ORMAN MÜHENDİSLİĞİ ALANINDA AKADEMİK ANALİZLER

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İÇİNDEKİLER

ECONOMIC ANALYSIS APPROACHES FOR THE EROSION PREVENTION FUNCTION OF FORESTS

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1. INTRODUCTION

Erosion, the gradual wearing away of the Earth's surface, is a complex and multifaceted process that has significant implications for the environment and human activities. Erosion is a natural process that shapes the Earth's surface. It occurs when rocks and soil are moved from one place to another by natural forces such as wind, water, ice, and gravity. The process begins with weathering, where rocks are broken down into smaller particles. These particles are then transported by agents like rivers, glaciers, or wind, leading to the alteration of landscapes, riverbanks, and coastlines (Görcelioğlu, 1976; Nut et al., 2021; Ozsahin et al., 2018; Webster, 2005).

The consequences of erosion can be severe and far-reaching. Soil erosion leads to the loss of fertile topsoil, reducing agricultural productivity and threatening food security. It can also cause sedimentation in rivers and lakes, affecting water quality and aquatic ecosystems. Coastal erosion threatens infrastructure, property, and even human lives. In mountainous regions, erosion can trigger landslides, posing risks to communities living in these

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areas (Steinhoff-Knopp et al., 2021; Tarigan, 2022; Wilkinson & McElroy, 2007).

Turkey, with its diverse geography and climatic conditions, faces various erosion challenges. Water erosion is prevalent in the Black Sea region, while wind erosion affects the arid areas of Central Anatolia. The country has implemented various erosion control measures, including afforestation and terracing. However, the complex interplay between natural factors and human activities continues to pose challenges in managing erosion effectively.

1.1.Impacts of Erosion

Erosion is a global issue, affecting every continent. In some regions, human activities like deforestation, mining, and unsustainable agricultural practices exacerbate natural erosion processes, leading to environmental degradation (Borrelli et al., 2017; Wilkinson & McElroy, 2007). Climate change, with its altered weather patterns and rising sea levels, is also contributing to increased erosion in many parts of the world (Borrelli et al., 2017; Borrelli et al., 2020; Tarigan, 2022).

In Turkey, annually, 642 million tons of soil are displaced due to water erosion, averaging 8.24 tons per hectare. The severity of water erosion varies across the country, with 60.28% of the land area experiencing very light erosion, 19.13% light, 7.93% moderate, 5.97% severe, and 6.7% very severe (ÇEM, 2023).

In agricultural lands, erosion primarily threatens the fertility of the soil. As the (Borrelli et al., 2017) topsoil is eroded away, the nutrient-rich layer that sustains crops is lost. This can lead to a decrease in crop yields and an increase in the need for artificial fertilizers, which can further degrade the soil (Pimentel & Burgess, 2013). The loss of soil also means that the land's ability to retain water is diminished, leading to increased irrigation needs and potential water scarcity issues (Han et al., 2020; Ramachandra, 2022). The economic implications for farmers and the broader community can be severe, leading to increased costs and potential food security risks (Chalise et al., 2019).

Erosion in forest lands can have a cascading effect on the entire ecosystem. The loss of soil can destabilize trees, leading to a loss of habitat for various species. As the soil is washed away, it can also carry with it seeds and young plants, hindering natural regeneration processes. This can lead to a loss of biodiversity and a weakening of the forest's ability to act as a carbon sink. Furthermore, erosion can alter the natural water flow, leading to changes in the availability of water for both plants and animals within the forest ecosystem (Pimentel & Kounang, 1998; Zuazo & Pleguezuelo, 2009).

Pasture lands, or grazing lands, are also susceptible to the detrimental effects of erosion. Overgrazing and poor land management can lead to the loss of the vegetative cover that protects the soil. Once this protective layer is lost, the soil becomes more susceptible to erosion by wind and water. This can lead to the degradation of the pasture, making it less productive for grazing (Centeri, 2022). In turn, this can affect livestock health and productivity, leading to economic losses for ranchers and potential impacts on meat and dairy supply.

