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Review

Preventing Natural Hazard Risks through Sustainable Site Design

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Abstract

This paper examines sustainable site design approaches with emphasis on preventing certain natural hazards. It explores the role of natural forms and land modeling as mediators concerned with the identity of site and place with a concern that design should be ecological and sustainable, using resources efficiently. This paper proposes that natural disasters such as landslides and erosion might be prevented by sustainable site design. Preparedness should start at the site selection phase with proper site analysis. After gaining an understanding of the causative mechanisms of these hazards, a set of site design principles for reliably avoiding the causes of the disasters is established.

Keywords: erosion, natural hazard, landscape architecture, site design, sustainability

Introduction

With the development of concern for ecology and environment, how to control the effects of natural hazards becomes an urgent problem. Building major designs has usually had a harmful effect on the environment; in many places, the land is more damaged than previously believed (Fig. 1). Natural disasters such as surface erosion and landslides in steep terrain related to various development practices, have been concerns in urban planning and management; however, almost no long-term research has been conducted on these issues. Designers must develop a respect for the natural landscape and expend more effort to understanding the interrelationships of natural systems and habitats, as well as the impacts of human uses on them. In this context, the development of sustainable site design should be achieved by seeking harmony between human intervention and nature.

Site design is a process of intervention involving the location of circulation, structures and utilities, and making natural and cultural values available to users [1-4]. Sustainable site design requires holistic, ecologically based strategies to create projects that do not alter or impair but instead help repair and restore existing site systems [5-7]. The growing concern of the possible impact of natural disasters and extreme events on the environment has recently created new demands for information from, and assessment by, landscape architects who specialize in site design and engineering. The study of site design focusing on land modeling has the potential to contribute towards a holistic approach in landscape architecture for sustainable development and prevention from risks of natural hazards [8]. In this context, characteristics of erosion and landslides should be specified.

Conceptually, the difference between erosion and landslide is quite clear — erosion is a water driven process, whereas landslides are gravity driven [9]. Landslides impact site productivity more severely but usually over much smaller areas compared with erosion. Although landslides are naturally occurring phenomenon in steep terrains, they pose significant hazards to humans and property [10]. Water flowing through or over the ground is often the trigger for a landslide. Any activity that increases the amount of water flowing into landslide-prone slopes can increase landslide hazards [11]. Surface erosion control should focus

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Fig. 1. Developments on sloped areas are major threats to natural habitat. The owners of a controversial housing development in Istanbul, AcarKent, are alleged to have abused a loophole in forest protection laws, clearing away as many as a thousand trees to make way for upscale villas. Aerial photographs show the massive destruction of the natural topography by creating flat surfaces on top of the hills, which may soon have disastrous consequences.

on maintaining ground cover and minimizing surface runoff and velocity, while landslide prevention must focus on minimizing pore water pressure accretion on steep, unstable slopes [11].

Most of the land (62 %) in Turkey has severe slope conditions and more than 75% of all land in Turkey is under high risk of erosion [12]. Among natural hazards, mass land movements are the most frequent and have the largest geographic distribution in Turkey. After a landslide in Senirkent, a small town of Isparta, on July 13, 1995, 195 houses were demolished and 75 people died. After this incident, rather than relocating the town, the authorities decided to build massive retaining walls to catch the debris and surface runoff. We should learn many lessons from such incidents. The assessment of topographic challenges in development areas and sustaining natural land with vegetation cover should be integrated into design practices. Designers and planners, therefore, should focus on sustainable site design requirements to prevent properties from natural hazards.

Sustainable Site Design Principles

Sustainable site design involves simple design and management practices that take advantage of natural site features and minimize impact on the natural environment [2, 4, 13, 14]. Below are some of the principles and approaches of sustainable site design [1, 8, 15-17].

Site Selection: Assessing Site Resources

The greatest impact to the environment when constructing a building occurs during site selection. The site selection process phase may well be the most important step to reduce or minimize the overall environmental damage of a development. All proposed sites should be analyzed to determine site characteristics that will influence building design. To this aim, the solar altitude, microclimate and topography should be assessed. During the site selection process, urban redevelopment sites and sites that have previously been damaged environmentally should be preferred.

