences between the SBE of the planted and not planted sites as dependent variable gave no results.

3.3. *The relationship between the influence of agroforestry networks on citizens' scenic beauty estimation and the socio-economic variables*

In each socio-cultural category of the sample, the sites with the planned new hedgerow network were preferred to the correspondent sites without the hedgerow (Fig. 5).

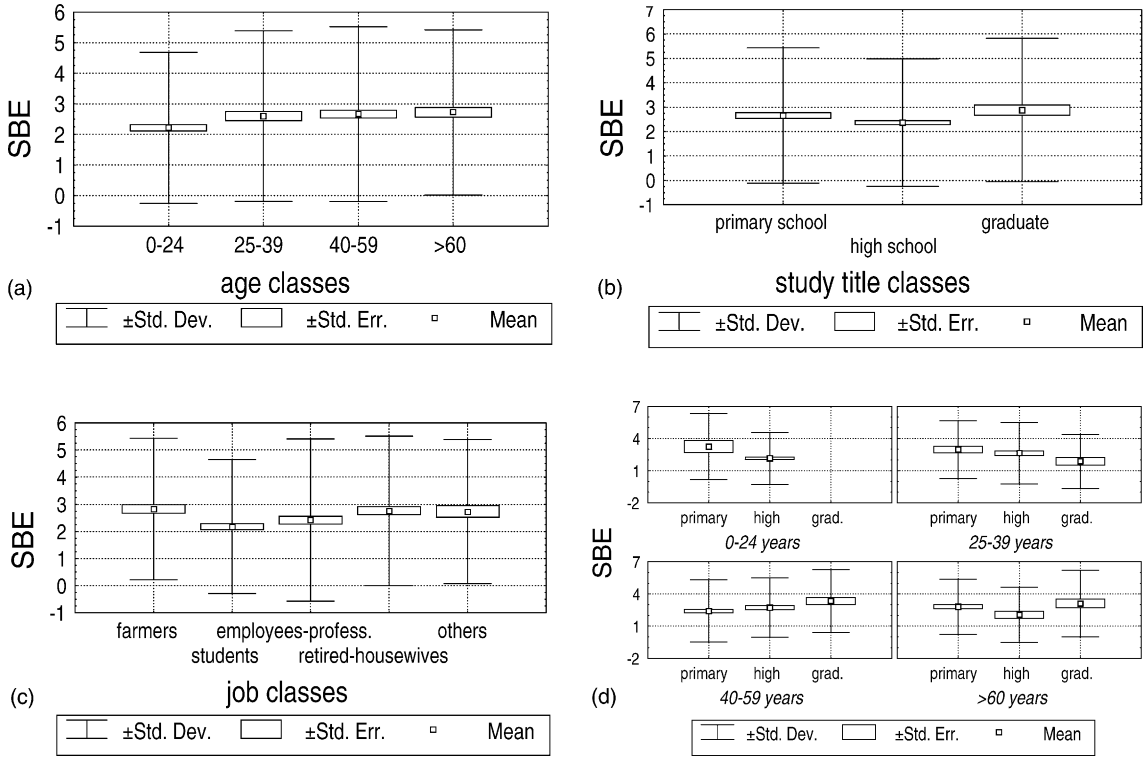

Fig. 3. Here are plotted the socio-economic influences on the SBEs of the whole sample. The ANOVA probability values are: (a) age influence, $P < 0.02$; (b) study title influence, $P < 0.02$; (c) job influence ($P < 0.002$); (d) study title and age influence (NS).

Site preference ranking was never significantly different among socio-economic classes, with the exception of sex and partially for location. In these cases the difference was linked to one site (site 5), that was given the highest value among the sites without hedgerows and the only image without hedgerow preferred to some images with hedgerow. The site is significantly more valued by females and is preferred by lagoon citizens (Venice and Isles) (Table 3).