Erosion in agricultural, forest, and pasture lands is a complex issue that requires careful management and sustainable practices. The loss of soil not only affects the productivity of these lands but can have broader environmental impacts, affecting biodiversity, water availability, and climate regulation.

1.2.The Role of Forests in Erosion Prevention

Forests play a crucial role in preventing and mitigating erosion. The root systems of trees and vegetation bind the soil together, reducing its susceptibility to being washed or blown away. Forests also act as natural barriers, slowing down the flow of water and wind, thereby minimizing their erosive power. In addition to protecting the soil, forests contribute to maintaining water quality by filtering and regulating water flow (Galindo et al., 2022; Ramachandra, 2022).

Forests provide not only soil protection but also significant ecosystem services as sources of timber and wildlife habitat. Their role in erosion control is multifaceted and contributes to the overall health and stability of the environment (Grammatikopoulou & Vačkářová, 2021; Jenkins & Schaap, 2018; Xie et al., 2010). Forests act as natural barriers against erosion, with their root systems binding the soil together and preventing it from being washed or blown away. The canopy of the forest also reduces the impact of rain on the soil, lessening the force with which water hits the ground and thereby reducing the potential for soil erosion (Ninan & Inoue, 2013). These natural mechanisms help maintain soil fertility, preserve water quality, and prevent landslides, contributing to the overall ecological balance.

Moreover, forests significantly contribute to the management of water flow, serving as natural reservoirs that absorb and slowly release water.. This function helps in reducing the risk of floods, controlling the flow of rivers, and maintaining the groundwater levels (Kramer et al., 1997; Vardon et al., 2019). By doing so, forests provide a vital service to both the environment and human communities, protecting against natural disasters and ensuring a stable water supply.

1.3.Erosion and Forest Ecosystem Services in Turkey

Forests, as vital components of our ecosystem, generate various positive externalities, while their absence or destruction can create negative externalities. Positive impacts include functions as carbon sinks, conservation of biodiversity, regulation of water flow, and provision of recreational and aesthetic values (Baskent, 2021; Jenkins & Schaap, 2018; Vatandaşlar et al., 2020). Conversely, the negative impacts include deforestation-induced habitat loss, erosion, soil degradation, and increased susceptibility to floods and landslides (Osman, 2013).

Forests, encompassing nearly one-third of the global land area (FAO, 2020), are vital providers of multifaceted ecosystem services that support human well-being and environmental sustainability. These services range from tangible economic benefits, such as timber and non-timber products, to ecological functions like biodiversity conservation, soil protection, and climate regulation (Jenkins & Schaap, 2018; Kornatowska & Sienkiewicz, 2018).

In Turkey, where almost 99.9% of forests are state-owned, the General Directorate of Forestry (GDF) under the Ministry of Agriculture and Forestry plays a pivotal role in forest management. The current regulation on ecosystem-based functional forest management in Turkey categorizes forest functions into three main areas: economic, ecological, and socio-cultural, with ten corresponding sub-functions (Table 1) (OGM, 2014).

One such crucial function is erosion prevention. Erosion prevention function is one of the ecological functions of forests. Five conservation targets are determined under this function. These are:

- Avalanche prevention
- Landslide prevention
- Stone and rock fall prevention
- Soil conservation
- Flood prevention

Table 1. Functions of Forests According to Ecosystem-Based Functional Forest Management Plan in Turkey

Main Function	Sub-Function	Description
Economic Function	Forest Products Production	Production of forest products for economic purposes
Ecological Function	Nature Conservation	Preservation of ecological balance
	Erosion Prevention	Prevention of soil loss through erosion
	Climate Protection	Mitigation of the effects of climate changes
Socio-cultural Function	Community Health	Supporting community health
	Aesthetic Function	Preservation of natural beauties
	Ecotourism and Recreation	Utilization for tourism and relaxation purposes
	National Defense	Protection of national borders and military units of strategic importance
	Scientific Function	Utilization for scientific research and observation
	Hydrological Function	Protection and management of water resources

