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First considerations about the need to plan for landscape amelioration purposes

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Keywords *Environment, Geographical information systems, Networks, Planning*

Abstract *In the last decade we realised several rural landscape amelioration plans (Italy) by means of diffuse reintroduction of agroforestry linear plantations. To this end a GIS decision support system was developed that has been progressively implemented after design problem solutions and field/simulation research. Given that hedgerow (re)introduction could be a means to ameliorate some rural landscape processes, up until today we have reached the conclusion that planning is a necessary way to optimise such a transformation for socio-economic and intrinsic reasons. Therefore we need to be able to distinguish the effect of the agroforestry systems (mainly hedgerow) among different scales (single planting/landscape) and different patterns (isolated systems/networks) to optimise their positive effects on landscape processes at different scales; and it is not possible to optimise landscape transformations by means of agroforestry network implementation without an action plan able to evaluate them.*

Introduction

Agroforestry can be a tool to achieve landscape amelioration from an environmental and economic point of view (Franco, 2000), and for this reason it may be implemented at several levels. This is the reason, for example, for the promotion of the agroforestry policies by the European Union (EU Regulation 1257/99) and other countries. Given that a considerable body of research has been published on agroforestry corridors, mostly on a local scale, and that there is a strong socio-political demand for the implementation of agroforestry networks, we decided, more or less ten years ago, to organise and develop this knowledge to aid design and planning procedures that would be effective at both the local (i.e. a single planting) and the landscape scale. The procedure has been developed continuously over this period, so that, at present, 200km^2 of rural landscape has been planned, covering several Italian municipalities.

The objectives of this communication are:

- to point out the reasons why planning is necessary to optimise landscape transformation by means of agroforestry network plantation;

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- to describe briefly the first results from some investigations of the landscape-scale behaviour of the agroforestry networks planning.

Since some of the outputs of the Planland©® GIS for the hedgerow network design and planning have been applied for the development of the this paper, the same GIS is briefly described in the Appendix.

Planning as a necessary tool for a sustainable landscape transformation: reasonong

The socio-economic reasons

We think that the main factors that promote landscape transformation by means of agroforestry network implementation are:

- the development of scientific knowledge and its technical application;
- economic policies (contract and incentive regimes); and
- landscape planning.

Development of scientific knowledge and its technical application. In the last two decades, scientific knowledge about the relationships between agroforestry systems and landscape has grown quickly from several points of view (agronomic, hydrologic, conservation, etc.) and at several scales of interest. However, we feel that there is a considerable gap between the development of this knowledge and its general application. This observation comes from our personal experience acquired not only in numerous meetings with farmers but also in international meetings, such as that at Rennes in 1997. The various training institutions, even those of a very high level (e.g. the French IDF), have not completely solved the problem of transferring the knowledge to those who can apply it. There is a lack of real contact and exchange (in number and evenness) between institutions and planters.

Moreover, there is not only a training problem. In our opinion, farmers have a greater and more efficient judgement capacity (Cudlìnová *et al.*, 2000) than some experts believe (economists, ecologists, planners), but they tend to resist innovation for two possible reasons. First, farmers have a strongly conservative attitude towards change, not necessarily regarding only agroforestry. In one of our studies, for example, farmers were shown to be the citizens who most valued the hedgerows from all points of view (aesthetic, economic, etc.). Yet, while showing a strong cultural link with this kind of landscape structure, they nevertheless under-utilised the EU incentives for encouragement of hedgerow plantation (Franco *et al.*, 2001a; Mannino *et al.*, 2001). The other reason could be the strong economic compression of agricultural markets in many European areas, which reduces the entrepreneurial freedom of farmers.

Considering these aspects, even if farmer training by competent institutions is a fundamental element in best rural landscape transformation, the probability that training could be the major engine of its coherent transformation (spatially and temporally) is very low. A systematic utilisation of this knowledge in the landscape transformation process (e.g. through planning) should generate a more efficient way to value it.

Economic policy. Today, European rural policies address the local choices and shape the new European Union sustainable development models. From an economic point of view, the fundamental engines of this reshaping are the contract/incentive regimes.