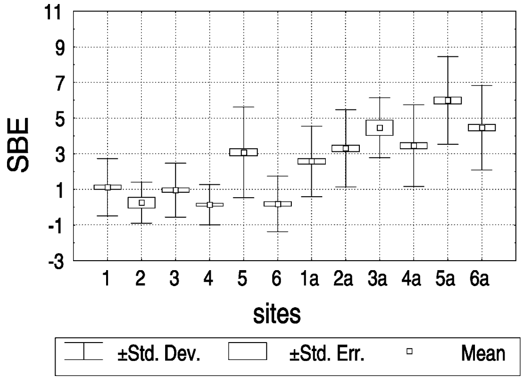

Fig. 4. The box plots of the SBE of each real and simulated sites (the sites codes refer to those reported in Fig. 2).

All other insignificant sites ranking differences detected in each socio-economic class were always mainly attributed to this site, which was more valued by young, students and the unemployed. The image is different to others because of the presence of water, high visual diversity and equilibrium between negative (e.g. bare field) and positive (e.g. trees) elements of perception value. Only two other sites, the less appreciated among the images with the most dispersed values, were ranked in a different way among socio-economic categories, but never significantly.

There are little judgement differences between socio-economic classes in the case of the non agro-forested sites (sites 1–6, Fig. 5), except for the site 5, less appreciated by farmland people (Fig. 5c).

Table 2
Results of the ANOVA and the Duncan test (main effect: sites) on the SB of the whole sample using the sites as factor variables

Site	Mean SBE	Homogeneous groups, α level $= 0.05$					
4	0.11	xxxx					
6	0.15	xxxx					
2	0.26	xxxx					
3	0.91		xxxx				
1	1.11		xxxx				
1a	2.56			xxxx			
5	3.13				xxxx		
2a	3.28				xxxx		
4a	3.49				xxxx		
3a	4.46					xxxx	
6a	4.52					xxxx	
5a	5.95						xxxx

ANOVA summary of sites effects: d.f. effect, 11; mean square effect, 518.53; d.f. error, 1689; mean square error, 4.03; F, 128.79; probability level, 0.00.

Considering only the images with the planned agroforestry network, the "young" class gave significantly lower values for each agroforested site in comparison with other age classes (Fig. 5a). Among job categories farmers give higher and less spread values than others (significantly as regards the students and the employees–professionals (Fig. 5b). Lagoon people give significantly lower and more spread values for each agroforested site than people from other locations (Fig. 5c).

3.4. The relationship between scenic beauty and landscape variables at different scales

3.4.1. The correlation with the "local" and "landscape" scale variables

The "social" mean SB values showed strong correlation even with "local" or with "landscape" scale variables (Table 4).

In the first case significant correlation were detected with the percentage of visible hedgerows and sky,

Table 3
Sites ranking in the socio-economic classes that preferred the sites in a statistically different way

Site ranking by sex[a]				Site ranking by location[b]					
Site	Male	Site	Female	Sites	Venice–Isles	Site	Mestre and suburbs	Site	Inland farmlands
	Mean SB		Mean SB		Mean SB		Mean SB		Mean SB
6	0.16	4	−0.02	2	−0.72	4	−0.06	4	0.06
4	0.18	2	−0.01	6	0.34	6	0.08	6	0.10
2	0.56	6	0.12	4	0.48	2	0.44	2	0.52
3	0.71	3	1.29	1	0.91	3	0.80	3	1.04
1	0.96	1	1.43	3	0.91	1	1.26	1	1.10
5	**2.69**	1a	2.17	1a	2.42	1a	2.47	**5**	**2.31**
1a	2.75	2a	2.78	2a	2.95	2a	3.39	1a	2.75
2a	3.53	4a	3.10	4a	3.23	**5**	**3.52**	2a	3.38
4a	3.69	3a	3.99	3a	3.28	4a	3.57	4a	3.59
6a	4.52	**5**	**4.02**	**5**	**3.81**	6a	4.73	6a	4.40
3a	4.99	6a	4.54	6a	4.36	3a	4.77	3a	4.74
5a	5.96	5a	5.91	5a	5.24	5a	6.50	5a	5.84

The site that produces the major effect is highlighted in bold.

[a] $F(11, 3026) = 5.79$; $P < 0.0000$.

