Integrating Aesthetic and Sustainable Principles in Stream Reclamation Projects

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*Abstract***:** Stream regularization and the use of rigid, inert construction materials in engineering projects are not adequate for sustainable planning and development. Biotechnical stream protection and erosion control is characterized by the conjunctive use of live vegetation with retaining structures and revetments. The present work explores some of the issues relating aesthetic ideals and values, with sustainability principles and reclamation measures in a stream line reclamation project. In developed societies aesthetics plays a relevant role in public acceptance of landscape interventions. The understanding of aesthetic aspects of landscape and the clarification of its relation to sustainable principles in a landscape reclamation project presents itself as a useful tool, resolving potential conflicts between ecology and sustainability principles and public perceptions and expectations. In stream development projects, between solutions that may harness natural processes, bioengineering is the key to managing long-term impacts and costs, relying on self-repair and adaptation, rather than external maintenance procedures. The solutions and techniques applied in the present reclamation approach might be interpreted in terms of social care and help to achieve ecologically richer and aesthetically pleasant landscapes. Stream reclamation is an ideal field where aesthetics and sustainability ought to be aligned, in order to overcome the human errors of the past and built a sustainable, but also beautiful landscape.

*Keywords***:** Landscape reclamation, sustainable development, aesthetic, bioengineering, Portugal.

1 Introduction

Plants and other natural materials have been used for centuries to control erosion in stream banks. Biotechnical stream protection and erosion control is characterized by the conjunctive use of live vegetation with retaining structures and revetments. Between solutions that may harness natural processes, bioengineering is the key to managing long-term impacts and costs [1].

Those techniques became less popular with the arrival of the Industrial Revolution. The use of rigid, inert construction materials in engineering projects allowed for exact geometric measurements and time invariant designs suited to precise hydraulic and stress calculations. Also, the low cost of energy, steel and concrete encouraged the abandonment of vegetation and natural structures for stream reclamation [2].

In developed societies aesthetics plays a relevant role in public acceptance of landscape interventions [3]. The understanding of aesthetic aspects of landscape and the clarification of its relation to sustainable principles in a landscape reclamation project presents itself as a useful tool, resolving potential conflicts between ecology and sustainability principles and public perceptions and expectations [4].

Landscapes are themselves resources [5] constantly changing in result of human interests and activities [6]. In fact, in western society scientific and technical definitions have come to dominate, producing changes and rearranging features of the landscape in such a manner that landscape deterioration is nowadays an issue of increasing concern [5]. The former scenario is particular evident in waterscapes where the necessity of correcting past errors in the use and handling of river ecosystems creates an imperative necessity of watercourses rehabilitation [6, 7] with aesthetic and sustainable principles in mind.

The importance of landscape aesthetic values has been recognized all around world [2] as a result several approaches and aesthetic theories have been established [2, 9, 10]. The dominant one is still today the scenic aesthetics or romantic aesthetic [11]. Largely appraised by experts [12] is considered by

some professionals as morally inferior [11] and by others "out of step" because it romanticize untouched and pristine landscapes [10].

Landscape aesthetic improvements have much to do with a sustainable development of landscapes [13]. In fact, and contrasting scenic aesthetics, which is considered to be inconsistent with contemporary ecology [10], and so with sustainability principles, other new aesthetic paradigms have been defined seeking to settle aesthetics and ecological sustainability [12]. The ecological aesthetics or environmental aesthetics based in biological principles of ecosystem management constitutes the main example [14].

The ecological aesthetic theory, despite a slightly different meaning, incorporates aesthetic and sustainable principles, as Parsons [11] suggested: "*the main conceptual thrust has been the planning and management of environments for both aesthetic and ecological sustainability*".

With the purpose to bring together aesthetic and ecological sustainability, ecological components are considered [15] this theory ought to assume that the appreciation of ecological states and processes is able to produce intense aesthetic experiences [10].

The concept of beautiful and the landscape preferences have changed over time [16]. Even though in some near future, people might come to judge differently one particular landscape that nowadays is judged based on what people see [8]. That may help to explain why people appreciate natural elements with aesthetic qualities in landscapes [17]. However, "Ecologically good" or "sustainable" are not synonymous of "looking beautiful" [18]. As a result aesthetics and ecological sustainability, two highly regarded values of landscapes, sometimes can conflict with one another. In fact several studies [e.g. 18, 19] have been reported, conflicts between public perceptions and ecological sustainability principles.