However, common sense suggests that it is likely to be a mistake to think that sustainable development and amelioration of the landscape could result from a series of lucky circumstances. In other words, there is a very low probability that the reaction of a single farmer (somewhere in Europe) to specific economic incentive regimes would be spatially or temporally equal to, and coherently addressed to, an optimum landscape resource allocation. The shortcomings of the EU rural policy in terms of coherence between targets and results are sufficiently well known without requiring insights from sociology, macro-economy or thermodynamics (ecological economy) to explain them. Answers to this discrepancy come, in our opinion, from:

- the conservativeness of farmers' economic behaviour, which has historical and cultural bases and is correlated with the farmers' ages; and
- the complexity of the reactions to specific economic incentive regimes, linked to the variegated social and cultural issues of the European rural landscapes.

Therefore, it is necessary to find out the linkages between socio-economic models fuelled by the economic regimes and the real structures (and functions) resulting in landscape transformations, obviously in an optimised and sustainable direction. Again, these mechanisms seem to be coincident with landscape planning.

The intrinsic reason. The second reason for the necessity of planning, regarding the (re)introduction of a hedgerow network is of an intrinsic kind. The term "ecological network" has been widely used in the last decade, ranging from purely aesthetic concepts to more restricted ecological definitions. This growing interest is surely based not only on increasing knowledge about the topic, but also on the strongly evocative semantic effect of the expression in the communicative perspective of planning. In our work, my have adopted the definition of Forman (1995): "... corridors of a single type intersect to form a network...".

But in every case the concept of a network implies the existence of a new structure comprised of other sub-structures, and a different perceptive/analytic scale. If the hierarchical theory is accepted as one of the basic theories of landscape ecology and is assumed to explain the relationship between structures and/or processes at different scales, it would be reasonable to expect that the landscape structure network should show different and peculiar behaviours compared with the individual structures (the corridors) that comprise it.

These behaviours can be measured as the influence of the network on defined landscape function and process, and should not simply be the sum of the effects of the individual components. Even if simulations or (more significantly) the field studies on this topic are less abundant than those regarding single corridors, some evidence of this kind does exist (see Burel and Baudry, 1999; Forman, 1995; Franco, 2000).

Some first suggestions about the influence of the scale and the pattern on the hedgerow networks' effects on landscape processes

We will try to develop the concept that an agroforestry (hedgerow) network presents a different behavior with respect to the sum of the single hedgerows that build it up, and for this reason it would not be possible to optimise landscape transformations by means of an agroforestry network without an action plan to value it.

Agroforestry networks' effects on cultural perceptive processes

In order to maximise the efficiency of resource allocation in landscape management, it is necessary to consider the values that society places on the non-market aspects of agroforestry networks. Taking this into account we consider, for two main reasons, the impact of socio-cultural processes on landscape in terms of landscape functions connected to landscape structures. The first reason is that human culture, even from the perspective of perception/ cognition, influences changes of landscape structures and these in turn influence culture (Arler, 2000; Nassauer, 1995; Turco and Zanetto, 1992). If perception of landscape can influence its transformation, this cultural process can modify the landscape fluxes of energy and matter. From the ecological point of view, there is no difference between humans modifying a shrubby area because they do not like it for scenic or cultural reasons, and beavers modifying the hydraulic assets of entire watersheds for other causes.

The second reason is that the several theories produced on this topic support the links between preference – human behaviour – landscape change, and are compatible with the "patch-corridor-matrix" model utilised in landscape ecology (Bell, 1999; Nassauer, 1995).

Utilising this approach we:

- tested the role of agroforestry networks on landscape beauty estimation, in order to assess the impact of a landscape amelioration plan by means of the GIS supported procedure (Planland©®, see Appendix) on the scenic beauty of the landscape; and
- analysed the relationships between scenic beauty and some landscape descriptors at the "local" (ground level) and at the "landscape" (aerial photographs) scale (Franco *et al.*, 2002).