[b] $F(22, 2994) = 2.90$; $P < 0.0000$.

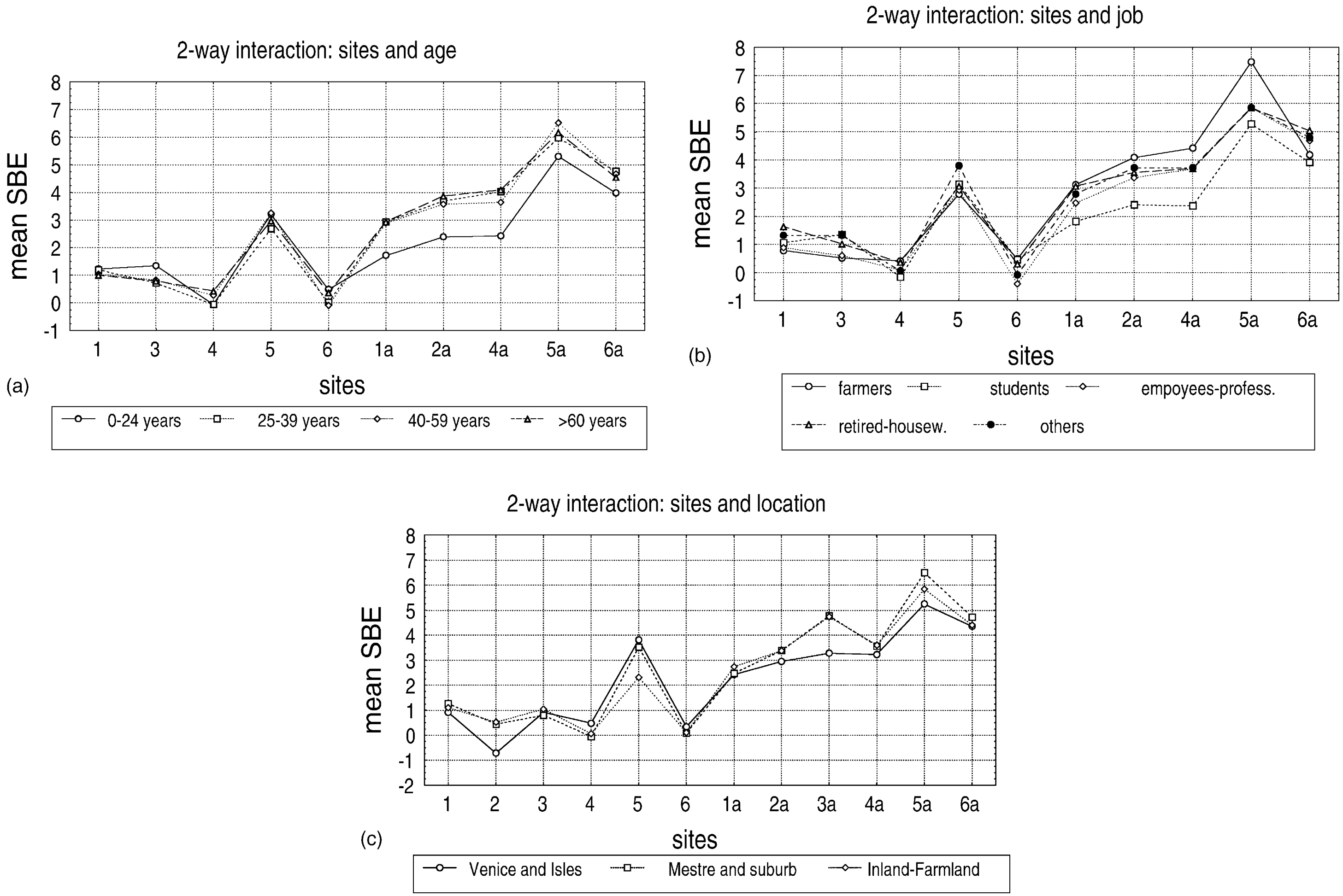

Fig. 5. Here are plotted the significant influences of socio-economic variables on the SB and/or site appreciation (the sites images and the codes significance are reported in Fig. 2); (a) age and site influence on SB; (b) job and site influence on SB, (c) location and site influence on the sites SB. In the plots (a) and (b) are not reported the sites 2 and 3a (see Section 2 for explanations).