Tánago & Jalón [7] stated that "*…man broke off this dialogue with his natural environment and thought he could usurp its superiority by technical means"*. According to Nassauer [20] aesthetics and ecology might be aligned by design and "*the awareness of what people enjoy and value in appearance of the landscape now*" but without to lose the ability to appreciate a landscape of tomorrow. The aesthetic quality is a fundamental component of the landscape [21] and traditional hydraulic engineering applied to some rivers eliminated his natural beauty [20]. Some researches indicate that simplified, monotonous and redesigned mathematically riparian landscapes are generally short of scenic beauty.

The incorporation of natural methods in the reclamation works, which entail the use of live materials, especially vegetation, such as the bioengineering techniques, fits harmoniously into the landscape and accomplishes the regulation, protection and stabilization of river courses [23]. In fact, live building materials, which were used for centuries for the protection of river banks, lakes and sea shores, were gradually forgotten, to be rediscovered after the turn of the last century [1].

In order to sustainable thinking succeed, the human action in landscape projects needs guidance [23]. In the present article, the word sustainability is not focused only in the ecological sustainability – one of the three main pillars of sustainability, but in contrast the term aesthetics, is taken in its broad sense, referring not only to the visual appeal of an environment but encompassing the full range of aesthetic and perceptual qualities and values [24]. Aesthetic, economic, and ecological landscape evaluation covariate as perceptual variables and they are not independent values [3], while the full value of a good or service can be calculated by estimating the demand for it [25]

In short, the current paper explores some of the issues relating aesthetics ideals, and values with sustainability principles and reclamation measures using as case study a stream reclamation project located in Algarve, Portugal.

2 Materials and methods

2.1 Case study description

The setting for the study is a countryside scenery landscape, in the core of Algarve, Portugal. The study covers a 500 meters stream with torrential flow. The integration in a new industrial park and the location near a residential area, made this project a critical case study, where ecological needs must meet human economic interests and aesthetic expectations.

2.2 Procedure

The landscape was analyzed for cultural, biophysical and aesthetical components, since they all have important effects on the reclamation alternatives. For purposes of stream analyses, the main natural features that influence its aesthetics – river typology, river morphology, biological components, natural and technological hazards – were examined as proposed by Silva [26]. Figure 1 is showing a graphical representation of the study concept in the present sustainable stream reclamation.

Figure 1- Idealised stream cross-section with aesthetic rehabilitation and bioengineering measures.

The bioengineering techniques were chosen after analysing functions and evaluating geotechnical, ecological, economic and aesthetic effects of several approaches [1, 22]. Constrains of application (biological, technical and time limitations) and construction cost were also considered along the selection process. Afterwards, species selection took place according to ecological, biotechnical, aesthetic properties and origin or provenance [6]. The next stage was to elaborate the reclamation project composed by the following design tools: master plan, grading plan, plantation and ground cover plan, cross-sections, etc.

During this study, special attention was given at the stage of vegetation care and maintenance, which are crucial to a successful accomplishment of stream rehabilitation projects according to Saraiva [6].

3 Results and Discussion

The project tried to reduce changes in the affected landscape, in order to minimise landscape instability and promote sustainability. In figure 1, the stream cross-section is showing an idealistic rehabilitation as a graphical representation of the final result.

Parallel to the stream, a 10 meters width "buffer zone" was delineated, according to Portuguese legislation (Law nº. 468/71, 1971-11-05 and Law nº. 54/2005, 2005-11-15). This strip will guarantee the stream protection from the nearby urban pressure and hazards.

In the present study several bioengineering techniques (Table 1) were used in combination in order to increase effectiveness of the reclamation project. Hydroseeding was applied to the stream margins, and to the 10 meters ´buffer zone`. Gabions were specifically selected to be used in the stream curves, in areas where the erosion can be a problematic issue. Live fascines, combined with hydroseeding, were used in the stream banks, where the steep slope (1:1 and 1:2) required more efficient measures. The latest procedure was necessary also due to space limitations in specific locations that implied a slope higher than the desirable.

Table 1 – Bioengineering techniques applied of the stream reclamation project.

Bioengineering technique	Area (m^2)	Ecological situation	Cost (€/m^2)
Hydroseeding	7765	10 m buffer zone	3,25
Gabion walls	210	High water velocity	110
Live fascines	1131	Unstable slopes	30

Figure 2 is showing the bioengineering techniques distribution in a stream section. The hydroseeding – the reclamation treatment for the margins and ´buffer zone` – was formed by two mixtures, containing different plants species composition and different seeding density. Trees were planted at the conservation ´buffer zone` 10 meter strip and shrubs were planted in the adjacent area.