Forests act as natural barriers, reducing soil erosion by water and wind, stabilizing the soil, and preventing landslides and flooding. The erosion prevention function is not only vital for maintaining soil health and water quality but also has an immeasurable monetary value. The cost of soil erosion in terms of lost agricultural productivity, degraded water quality, and increased vulnerability to climate change can be astronomical, making the erosion prevention function of forests priceless. The multifunctional nature of forests thus calls for an integrated approach that balances the diverse needs of present and future generations, aligning with universal principles for forest protection and management.

1.4. Economic Impacts of Erosion Prevention through Forests

Flood and erosion can be viewed as negative externalities, unwanted side effects that impose costs on society. When forests are removed or degraded, their natural erosion control functions are lost, leading to increased soil erosion and a higher risk of flooding. These negative externalities can have devastating effects on agriculture, infrastructure, and human lives (Öztürk et al., 2010). The costs associated with flood and erosion are not merely environmental; they are also economic (Ninan & Inoue, 2013; Telles et al., 2013). The loss of fertile soil can lead to decreased agricultural productivity, while increased flooding can damage infrastructure and disrupt local populations (Görcelioğlu, 1976; Pimentel & Burgess, 2013; Pimentel & Kounang, 1998).

The financial burden of these consequences often falls on the general public, instead of on those who caused the deforestation. This creates a complex situation where individual or small group decisions, such as deforestation for economic gain, can have far-reaching effects on the broader community (Ninan & Inoue, 2013). These effects include environmental damage like erosion and flooding, which can lead to agricultural loss and infrastructure damage. Unfortunately, the costs of these widespread impacts are not borne by those who make the decisions but are instead shouldered by society as a whole. This leads to a misalignment between personal decisions and their wider impact on society, highlighting disconnect where the immediate benefits to a few can result in long-term costs for many.

As an example, in the province of Artvin, the Murgul Stream Catchment is home to six consecutive run-of-river-type hydroelectric power plants (RoR-HEPP). When viewed on a narrow scale, these plants provide economic benefits to specific individuals or institutions. However, when examined on a broader scale, it becomes evident that these facilities inflict significant harm on the ecosystem. This situation concretely illustrates how individual or small group decisions can create a misalignment with the broader effects on society. The RoR-HEPP in the Murgul Stream Catchment, while providing economic gains, are causing serious problems related to aquatic life, vegetation, habitat fragmentation, and water quality. This creates a misalignment between personal decisions and their wider impact on society, raising significant questions about the sustainable use of natural resources (Özalp et al., 2012; Özalp et al., 2010; Özay et al., 2018).

1.5.Objective of the Study

Environmental problems such as erosion, flood, avalanche, landslide and stone and rock fall are more than mere externalities; they represent real costs that must be considered. A simplistic calculation of loss, focusing only on life and property, would underestimate the true economic damage. Therefore, to gauge the real economic loss accurately, alternative economic valuation methods are explored.

This study aims to examine the economic valuation methods that can be used in the economic analysis of the erosion prevention function of forests. For this purpose, firstly valuation of on-site and off-site damage of soil erosion is discussed. Then, among the methods used to estimate the economic value of non-marketable goods and services, those that can be used to estimate the value of the erosion prevention function are given in detail. The advantages and weaknesses of these methods are also presented. The study also examines alternative valuation methods to provide a more comprehensive understanding of the economic impacts associated with externalities of forests.

2. ECONOMIC VALUATION APPROACHES OF EROSION PREVENTION FUNCTION

Until the 1960s, ecosystem goods and services provided by natural resources have been assumed to be almost unlimited; defined as “common goods” or “free goods”. For this reason, these goods and services have been considered as sufficient for all countries in industrialization and economic growth processes. The view of natural resources as free goods has led to their excessive and unsustainable consumption. By the 1970s, it had become clear that economic growth and development policies that ignored natural resources could not be sustainable in the long term. For this reason, an approach based on human and environmental dimensions has started to be adopted in economic development and the sustainability of ecosystem services has come to the fore (Demirci, 2022; Kaynak, 2009; Karabıçak and Armağan, 2004).