Table 4
Spearman correlation between SBE and the “local” and “landscape” scale variables (see Section 2 for explanations)

	Valid number	Spearman R	t $(N-2)$	P level
“Local” scale variables				
Mean SBE and water	4	−1.00		
Mean SBE and vegetated banks	6	0.45	1.02	0.365
Mean SBE and bare field	17	−0.47	−2.05	0.059
Mean SBE and traks	7	0.17	0.39	0.716
Mean SBE and margins	5	0.16	0.28	**0.800**
Mean SBE and Shannon–Wiener visual diversity	17	0.34	1.40	**0.053**
Mean SBE and enclosure	16	0.89	7.44	**0.000**
Mean SBE and sky	17	−0.76	−4.55	**0.000**
Mean SBE and agroforestry network	14	0.84	5.36	**0.000**
“Landscape” scale variables				
Mean SBE and patches Shannon–Wiener diversity	17	0.82	5.46	**0.000**
Mean SBE and agroforestry network circuitry	17	0.82	5.54	**0.000**
Mean SBE and agroforestry network connectivity	17	0.77	4.62	**0.000**
Mean SBE and agroforestry network density	17	0.69	3.72	**0.002**

Significant probability values are highlighted in bold.

enclosure estimation and visual diversity. In the second case all correlation’s were very significant.

3.4.2. The regression models with the “local” and “landscape” scale variables

No differences were detected between the regression models of the whole sample and the regression models of the sub-samples based on the socio-economic variables that showed a significantly different SBE, so only the whole sample results were considered.

Even with high variance explained (Table 5) all linear models tested had normality and linearity problems, and for the most significant ones the explanatory variables selected were: Shannon–Wiener visual diversity; the enclosure estimation; agroforestry network and perceived sky percentages. Lack of inference robustness was influenced by the non linearity of some variables and the strong collinearity of others.

The use of the piecewise linear model strongly increased the inference robustness of the model and the explained variance (99%).

The scale change of the used dependent variables (from the “local” scale to the “landscape” scale) reduced the confidence of the multiple linear regression models tested, for collinearity, lack of linearity and normality problems. The strongest model among those tested is based on diversity and connectivity as explicative variables (Table 6).

Using intrinsically non-linear models increases the predictable robustness of the model (linearity and normality most of all) as explained variance does. By

Table 5
The multiple linear regression model estimated for SB using the “local” scale variables

	β (S.E.)	B (S.E.)	t (8)	P level
Intercept		−6.55 (0.86)	−7.58	0.000
Sky	0.60 (0.08)	0.12 (0.02)	7.44	0.000
Agroforestry network	1.69 (0.26)	0.42 (0.06)	6.46	0.000
Enclosure	−0.19 (0.21)	−0.03 (0.03)	−0.92	0.383
Shannon–Wiener visual diversity	0.88 (0.07)	1.47 (0.11)	13.51	0.000

See Section 2 for the variables description. $R = 0.995$; $R^2 = 0.991$; adjusted $R^2 = 0.987$. $F(4, 9) = 246.69$; $P < 0.00000$; S.E. of estimate: 0.19.

Table 6
The intrinsically linear multiple regression model estimated for SBE using the "landscape" scale variables

	β (S.E.)	B (S.E.)	t (9)	P level
Intercept		1.10 (0.56)	1.98	0.068
Connectivity	0.65 (0.20)	0.04 (0.01)	3.27	0.006
Diversity	0.24 (0.20)	0.06 (0.05)	1.20	0.250

$R = 0.825$; $R^2 = 0.681$; adjusted $R^2 = 0.636$. $F(2, 14) = 14.95$, $P < 0.0003$; S.E. of estimate: 1.19.