The results showed that a positive impact on landscape perceptive evaluation was produced by the planning procedure utilised to optimise the role of agroforestry networks in landscape amelioration (undertaken from the conservation, agronomic, economic and hydrologic points of view). Then, a sound functionality was found between scenic beauty and the pattern metrics used at the landscape scale. In this case, the main explanatory factor between the selected metrics (patch diversity, network density, connectivity and circuitry) was the network connectivity. This is an "intrinsic" topological characteristic of a network that neither exists in its individual structural components (corridors), nor is accounted for simply by the presence of the individual components (even when connected), in this case measured by density.

Agroforestry networks' effects on hydrological landscape processes
Agroforestry networks could play an important role in the hydraulics of watershed management. In this case, an important evaluation element is based on the degree of dislocation of the networks' links and nodes and not simply on the network density (Gascuel *et al.*, 1997; Merot and Durand, 1997).

To estimate the influence of the landscape structure "agroforestry network" on hydro-geo chemical landscape processes, we used the calculations of the nutrient non-point source pollution (NPSP) abatement capacity before and after implementation of agroforestry network amelioration planning for seven northern Italian municipalities, ranging in area from 7 to 33km^2. In these municipalities, the planning tool is now in operation. The estimations were made using the NUT model described in the Appendix.

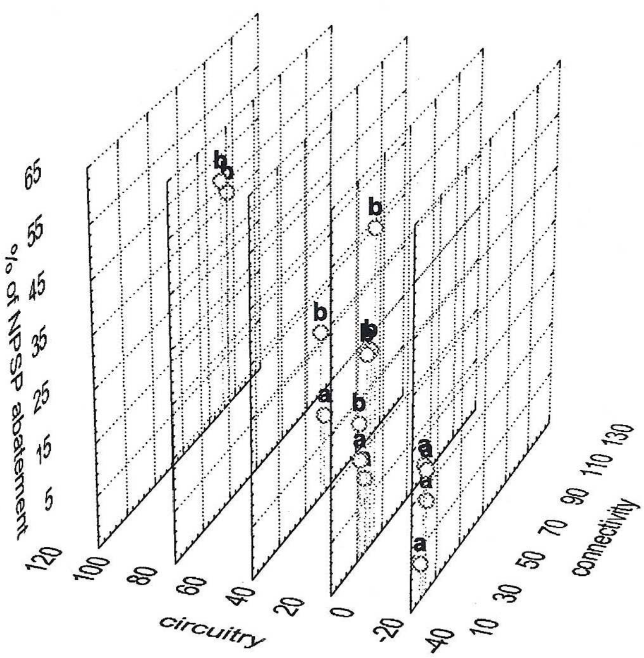
The results show that in the optimised agroforestry networks (after planning), the NPSP abatement capacity increases as the connectivity and circuitry of the networks increase (Figure 1), and that this increase is significantly correlated to these intrinsic characteristics of the network (Figure 2).

Actually, the functional relationship between the network density and the abatement efficiency (Figure 2), here described by a simple linear regression model, changes from insignificant to significant when the network efficiency increases. This implies, from the hydrologic landscape process perspective, that:

- the agroforestry network expresses peculiar functional characteristics not simply related to the sum of the individual components;
- an increased efficiency estimation for the network corresponds to an increased NPSP abatement efficiency; and
- given two agroforestry networks with equal density, the optimised one (e.g. in the connectivity and circuitry parameters) shows higher performance in the abatement capacity.

The "intrinsic" characteristic of this kind of landscape structure has, therefore, to be considered when estimating its influence on the landscape processes.