Blend with Existing Topography

There are many different types of landforms, including valleys with various slope angles, dimensions and surficial deposits, which require further consideration for the assessment of site vulnerability to erosion and landslides. In many urban environments steep slopes predominate, requiring special siting of structures and costly construction practices. The property's topography—including slopes, dominant landforms and soil composition—has a dramatic impact on developments. Topography is, therefore, critical to the design and layout of buildings, stormwater controls and drainage. When grading must occur, it should blend with the natural landform as much as possible (Fig. 2).

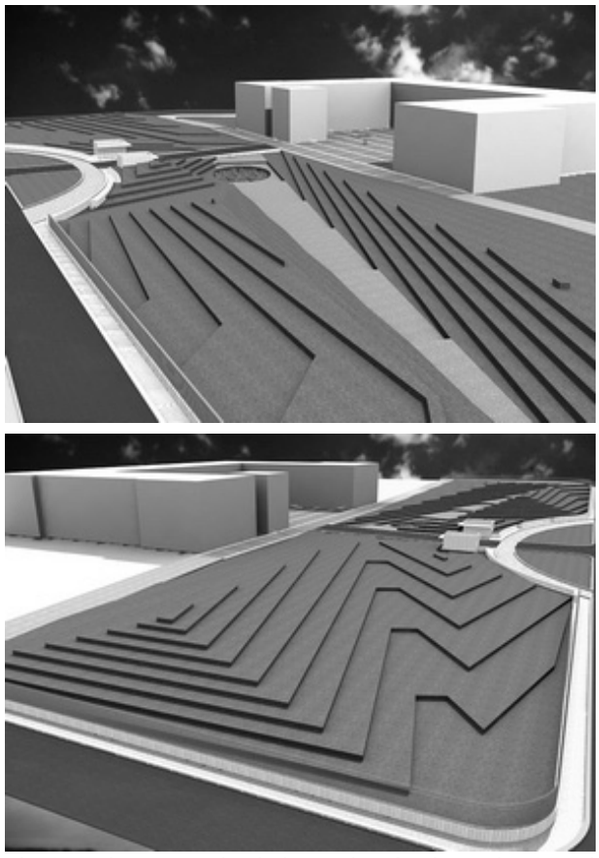

Fig. 2. In the current site design project for the Jordan Armed Forces Public Security Directorate Complex, Amman, we—the design team of four—used natural topography as an element of art (Views of the entrance spaces of the PSD complex). Proposals were displayed on 3D renderings.

Defining the Use of Existing Vegetation

The existing vegetation should be viewed as an asset to enhance design (i.e. natural shading, reduced landscape construction and maintenance) and reduce impacts of the development (i.e. reduced storm water runoff and increased filtration) [18, 19]. Existing vegetation, especially native plants, should be preserved. Excessive paving and monoculture lawns should be avoided. A landscape designer's major role should be to use local species for planting and preserve existing mature trees.

Planting Design for Site Prevention and Engineering

Sustainability can be enhanced by careful planting design, which requires less maintenance, contributes to the overall visual quality of the landscape, increases erosion control and maximizes storm-water management. Planting design should be based on the natural character, seasonal and climatic variations, types of native vegetation, soil type and topography. These issues create design opportunities and constraints and contribute to the sustainability of the landscape. A major contribution of planting design is the prevention of soil erosion; the landscape designer takes special care to mitigate soil erosion by assessing the topography, soil character, density of rainfall and storm water runoff. Good design and construction practices prevent downstream water and drainage structure and loss of valuable topsoil (Fig. 3).