Table 7
The intrinsically non-linear multiple regression model estimated for SBE using the "landscape" scale variable (piecewise linear regression with breakpoint)

	Estimate
Constant B_0	0.8
Circuitry	0.01
Connectivity	0.01
Diversity	0.07
Constant B_0	10.44
Circuitry	0.14
Connectivity	−0.11
Diversity	0.04
Breakpoint	3.12

Final loss: 4.37; $R = 0.96$; variance explained: 93.04%.

applying best trade off between these two aspects of regression models reliability was obtained using diversity, connectivity and circuitry as independent variables (Table 7).

3.4.3. The relation between the SB and the agroforestry network density

It is interesting to note that density is related to the SB in a bell-shaped way (Fig. 6), as expected in a reforested landscape (Hunziker, 1995). The relation it is necessarily partial because this study refers to a real hedgerow planning design, where density threshold is limited by the optimization constrains of conflicting agroforestry functionality in a specific rural landscape (with its agricultural model and allotment). The outlier SB value (site 5a) correspond to the most appreciated landscape, with a clearly visible water course. In the case of the site 5a (the most appreciate) the presence of the channel strongly influence the hedgerow density and SBE relationship.

3.5. The test on the VQC empirical procedure

The results of the VQC empirical procedure test are reported in Fig. 7. They show a good correspondence between the ex ante procedure outputs (used in the GIS procedure to forecast the SB) of the four experts, and the mean "social" SBE for each site. The values estimated by means of VQC are always inside the S.D. range of the social response to the landscape perception.

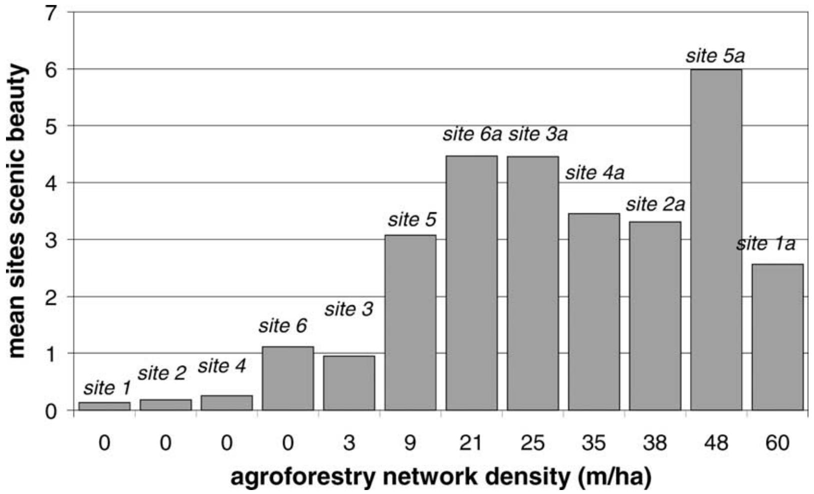

Fig. 6. It is plotted the relationships between agroforestry network density and SBE. The outlier SB value (site 5a) correspond to the most appreciated landscape with a clearly visible water course.