The importance of this result is in its clarity, simplicity and intuitive appeal. The limitations are in the model used: it is a management model that has been



Note: Values of connectivity and circuitry are expressed as the percent as regard as the theoretic maximum ones

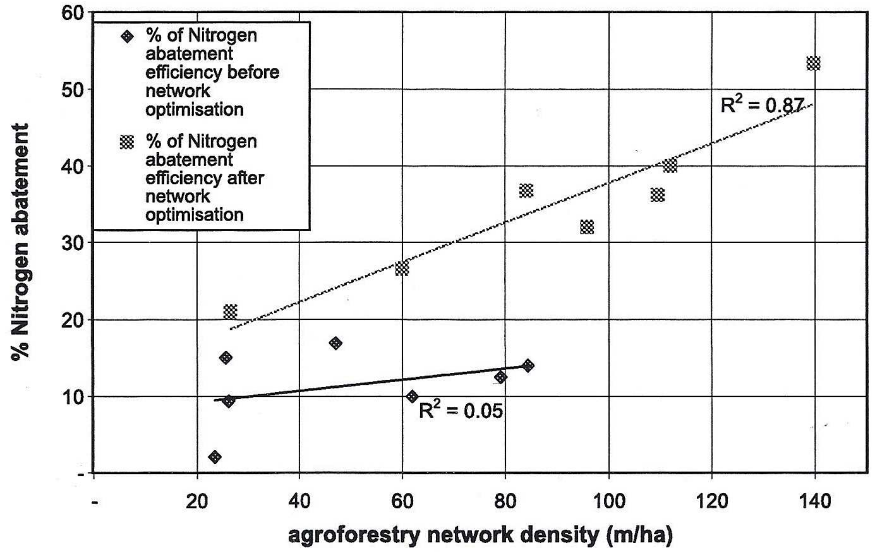
Figure 1.
The mean landscape values before (a) and after (b) the agroforestry network planing of the connectivity and circuitry versus the estimated percentage of nitrogen abatement efficiency

tested at the field scale but not at the landscape scale. However, the structure of the model is robust, and at large temporal and spatial scales (planning scale) the basic relationships found appear realistic. It seems that these findings could stimulate new research in this direction.

Agroforestry networks' effects on landscape wind fluxes

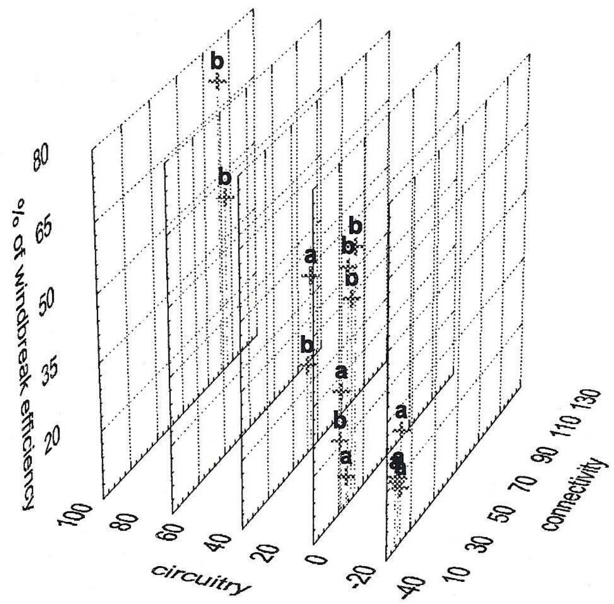
The wind model (see Appendix) was used in the same way as the analyses described above, and the results are very similar in content, as can be seen in Figures 3 and 4, formatted in the same way. The model is a robust management one, based on well-documented relationships from the empirical and theoretical point of view, but cannot estimate the "landscape effect" of the windbreak network (which is very difficult to estimate with a management model). Yet, it does account for all the single plant effects, and for the complexity of their overlapping.

The results are interesting because a simple GIS model, based on a different logical or operational assumption than the NPSP abatement one, gives a similar output in the ecological and theoretical implication when analysing the relations between this structure and another landscape function (the wind fluxes), and shows a non-summative response at the larger scale.