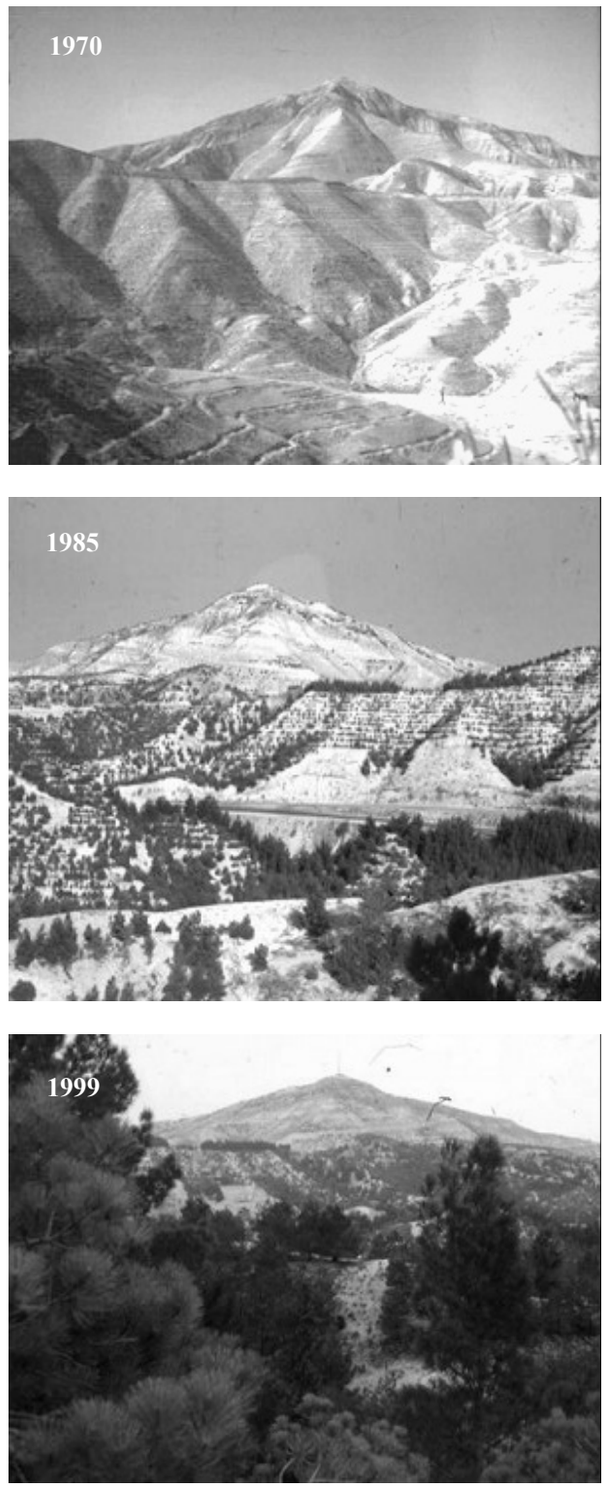

Fig. 3. Landscaping steep slopes with terracing reduces erosion risk on steep terrains. The images, which have been captured from the same angle, show a forestation process in Turkey. Loss of topsoil in the region is minimized after the installations.

