Chapter 1

INTRODUCTION TO ECOTECHNOLOGICAL SOLUTIONS

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Abstract: *We introduce the terminology used in this book and outline the scientific principles behind the definitions given for ecotechnology, eco- and ground bio-engineering. We focus on the use of restoration and management techniques for slopes prone to shallow mass movement and erosion through natural events such as storms. The use of protection forests is discussed, along with their mechanical stability during wind storms, landslides and rockfall events. Which ecotechnological solution to use in any given situation is outlined, depending on the scale of the problem, economics and the consequences of action and inaction.*

Key words: eco-engineering, ground bio-engineering, landslides, erosion, rockfall, storms

1. INTRODUCTION

"Ecotechnology is the use of technological means for ecosystem management, based on deep ecological understanding, to minimize the costs of measures and their harm to the environment" (Straskraba 1993). The science of ecotechnology is similar to that called "ecological engineering," which in turn has been described as "the management of nature" (Odum 1971), or as "the proactive design of sustainable ecosystems which integrate human society with its natural environment, for the benefit of both" (Mitsch 1996; Painter 2003; Mitsch and Jørgensen 2004). Ecological engineering involves mostly creation and restoration of ecosystems whereas ecotechnology encompasses the management of ecosystems (Mitsch and Jørgensen 2004). Both subjects have largely been devoted to the sustainability of wetlands,

J.E. Norris et al. (eds.), Slope stability and erosion control: Ecotechnological solutions, 1–8.

wastewater and aquaculture (Painter 2003), but can be applied to a larger range of environments. In this book, we will focus on the restoration or protection of sites using eco- and ground bio-engineering techniques, both of which fall within the science of ecotechnology. Eco-engineering has recently been defined as the long-term, ecological strategy to manage a site with regard to natural or man-made hazards (Stokes et al. 2004). For natural slopes, such hazards can be mass movement of soil, e.g., landslides, avalanches and rockfall, or erosion, e.g., sheet and gully erosion or river bank erosion. By combining ground bio-engineering techniques with long-term solutions, slopes can be managed effectively to minimize the risk of failure.

Ground bio-engineering methods integrate civil engineering techniques with natural or man-made materials to obtain fast, effective and economic methods of protecting, restoring and maintaining the environment (Schiechtl 1980; Coppin and Richards 1990; Gray and Sotir 1996). The use of, e.g., geotextiles or brush mattressing to arrest soil run-off and the planting of fast-growing herbaceous species to fix soil, are typical ground bio-engineering techniques. The correct choice of plant material is difficult, as knowledge is required concerning the ability of the plant to grow on a particular site, and also the efficiency of the root system in fixing and reinforcing soil on an unstable slope. Although such information may be available for a particular species, its performance in the long-term also needs to be known, e.g., grasses often die back in summer and should be combined with shrubs so as to avoid slippage or erosion problems. Shade intolerant species will also decline as shrubs and trees grow taller over a longer period of time. Long-term solutions therefore need to include the use of appropriate management strategies and the employment of Decision Support Systems (DSS). Such tools could also be integrated into Geographic Information Systems (GIS) to predict future risks. Such management techniques are particularly effective in large-scale areas in Europe, e.g., ski resorts, mountain slopes and forest stands (Dorren and Seijmonsbergen 2003).

1.1 Using eco- and ground bio-engineering techniques

Examples of where eco-engineering techniques would be most useful are in situations whereby human safety is not an immediate issue, the site is large-scale, or where protecting structures are already in place, e.g., rock trap nets, avalanche barriers and gabion walls. When deciding to carry out eco-engineering techniques on an unstable slope, the engineer must first determine the nature of the slope, type of soil, type of native or desired vegetation and the likelihood of any catastrophic event occurring which would decrease slope stability during the restoration time (Figure 1.1). If the risk of danger to human life and infrastructures is low, the engineer must consider the size of the site and costs to be incurred throughout the life of the project. If the site is on a small-scale and the cost of construction, e.g., fascines, live stakes and branch nets, planting and upkeep is equal to the economic, aesthetic and safety gain at the end of the project, ground bio-engineering techniques can be considered. If the site is large-scale, e.g., a mountain slope, the expenses incurred in carrying out certain bio-engineering techniques may be too high for the gain produced, and eco-engineering techniques may be used. However, it must be remembered that any gain as a result of an eco-engineering project will only be in the long-term.