Note: The data have been regressed with a simple linear model and R^2 values are labelled

Figure 2.
The mean landscape values before (a) and after (b) the agroforestry network planing of the density (m/ha) versus the estimated percentage of the nitrogen abatement efficiency



Note: Values of connectivity and circuitry are expressed as the percent as regards the theoretic maximum ones

Figure 3.
The mean landscape values before (a) and after (b) the agroforestry network planing of the connectivity and the circuitry versus the estimated percentage windbreak efficiency

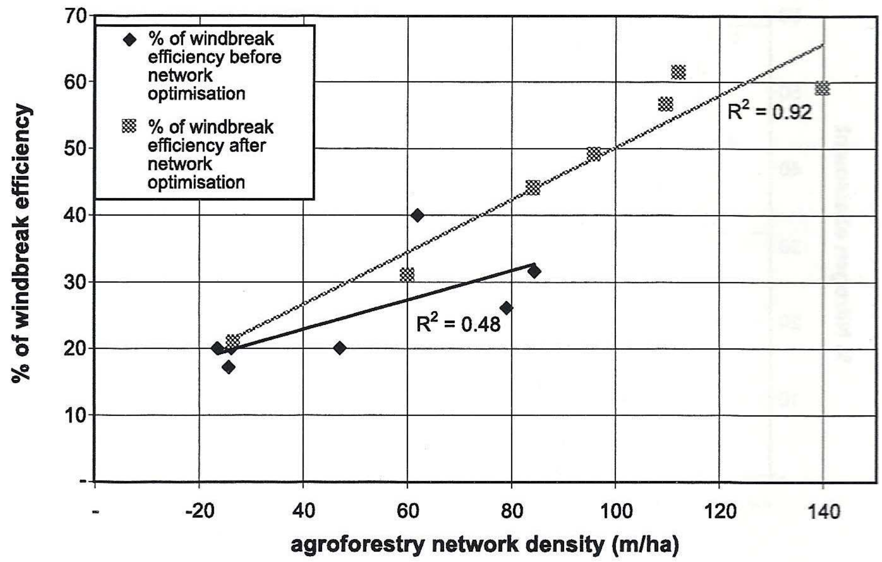


Figure 4.
The mean landscape values before (a) and after (b) the agroforestry network planing of the density (m/ha) versus the estimated percentage windbreak efficiency

Note: The data have been regressed with a simple linear model and R^2 values are labelled

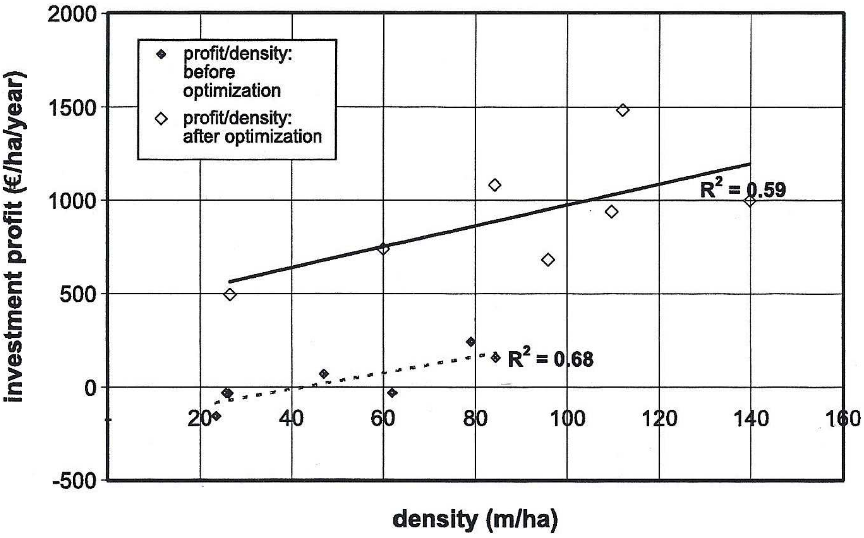
Agroforestry networks' effects on the economic landscape processes

Using the same planned areas, we tried to analyse the relationships between the agroforestry networks and the investment profit of the landscape-scale plantations. The profit was estimated by actualising at the twentieth year the net values of costs (lost crop incomes, planting, management) and direct benefits (EU incentives, timber incomes) calculated in a conservative way (that is, excluding the non-market items and considering a single reference crop) for all the existing or planned plantations. Then, the mean landscape results of the same seven landscapes (before and after optimisation) were compared with the structural/functional network parameters. Figures 5 and 6 show the first results.