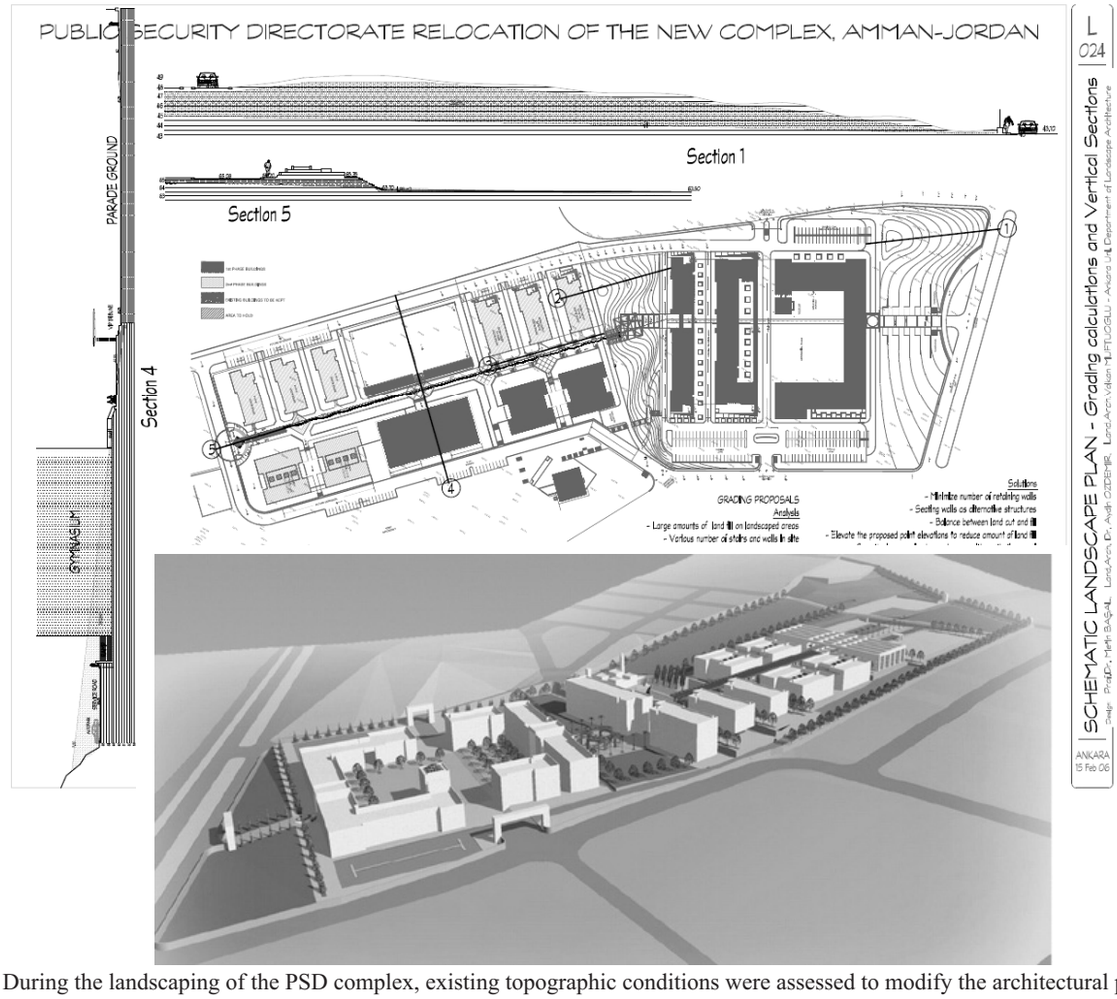

Fig. 4. During the landscaping of the PSD complex, existing topographic conditions were assessed to modify the architectural project; the aim was to lower the application costs. The architectural plan proposes large volumes of cut and fill; we illustrated a new plan for the development with minor changes of spot elevations. The solutions to grading problems were displayed as several vertical sections.

Understanding Topographic Conditions of the Site to Avoid Cut and Fill

Preparation of a preliminary site plan and related grading plan can determine whether there will be serious imbalance of cut and fill [16]. In site planning and grading plans, cut and fill practices are common; the strategy should be to avoid or minimize cut and fill practices that either carry soil off-site or bring soil onto the site [20]. It is always advantageous to restrict cut and fill to on-site movement (Fig. 4). Grading solutions, such as minimizing the use of retaining walls, and seating walls, balancing cut and fill volumes, re-elevating the building entrances, creating smooth slopes around the structures and maximizing an aesthetic appeal, should be adopted in plans.

Structural and Ecological Engineering Solutions

To mitigate the problems of natural hazards, site engineering solutions and approaches should be proposed, including many alternatives that may be classified as hard structural or alternative ecological engineering approaches [21]. Hard structural methods are solutions that use construction materials such as retaining walls and large rock revetments to prevent properties from natural hazards. These hard engineering structures significantly alter the ecosystems and can impose an adverse effect on natural land. On the other hand, a natural system-oriented site engineering solution may be termed soft engineering [21], since their function is to prevent natural hazards without disrupting environmental habitat. These alternatives may be considered naturally self-sustaining and ecologically relevant. This approach creates both aesthetically and functionally pleasing landscapes that can be self-sustained instead of requiring expensive human preservation efforts [21].