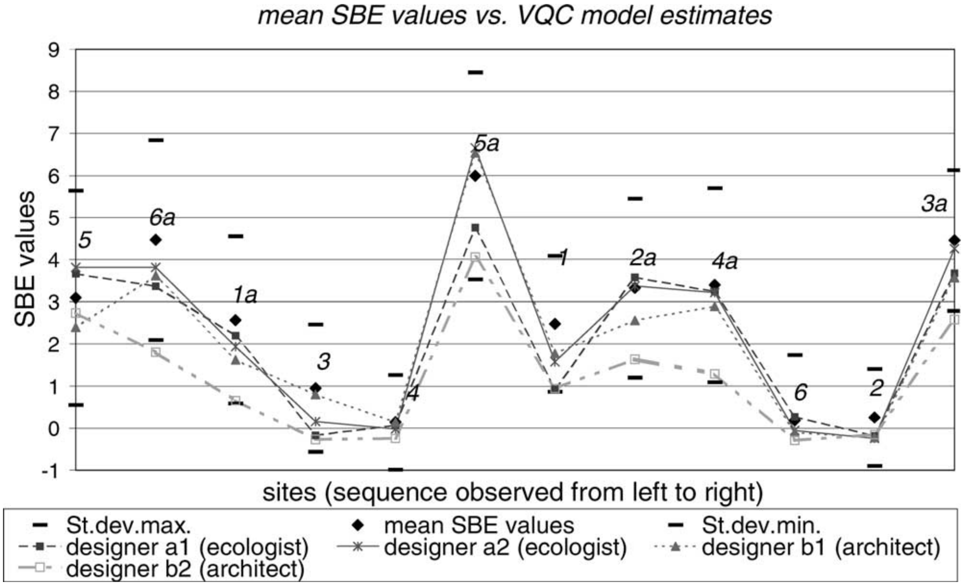

Fig. 7. Comparison between the outputs of the VQC empirical procedure by the four experts and the “social” SBE for each site (see text for explanations). The sites images and the codes significance are reported in Fig. 2.

There appears to be a difference between the architecture and non-architecture designers tested, the second group being closer to mean social SB values. This is a first assessment of the testing, a deeper valuation would require a statistical sample of experts.

4. Discussion

In those cases where there is a slightly significant influence of some socio-economic variables on this type of aesthetic landscape evaluation, this has been found to be mainly due to the factor of age. In fact other socio-economic variables that influenced SB, as the (university) “student” and the “high school degree” classes (Fig. 3), corresponds, ultimately, with the “young” class. This result is consistent with some studies but not with others (Daniel and Boster, 1976; Lyons, 1983; Tempesta and Crivellaro, 1999).

All the strata of the sample show the same trend regarding the sites valuation (Figs. 4 and 5).

Given that the appreciation framework for this landscape appears to have a common basis, it would appear that—at this level—differences in visual agreement are of cultural origin. Differences have been detected for categories of people who lack personal or socio-cultural experience (which is not necessarily learned at school), or who have probably the need for personal affirmation and/or personal re-equilibration from strong aesthetic or functional models (for example, the valuation of the elder graduates was closer to the mean SB values of the whole sample—that is, the “society” SB—than that of the university students of urban or environmental fields).

With regard to the specific role of the agroforestry networks on landscape perception, this was consistently found to be positive, at a statistically significant level (Fig. 4; Table 2). This result is consistent with other studies on rural landscape appreciation in the same area (Venetian flat, Tempesta and Crivellaro, 1999), and in general in those landscapes that appear to be partially reforested (see for review Hunziker, 1995).

In this case, all sites with planned agroforestry networks were significantly preferred to the same sites without them, and all socio-economic categories appreciated the same sites in the same way (Fig. 5), even if there were some differences in the weight and distribution of the values.

Differences in sites appreciation ranking seems to be secondary and linked to different perception role in some socio-economic classes, of cultural or deeper types. In this case, the most significant difference that was actually detected in the site ranking was based on gender and was in relation to a single image that was dominated by the presence of water (Table 3; Fig. 2). The sex-based difference in perception may have been either coincidental or linked with an intrinsically different response to the presence of. It is not possible to go beyond such speculations on the basis of our data, but these results support similar results of more detailed studies on this topic (e.g. Bourassa, 1991) and does not challenge previous agroforestry appreciation results.

In the other cases, the differences are more clearly linked to cultural stimulation: the image with water also influenced the lagoon citizens and this may not be a chance finding, however, because the same category is influenced by questions linked to water and, in particular, water quality (Mannino et al., 2001).

The role of an agroforestry network appreciation (in terms of mean SB value and its dispersion) increases with age, type of activity and location of domicile: these variables are reasonably linked to the respondents wisdom/experience, management role in the landscape and sense of landscape belonging. Given that the other connections are clear, in the first case the relationship between age and wisdom/experience is reasonable because it is not based on a particular technological expertise, but on a general, sound experience about the life in the landscape and in its cultural heritage (with deep and strong historical roots).