In the case of density (Figure 5), a physical attribute of the net, the results show that there is a similar relation between the two parameters before and after planning (the slope of the linear function), and in the planned situation the profit is higher at the same network density.

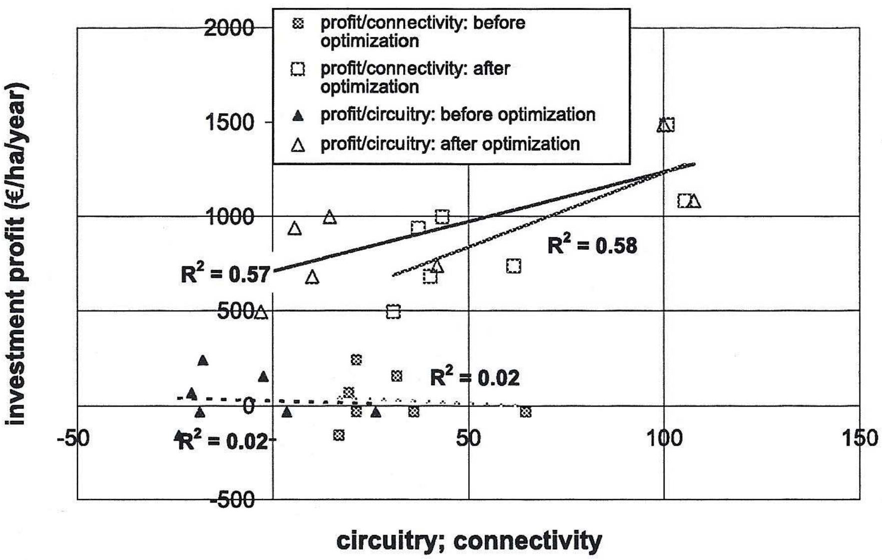
This is due to the fixed relation between the physical presence of plantations and EU incentives (the regression slopes), and to the increase of the structural and functional quality of the designed plantations, which brings higher benefits (incomes and incentives).

In the other case (Figure 6), there is a relationship between the increase of network efficiency (measured by the clear increase of connectivity and circuitry) and the network investment profit; but the more interesting result is that in the unplanned situation there are no functional relationships between these parameters and the economic one (the linear regression model is not significant),



Note: The data have been regressed with a simple linear model and R^2 values are labelled

Figure 5. The mean landscape values before (a) and after (b) the agroforestry network planing of the network density (m/ha) versus the investment profit (€/ha/year)



Note: The data have been regressed with a simple linear model and R^2 values are labelled

Figure 6. The mean landscape values before (a) and after (b) the agroforestry network planing of the network circuitry and connectivity (m/ha) versus the investment profit (€/ha/year)

otherwise in the optimised situation the relations become significant. So the more efficient the networks, the more significant the increase in agroforestry investment profit, and in the case of inefficient networks (see the unplanned situation) the profits can be negative, even considering EU incentives.

From the agroforestry investment profit perspective, this implies that:

- the efficiency, not simply the existence, of the networks has to be considered to increase agroforestry investment profit at the landscape scale; and
- given two agroforestry networks with equal density, the optimised one (e.g. in the connectivity and the circuitry parameters) shows higher economic performance at the landscape level.

Ongoing activities in this field

In order to deepen these findings, at our university we are developing simulation and field research on the following items:

- The reproduction of all the reported analyses on a large area (150km^2) divided by grids of several resolutions, to extend and confirm the first results and to analyse clearly the scale (area and resolution) and influence of landscape type.
- The analyses of the landscape structures and functions in three rural landscape types from several points of view (floristic, faunal, and productive) to eventually discover intrinsic landscape properties and the degree of their influence on biodiversity and on some selected landscape processes (stuctured to allow comparison with other groups' research on the same subjects).
- The calibration at the watershed scale and at the planning time-scale of the NUT model.