Stormwater Management

It is important to limit the disruption of natural water flows through the development sites. This can be achieved by minimizing stormwater runoff, increasing infiltration and reducing the amount of contaminants available to pollute the water [16, 22]. The lack of stormwater management can lead to erosion, water pollution and sedimentation build

Fig. 5. Surface water should be directed to planted areas and ponds to reduce the risk of flooding. Pictures show the applications in North Carolina State University Main Campus site. A pond, which is located next to dormitories, collects surface water from parking lots.

up in streams. Designs should utilize a site's strengths (i.e. existing topography, drainage patterns) and direct stormwater to planted areas to minimize irrigation requirements. Some of the engineering practices for stormwater management include stabilizing soil during and after construction, utilizing natural means where possible (i.e. straw bail dams, jute netting, hydroseeding), using bioengineering techniques and interweaving woody cuttings that reduce the potential for full-scale washouts more common to rigid constructions (Fig. 5).

Provide Responsible On-Site Water Management

Conventional practice is to carry stormwater off-site in storm sewers. A more sustainable approach is to allow that water to soak into the ground to replenish aquifers and reduce downstream flooding. Carefully planned filtration basins and measures to reduce impermeable surfaces are generally less costly than the conventional practice of constructing storm sewers and building large retention ponds.

Minimize Disruption to Landforms and Drainage Patterns

By minimizing disruption to landforms and drainage patterns, designers can avoid related impacts on vegetation and loss of habitat, both on and off the site. Soil surface disturbance creates an immediate potential for loss of topsoil by wind and water erosion, sediment to be carried away and deposited downstream and long-term effects on the pattern of runoff.

Minimize Paved Area

Major developments and projects include large hard surfaces such as parking lots and sport facilities. Sustainable site design prefers the use of water-permeable or porous paving on these surfaces. By removing the fine elements of concrete and asphalt, water is allowed to percolate into the soil. Designers should place porous paving in locations that will not receive significant amounts of sediment, debris or other material likely to hinder performance. Minimizing road length to a building reduces impervious surfaces, helps preserve open space and reduces resource consumption—all while reducing costs. During the concept plan development, narrow streets and driveways would be preferred; designers should look for ways to reduce parking area requirements.

Consider Sustainable Siting Requirements

Buildings, utilities and stormwater measures have particular siting requirements. For this purpose, designers should position roads, including walkways, pathways and driveways, so as to minimize gradient. This will reduce the velocity of surface runoff. Designers should place landscaped areas in positions that will receive runoff from upstream areas. This will promote infiltration and filtering of surface runoff.

Emerging Issues and Future Directions

Our urban environments experience accelerated rates of erosion risks. The primary goal of landscape designers should be to implement a natural systems engineering approach to protect urban environments. The goals should be to design and implement sustainable site design approaches to stabilize the urban land, to develop principles and alternatives of site design and to suggest a future models of site prevention. This paper proposes that natural disasters might be prevented by sustainable site design approaches; preparedness should start at the site selection phase with proper site analysis.

Landscape design projects integrating sustainable site design approaches have been part of plans that have been strongly orientated towards improving the environment. For sustainability purposes and ecological validity, landscape design cases should engage with the natural environment

and ecological values should be given special emphasis. Designers, therefore, should aim to promote sustainable site design approaches; the principal component of sustainable site design is to harmonize the relationship between humans and buildings, between buildings and the environment, especially natural landforms. For designers, manipulation of the landform, which adds variety to the setting and reduces the sense of visual clutter common to urban centers and complex interchanges, is a very effective tool for modifying landscape elements.

Comprehensive understanding of natural systems coupled with the application of management tools such as environmental evaluation and risk assessment can make a major contribution to a reduction of risks and mitigation of any impacts. In this respect, there is a need to highlight the role that comprehensive environmental management and site planning can play in reducing the risk of disasters, and to mitigate the consequences if they should nevertheless occur—both on human lives and on the broader ecology. Therefore, this paper illustrates how sustainable site design practices in the early stages of site development can be a useful tool for policy makers, planners and designers concerned with the risks of natural hazards.

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