The university appears to influence the "young" towards a perception and an emotional response that are different to what was found for the whole sample. This, in turn, is probably due to both a learned aesthetic and cultural models that contrast with, or have a different weight from what the community has, and/or may be due to a lack of information (Brunson and Reiter, 1996) about the role of these landscape structures (Franco et al., 2001; Mannino et al., 2001).

Having verified that (1) even if some socio-economic variables do slightly influence the citizens' landscape aesthetic perception they actually do not influence the preference trend of the observed rural landscapes (e.g. everybody assigned the same kind of judgments to the same sites, even if with some intensity differences), (2) these socio-economic variables have no significant influence on the positive role of an agroforestry network in landscape appreciation, (3) these socio-economic variables do not influence the regression models outputs of SBE, we then tried to look for relationships between landscape descriptors and the whole sample ("social") SB.

The "local" scale variables most strongly correlated to SB have been visual diversity, enclosure estimation, and the presence of attractive elements like trees and water. These results are empirically consistent with several common foundations of the theories produced on this topic, and outlined in Section 1.

The correlation calculated between SB and "landscape" scale metrics in the same site were always positive and significant, showing a non-functional relationship between SB and landscape pattern. In the presence of diversity in landscape patches and of agroforestry network efficiency, the quality of landscape perception increases.

These relationships were estimated by means of regression models, that are weak because of non-linearity, non-normality and collinearity of some variables. The problems of inference robustness are greatly reduced by using intrinsically non-linear models, which could allow for their use as applicative tools. Functional relationships are evident between landscape appreciation and (1) some composition relations of perceived elements (diversity, enclosures), and (2) some visual elements (percentage of sky, percentage of trees and shrubs plantations). Again the results are empirically consistent with the founding elements of the theories outlined in Section 1.

On the basis of these data, it is not possible to clarify more the significance that the characteristics of these single visual elements have in the SBE. We cannot, for example, specify the influence of single aspects of plantation (composition, structure, season) or water (color, river banks). Other researchers have investigated these effects (e.g. Gregory and Davis, 1993; Kellomaki and Savolainen, 1984; Lamb and Purcell, 1990) and we can only indirectly confirm the importance of water in landscape evaluation and state that the presence versus absence of agroforestry systems is a strong explanatory variable of landscape appreciation.

By changing the scale of analysis, the functional relations between SBE and landscape pattern are confirmed. The increasing compositional diversity of landscape and the increasing structural efficiency in the agroforestry network increase landscape appreciation. In this case, the relationship is not simply determined by the partly bell-shaped function (Hunziker, 1995; Fig. 6) between the increase of agroforestry systems and SB (density is not selected in the best regression models), but between "intrinsic" characteristics of the agroforestry network (here estimated by connectivity and circuitry) and landscape appreciation.

At the "landscape" scale of analysis/perception, therefore, there are those intrinsic characteristics of the network (a structure that does not exist at the "local-patch" scale) that appear to influence the agroforestry network role in landscape beauty appreciation.

This appears to be a particularly important outcome, because the same results have been obtained when very different kinds of landscape processes have been linked to the agroforestry network: both wind and non-point source pollution control (Franco, 2002). In each case, the explanation for network behavior in empirical simulation analyses showed a stronger relationship with the "intrinsic network" characteristics (measured by connectivity and circuitry) than presence on its own (as estimated by density) (Franco, 2000).

The regression models were useful in the investigation of the functional relationships between variables and, in the case of piecewise models, to give potential empirical tools for design. In this case, the variables selected in the final models were not highly correlated for the strong formal resemblance of the algorithms.

The expert rating empirical estimation of SB utilized by the GIS procedure shows a high level of agreement with the mean "social" SB. Even though it is only a qualitative test, the results are interesting enough for further investigation and show that some of the criteria/descriptors utilized in the VQC procedure and investigated in the study (such as the presence of vegetation, the ratio of open/closed space, and visual diversity) are—as expected—significantly and functionally linked to landscape perception and value.

5. Conclusions

The conclusions presented below address each of the aims of this paper, as outlined in Section 1.