Conclusions

We believe that it is useful to consider landscape management problems in terms of connected categories (e.g. nature conservation, aesthetic valuation, economic cost and benefits, etc.). In particular, in dealing with agroforestry networks, socio-cultural or socio-economic landscape processes are linked to the landscape structures in a landscape ecology perspective (Forman, 1995; Burel and Baudry, 1999) and for this reason they can be treated as landscape functions in addition to biotic or hydrologic fluxes.

This is the approach we tried to use and brought to the consideration of this paper. Considering the (possible) landscape recovery/amelioration by means of agroforestry implementation, we are convinced that planning is obligatory to optimise such transformations in a sustainable way. Planning is effective at the landscape scale where the structure/process relationships have to be understood and managed.

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Appendix. A synthetic description of the Planland©® procedure

The aim of this section is not a full analysis of the procedure, described elsewhere (Franco, 1997, 2000; Franco *et al*., 1999), but simply an introduction as some of its outputs have been used for the theoretical rationale of this paper.

The Planland©® procedure framework

The conceptual and operative basis of the GIS-supported procedure comes from the landscape ecology for the descriptive patch-corridors model adopted, used even in the theoretical assumption or in the computational architecture, and the overall and particular planning/design goals adopted (Table AI) (e.g. Selman and Doar, 1992; Forman, 1995).

The procedure is made up of a sequence of analyses and evaluations that are driven by a GIS-supported assessment of several indices/models. These are calculated from geo-coded measures of structural and functional landscape characteristics and each index/model gives information about some aspect of the landscape. Thus the comparison of several indices allows for a global evaluation of the planning goals. The mapped landscape structures (the patches and corridors used in landscape ecology) are inserted with their ecological and economic characteristics (silvicultural status, land use, crop incomes) in the reference patch and corridor GIS layers; other landscape characteristics (soil types, hydrology) are inserted in other GIS layers.

Variation of the land use in patches or corridors, or insertion or deletion of patches and/or corridors in the GIS, results in some structural and functional landscape modifications, which are evaluated by means of the indices output. Optimisation of the indices leads to the landscape amelioration goals; the landscape analyses and design specifications are evaluated from several points of view and the results of the choices are clearly shown. The procedure involves two successive phases: an analytical phase for the existing status definition and a design phase for the optimisation of the objectives. Each phase utilises the same evaluation tools for the synthesis of the information, which gives the procedure methodological coherence. The procedure is developed by means of the simulation of changing scenarios (Figure A1). This progressive evaluation and feedback comparison leads to a final design that optimises the defined objectives.

Indices/models

Here we will describe some procedure evaluation modules, made up by models or indices, used in the analyses reported in this paper. For a more complete discussion, refer to Franco (2000).

Non-point source pollution abatement capacity (NUT). This is a GIS management model that is based on empirically defined relationships between the hydrological/pedological background and the structure (horizontal and vertical complexity, width) of the agroforestry systems. For each plantation, the abatement percent capacity (of surface run-off and shallow groundwater flow) on a mass-data basis are estimated in relation to:

- the plantation structure and composition (only in the presence of plants capable of N-fixation);
- the location with regard to the field and or the hydraulic network; and

Main objectives	(1) To optimise the comprehension (order of visual elements, patches and corridors) the readability (possible path finding), the perspective/refuge distribution and the isolated trees presence in the landscape (2) To maximise the heterogeneity and complexity/mystery of the landscape, balancing the *genius loci* and the perceptive unity/diversity (3) To optimise the patches shape/dimension and corridor distribution (i) to minimise management costs and lost income, (ii) to maximise micro-climatic functions and wildlife conservation (4) To maximise the nearness and density of the vegetated patches and the connection and circuitry of vegetated corridors, maintaining a visual balance of the empty/solid volumes between 1/3 and 2/3 (5) To maximise the ecotopes compositive and structural complexity, functionally to cost/benefit balance (environmental, economic) (6) To maximise the hydrological functions of vegetated network, and the perceptive presence of water
Secondary objectives	(1) To optimise the patches dimension (i) to create stepping stones, (ii) to develop ecotones (2) To allow at least two escape ways in every corridor node (3) To optimise patches' distance in order to obtain (i) values covered by the focus species, (ii) values not grater than 1km (4) To maximise margins circumvolution, iso-diametricity and width of wooded patches