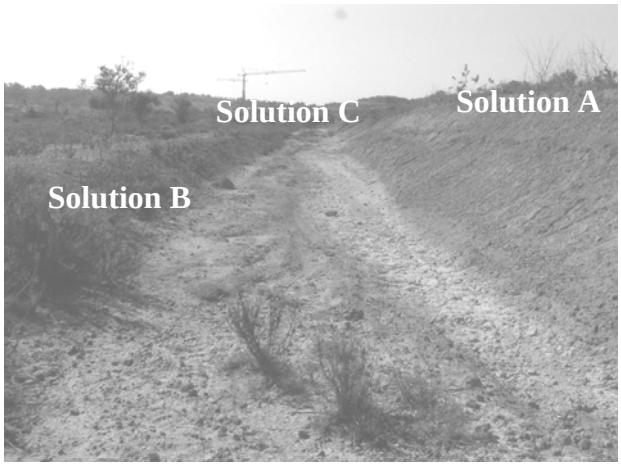

Figure 2 - Distribution of the adopted bioengineering techniques on the study area.

Table 2 shows the list of species proposed for the stream reclamation project, which was used in combination with the following solutions.

- Solution A (used in ´buffer zone`) – Hydroseeding mixture of: *Cistus cripus* 10%; *Crataegus monogyma* 10%; *Lavandula* sp.10%; *Myrtus communis* 10% ; *Nerium oleander* 10%; *Pistacia lentiscus* 15%; *Rhamnus alaternus* 10%; *Cynodon dactylon* 5%; *Trifolium repens* 5%; *Festuca arundinacea* 15%.

- Solution B (used in accentuated, unstable slopes of 1:1 to 1:2) – Live fascines and hydroseeding mixture of: *Festuca arundinacea* 35%, *Cynodon dactilon* 15%, *Festuca rubra rubra* 50%.
- Solution C (used at curves and high erosion risk areas) - Gabions or stone walls.

Table 2- List of species proposed for the reclamation project

Vegetation type	Species	Individuals planted (n)	Propagation type
Trees	*Tamarix africana*	12	Seed/stalk
	Fraxinus angustifolia	13	Seed/stalk
	Olea europea var. sylvestris*	38	Seed/stalk
Shrubs	*Crataegus monogyma*	-	Seed/stalk
	Nerium oleander	77	Seed/stalk
	Rhamnus alaternus	13	Seed
	Pistacia lentiscus *	47	Seed/stalk
	Myrtus communis *	10	Seed/stalk
	Lavandula sp. *	-	Seed/stalk
	Cistus sp. *	-	Seed
Herbs/ Grasses	*Cyn*Tamarix africana* Poiret	-	Seed/rootstalk
	Festuca rubra rubra	-	Seed/ rootstalk
	Festuca arundinacea	-	Seed/ rootstalk
	Trifolium repens		Seed

*Specie identified in the study area.

The selection of suitable plants is a requisite for the success of the reclamation measures adopted [1]. Consequently, the project sought out plants and plant materials from areas in close proximity in order to reduce costs and increase potential success of the reclamation. Also, the selected vegetation was characterized by wide ecological amplitude, water stress tolerance, adaptation to local conditions, fast establishment and low maintenance cost.

Bioengineering techniques had an important role in the present stream reclamation project, allowing, the stream bank stabilization and the aesthetic appeal enlargement, helping to define a dynamic landscape of great natural beauty. In this respect we find remarkable similarities between Tánago & Jalón [35] and the present paper, as these authors presented similar study cases where restoration of rivers banks was used or considered in a wider meaning "*…a restoration of natural processes*" in order to guarantee ecological processes and natural beauty in river landscapes.

The present approach seems in harmony with the definition of "sustainability" presented by Miles [27] where sustainability is assumed like an integrative modernization given that it is aiming at development forms that are both society-friendly and nature-friendly. In figure 3 it can be seen a profile of the stream bank after bioengineering reclamation showing a restoration of ecological processes. The trees and shrubs proposed were displayed as it shows in the plantation plan (Figure 4). The ground cover species helped defining the project character and assure the total integration of the study area in the surrounding landscape.

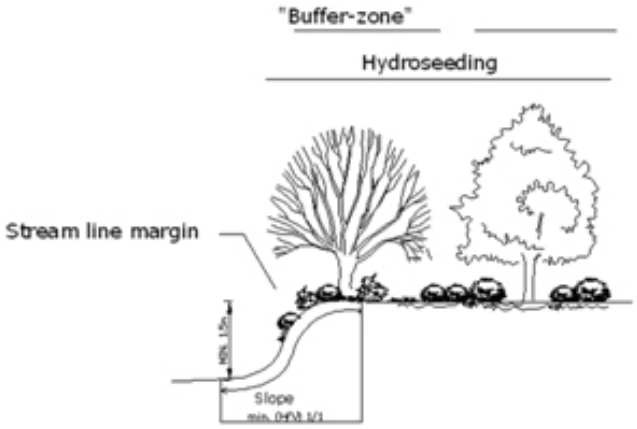

Figure 3- Typical profile of the main solution adopted for the study area (Autocad 2007 software).