Aim 1: Irrespective of whether or not there were some statistically significant influences from socio-economic variables on the SB of the rural landscape investigated (e.g. the SB of the whole sample of the pooled sites), every socio-economic category gave the same kind of judgment for the same kind of landscape. In other words, the statistical measure of SB for the whole sample for each landscape represented the "society" measure. The partly bell-shaped relationship between the agroforestry systems presence (hedgerow) and SBE was one of the factors that influenced the sample appreciation of this kind of landscape. The socio-demographic influences that were identified were generally culturally determined, and mostly generated by age differences: the appreciation of the presence of an agroforestry network increases with some factors (age, activity and location of domicile) that can reasonably linked to the level of wisdom/experience, landscape management role and sense of belonging. These factors were the same that influenced the contingent values that were assigned to this landscape structure by the same sample (Franco et al., 2001) and they have been already pointed out as driving forces in a landscape appreciation process (e.g. O'Neill and Walsh, 2000).

There was, however, one case for which the influence on landscape preference might have been of a deeper origin, due to sex and linked to the presence of water. Even if the data for further investigation were not available this result it is coherent with results the other studies on this topic.

Aim 2: Each site that had planned agroforestry networks was significantly preferred to the corresponding one without such networks. This result show that a positive impact on landscape perceptive valuation was produced by the simulated output of the planning system (PLANLAND$^{®©}$) that was utilized to optimize the role of agroforestry networks in landscape amelioration undertaken from the conservation, agronomic, economic and hydrological points of view.

Aim 3: The landscape variables used for the analyses of the "society" SB value of the rural landscapes, were defined on the scales for the "local" (human-natural, ground level) and for the "landscape" (not human-natural, aerial photographs) perceptive. Given the number and characteristics of the variables selected, in the case of the "local" scale, the variables (the percentage of visible elements in each picture and the indexes of visual composition) that were selected by correlation and regression models were in accordance with theoretical expectations for the importance of visual diversity, of enclosures, of sky horizon level and of the presence of plantation. For landscapes such as the one that was analyzed, and for the agroforestry perceptive impact estimate, the regression model tested at this scale could be useful as a quicker and simpler empirical tool for design at the "local" scale than that created for the PLANLAND®© planning system (VQC).

In the case of the "landscape" scale, a sound explanatory functionality was found between SB and the used landscape pattern metrics, and it appears that

- landscape pattern metrics selected in the PLANLAND®© GIS procedure for the analysis and design of agroforestry network optimization showed a good explanatory power for the utilized SB (which represents in this case the estimate of a "social" process of landscape perception, cognition and valuation);
- in the case of the agroforestry network metrics, the main explanatory factor lies not simply in the partly bell-shaped relation with the density, but in the intrinsic characteristic of the agroforestry network (a landscape structure that does not exist at the "local-patch" scale level) that is described by connectivity and circuitry;
- it is reasonable to expect that the impact of the agroforestry network on SBE could be analyzed and predicted with the empirical regression models obtained, in view of their affordability, simplicity and speed.

Aim 4: Even though the utilized test was only graphic and not statistical, the expert rating perceptive estimation procedure used in the PLANLAND®© GIS planning system produced a high level of agreement with the SBE research results, and the results are interesting enough for further investigation, even if the procedure is weaker than *representative* models from the theoretical point of view and is very time consuming (both for three-dimensional rendering simulation and for the expert response elaboration for each single selected point of view). The VQC procedure has been carried out for perceptive estimation of a generic landscape, but gave good results for this kind of rural landscape.

In conclusion, we believe that the optimization of wind control, water quality control, agronomic effects, economic cost and benefits, and aesthetic perception can be reached if all these processes are treated as landscape functions affected by landscape structure (including both agroforestry plants and networks) at different scales. Applying this approach, the results obtained by the GIS procedure simulation are positive for all of the processes that were considered, and do not have a summative impact on changes to the scale. Model outputs have been implemented in field tests for the hydrological processes (Franco, 1998, 2000), socio-economic processes (Franco et al., 2001; Mannino et al., 2001) and perceptive valuation (carried out for this study).

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