Typical eco-engineering practices may include the use of DSS (Gardiner and Quine 2000; Mickovski et al. 2005; Mickovski and van Beek 2006, see Chapter 8) to determine how and when to plant depending on soil and slope type and the hazards to which the site is exposed. Management strategies are then proposed for the upkeep of the site. For example, a mountain protection forest should consist of broadleaf species, the number of wild ungulates should be limited and thinning and felling should be carried out with care (Motta and Haudemand 2000). Similarly, in conifer forests subjected to frequent storms, the upwind border of the stand could be planted with broadleaf species and pruned to create a 'ramp', or shelterbelt type structure. Such a structure would cost little to maintain and would allow the prevailing wind to pass over the plantation, rather than penetrate into the stand (Quine et al. 1995).

Eco-engineering is beginning to emerge as a future research area in Europe which engineers and ecologists should consider both in education and application (Stokes et al. 2007). Human activity over the last 100 years has been concerned with increasing productivity through technological progress, at the cost of environmental degradation (Painter 2003). It is now necessary to repair this damage, although with limited resources, many countries are unable to invest heavily in environmental restoration of degraded lands. Eco-engineering techniques can therefore provide a low-cost, long-term solution in certain cases.

As mentioned previously, ground bio-engineering is defined as the use of living plant materials to perform some engineering function, from simple erosion control with grass and legume seeding or more complex slope stabilisation with willows (*Salix* sp.) and other plants (Schiechtl 1980). The response is fast which is particularly important for stabilizing a denuded slope.

The function of vegetation in bio-engineering can be divided into four groups (Schiechtl and Stern 1996), which are:

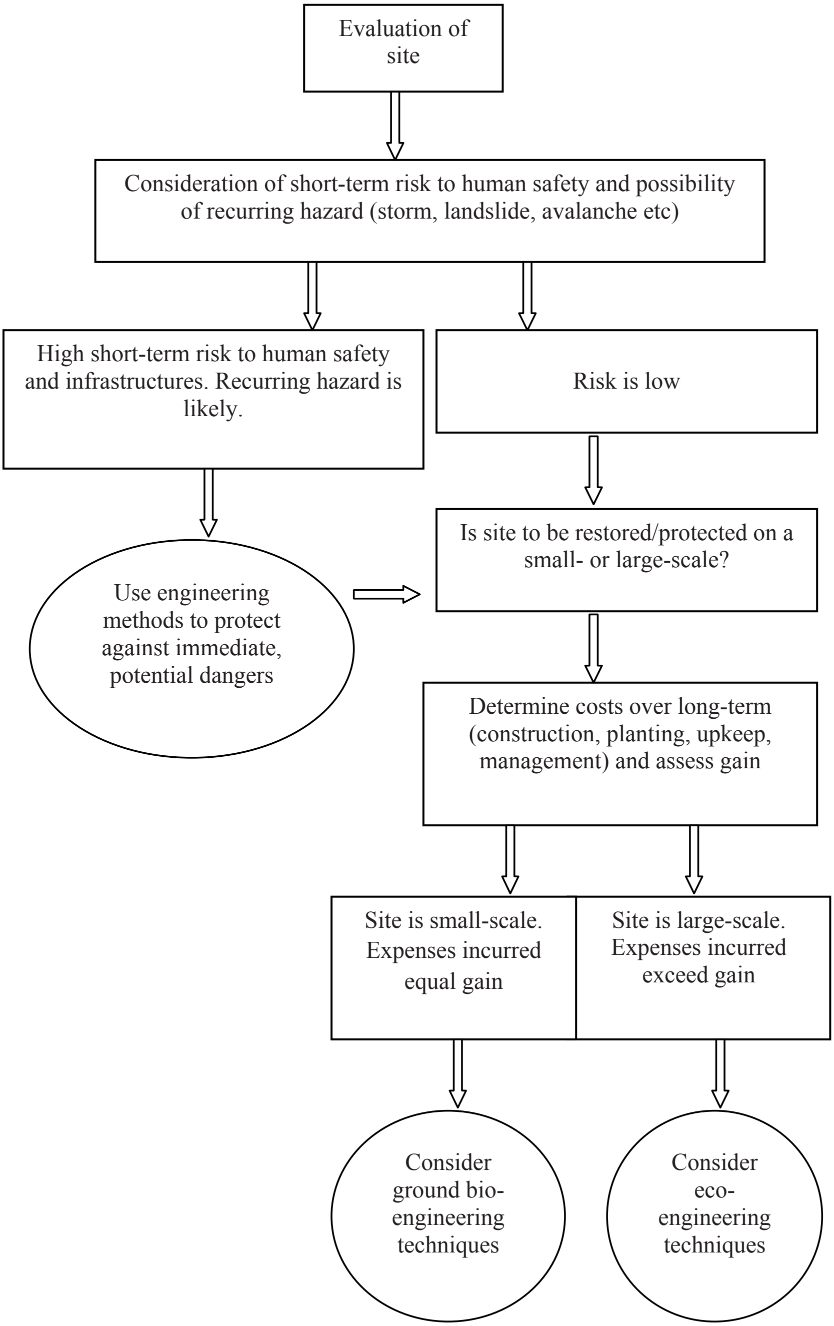

Figure 1-1. When considering the implementation of ground bio- or eco-engineering techniques, the engineer must take into account the potential dangers, size, cost and gain of the project.

1. *Soil protection techniques* rapidly protect the soil, by means of their covering action, from surface erosion and degradation. Such techniques improve water retention capacity and promote biological soil activity.
2. *Ground stabilising techniques* are designed to reduce or eliminate mechanical disturbing forces due to the soil mass. These techniques stabilise and secure slopes liable to slides by means of root penetration, decreased pore water pressure through transpiration and improved drainage. In principle, they consist of linear or single point systems of shrubs and trees.
3. *Combined construction techniques* shore up and secure unstable slopes and embankments by combining the use of live plants with inert materials (stone, concrete, wood, steel, and geosynthetics). This method increases the effectiveness and life expectancy of the measures employed.
4. *Supplementary construction techniques* comprise seeding and plantings in the widest sense of the word; they serve to secure the transition from the construction stage to the completed project.

Pioneering woody species are of particular importance in the development of ground bio-engineering systems. This group of plants represents the succession bridge between the herbaceous initial colonisers (seeded grasses and legumes) of a disturbed site and later seral types and thus plays a key role in succession advancement of the site (Polster 2003). Woody vegetation improves the hydrology and mechanical stability of slopes through root reinforcement and surface protection (Sotir 2002).

The role of vegetation in stabilising slopes is not limited to general planting techniques. One aspect of ground bio-engineering is to use living plant material to build structures to stabilise the problem site. All construction materials must be strong enough to withstand the forces acting on them. Since it is the intention to build structures of living materials, these materials must sprout and grow, therefore the materials must be in a condition that will promote their subsequent growth. Plant material is typically in the form of stem cuttings when planted and must therefore be capable of forming new roots and shoots (Polster 2002).

By using vegetation in the structure it is possible to manipulate the depth at which rooting occurs. For example, live willow stakes can be planted at a depth of 2.0 m below the surface as long as anaerobic conditions are not present (Steele et al. 2004). With traditional planting methods, roots would not normally reach this depth.

There are limitations though to ground bio-engineering methods and include:

1. Installation is often limited to the plants' dormant season, when site conditions may limit access, e.g., heavy snowfall or waterlogging.
2. The availability of locally adapted plants may be limited.
3. Labour needs are intensive and skilled, experienced labour may not be available.
4. Labourers may not be familiar with ground bio-engineering principles and designs, so upfront training may be required.
5. Alternative civil engineering practices such as soil nailing and geosynthetic reinforcement, which have well defined engineering parameters are widely used, marketed and are more commonly accepted by society and contractors (Franti 1996) especially for stabilising infrastructure slopes.

2. HOW TO USE THIS BOOK

This book has been written to provide non-specialists with the information needed to characterize an unstable slope and to decide how best to restore and/or manage the site in the long-term. Chapters 2 and 3 explain how to describe a natural or man-made slope and provide information on the different types of mass wasting which can be found. How plants reinforce soil on unstable slopes is presented in Chapter 4, with an in-depth description of root system mechanical and morphological properties. In Chapter 5, the authors discuss the principles of hazard assessment on slopes prone to mass movement and erosion. Not only is soil movement described, but tree stability during wind storms is explained, a factor which can seriously aggravate soil movement on forested slopes. Engineers require information about which species to plant on a given slope, and a comprehensive list is provided in Chapter 6. On slopes where rapid remedial measures need carrying out, ground bio-engineering methods can be used and a wide selection is presented in Chapter 7, along with the long-term management of forests against storms and rockfall. Finally, perspectives for future eco-technological research are given in Chapter 8.

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