Since public preference is commonly correlate with the amount of natural elements in the setting it is not surprising that bioengineering techniques, which requires the use of several natural and live materials, constitutes a powerful alternative for stream reclamation interventions [28]. Other benefits of bioengineering techniques are the self-repair and self-evolution character of the natural elements used in the project. Also it has to be mentioned the increasing stabilization capacity with time of the live materials used.

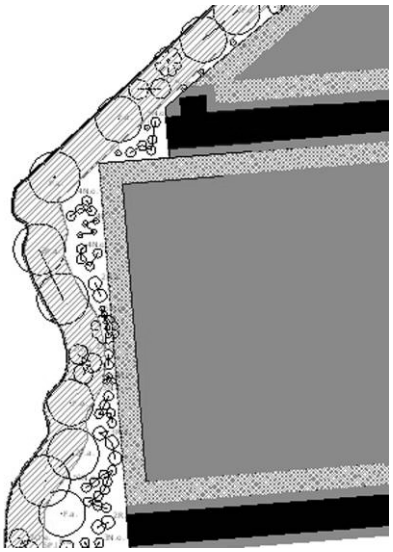

Figure 4. Detail of the plantation and ground cover plan of the study area (Autocad 2007 software).

The results showed that the recommendation of Gobster [18] – *adoption of an aesthetic alternative, which incorporates principles of ecology* – is a way in which aesthetic and sustainability values might be integrated. However, Gobster goes further and points out that, beauty and other aesthetic values may be preserved through the implementation of bioengineering techniques that give a sense of naturalness, which is highly appreciated by public according to Ikemi [28]. In fact, Tanago & Jalón [7] considers *"…aesthetics of river processes as a synonymous of naturalness"*.

The present study reinforces the idea that aesthetic experiences can be drawn from restored river landscapes. Even though Nasaauer [19] mention that when people fix their attention only on characteristics of scenic landscapes, they undervalue the power of landscape appearance and as a consequence they may be compromised.

In the present study, bioengineering techniques replaced traditional civil engineering measures entirely. Nevertheless, it must be recognized that the use of vegetative materials has biological, technical and time constraints. Needs of larger space, timing of construction, time necessary to establish vegetation and waiting time until maximum performance, are the most important constraints. In some cases construction costs can also be a limitation due to labour cost comparing to the "hard" civil engineering techniques. This is why bioengineering techniques are not always a substitute, but commonly a supplement of the conventional purely technical methods [1].

According to the results of the stream reclamation project studied, the scenic beauty and aesthetic aspects are important attributes of the landscape, not only because beauty is readily available for public critique [9], but mainly because landscapes perceived as aesthetically pleasing are more likely to be appreciated and consequently protected more than landscapes perceived as ordinary or unattractive [30]. This is of particular importance in contemporary society, because people still make judgments based on visual characteristics and not on long term perspectives.

Many authors [27] attempted to integrate aesthetics, ecology and sustainability. But only some (e.g. [7]) addressed those issues at a common practice approach. From the perspective of the analysis adopted in the present work it is believed that, through the combination of some of the most contemporary aesthetic theories and ecologic principle, this study case, describe a straightforward approach that shows how to convert theory into practice with the purpose to fulfil ecological and aesthetic expectations in river landscapes. The combination of bioengineering techniques and landscape design may assist to prevail over one of the 20th century's great errors the separation of science from art [7].

4 Conclusions

The present work shows that aesthetic and ecological principles could be integrated in stream reclamation projects. Plentiful use of vegetative materials combined occasionally with inert construction materials in stream reclamation projects is the most adequate for sustainable planning and development. The main advantages of the present project were various, with the most relevant biodiversity and habitat conservation, landscape improvement, soil increasing stability and ecosystem functions preservation with possibility of self maintain and evolution. The success of the present reclamation project depended of the balance achieved between factors of ecological, economic and aesthetic nature, which are as important as difficult to integrate.

In the present stream reclamation project, aesthetic values and bioengineering techniques were in harmony with sustainability goals. In stream development projects, between solutions that may harness natural processes, bioengineering is the key to managing long-term impacts and costs, relying on self-repair and adaptation, rather than external maintenance procedures. The solutions and techniques applied in the present reclamation approach might be interpreted in terms of social care and help to achieve ecologically richer and aesthetically pleasant landscapes. Stream reclamation is an ideal field where aesthetics and sustainability ought to be aligned, in order to overcome the human errors of the past and built a sustainable, but also beautiful landscape.

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