Table AI.
Landscape ecology – main and particular objectives of restoration design

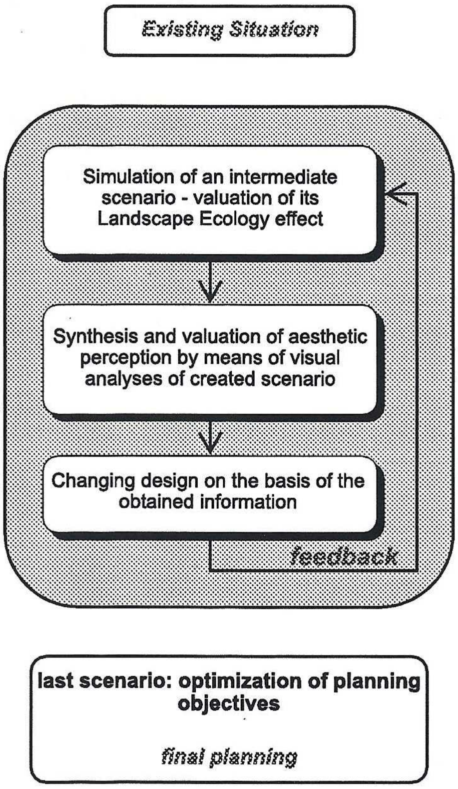

Figure A1. The GIS supported procedure (Planland©®) flow-chart

- the hydrological type on which the plant is located (estimated by the water table and pedological data of the layer GEO).

In this way, each plantation shows different degrees of non-point source pollution abatement capacity that are related to its internal structure and position in the landscape. The relationships between each kind of hydrological type and agroforestry system type have been conservatively estimated from published data, both measured and simulated. These have been calibrated at the local scale in a five-year field test (Franco, 1997; Franco *et al.*, 1999). When the data for the whole hydraulic network are available in the corridor layer, the estimation is based on the direct buffering by the agroforestry systems of the drainage system. If these GIS data are not available, the system uses an alternative simplified procedure that estimates the length of the cultivation not bordered by hedgerows, and considers as null the non-point source pollution abatement from this border. The abatement efficiency has been defined as the percentage of non-point source pollution (as nitrogen) abated by the network. Values substantially less than 100 indicate a low efficiency abatement effect of the agroforestry network, whereas values near 100 show high efficiency.

Windbreak effect (wind). This GIS model estimates the "weak zone" surfaces generated by a semi-permeable windbreak with a GIS buffering procedure. The zone simple estimation is based on the dominant wind direction, established by the user with a simple graphic utility and based on the meteorological data availability, and on the single windbreak structure (height and width). All the windbreaks are assumed to have the same permeability (porosity). The empirical relationship between these parameters is well described in the literature, both with field and theoretical work (for reviews see Forman, 1995; Franco, 2000). The windbreak efficiency has been defined as the percentage of the agricultural surface occupied by the weak zones and/or the percentage of overlapped sheltered surfaces. Values lower or higher than 100 indicate a low efficiency effect of the agroforestry network, whereas values near 100 show high efficiency.

Connectivity (CON); Circuitry (CIR). First described by Forman and Godron (1986), these indices are utilised to estimate the quality of functional exchange in a corridor network, and are based on the topological relationship between the network nodes and links.

They are supposed to be correlated to several landscape functions, but they do not have an intrinsic ecological meaning: their semantic meaning in the graph theory is different from that of their empirical utilisation. For their application to the real world some conventions need to be adopted (e.g. Selman and Doar, 1992).

Landscape scenic beauty estimation (SBE1). This index is an empirical multiple regression model that relates the landscape scenic beauty estimation to the agroforestry network characteristics at the landscape scale (Franco *et al.*, 2002). It has been adopted only in the regions where the model has been implemented. Before being used elsewhere, it has to be tested for a specific site.