With natural resources being considered as scarce resources, the idea has emerged that these resources should have a price or value in return for the benefit derived from their use by consumers. It is easier to determine the value of goods and services for which there is a direct market because the price is formed in the market transactions, whereas it is difficult to estimate the value of environmental goods and services which are not traded in the markets. Therefore, many approaches and methods have been developed to estimate the economic value of various ecosystem services (Harris and Roach, 2018; Perman et al., 2003).

As being one of these ecosystem services of forest resources, erosion prevention function is crucial both in terms of ecological and economic reasons. However no single method has been established for economic valuation of this function. Instead different approaches such as economic analysis of decline in soil fertility and agricultural productivity, pollution effect of erosion and conservation techniques have been used (Hacisalihoglu et al., 2010; Calatrava-Leyva and Gonzalez-Roa, 2001). For instance, some studies focus on the valuation through physical measurements such as on-site and off-site damage of erosion. These studies examined the effects of erosion and made various estimates of the costs of soil erosion by adopting the approach that the relationship between erosion and production is directly linked to income and costs. The classification is shown in Table 2 (Telles et al., 2013).

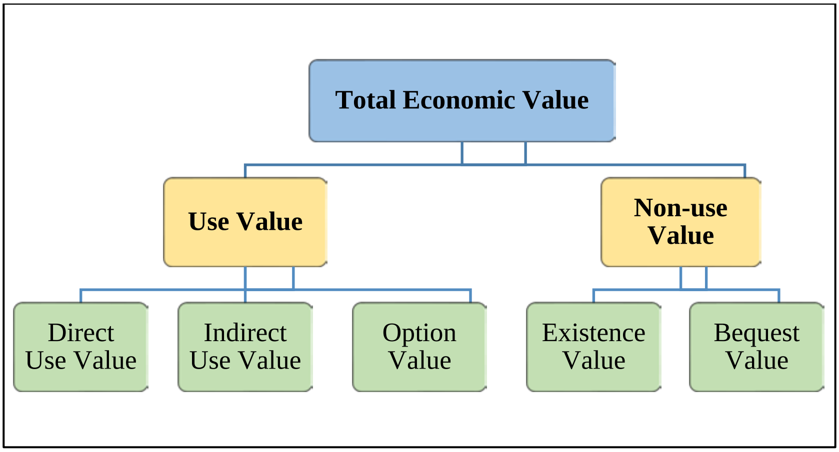
Table 2. Valuation of the on-site and off-site damage of soil erosion

On-site damage	Off-site damage
Nutrient loss	Sedimentation
Lost yield	Flooding
Drop in land values	Water treatment
Biological losses	Electrical power generation
	Repairing public property
	Global warming
	Disasters
	Food price increases

The main challenge with this approach is to accurately calculate the costs caused by erosion. There are economic consequences of both on-site and off-site soil erosion that affect different economic sectors differently. There are three cost types of erosion according to different groups of beneficiaries: private cost to the farmers (such as agricultural yield loss and nutrient erosion), business cost (such as dam sedimentation and water treatment costs) and societal cost (habitat loss and water pollution). Total cost is calculated as the sum of these three costs (Alam, 2018).

On the other hand there are some other studies that directly estimate the value of soil conservation in monetary terms and socioeconomic studies or approaches to erosion or soil conservation. In these studies generally total economic value (TEV) approach is used. TEV has been widely used to quantify all the values of ecosystem goods and services of natural resources that are used by human beings (Adhikari and Nadella, 2011; Merlo and Croitoru, 2005). In general, TEV is divided into two main categories: "use values and non-use values" (Merlo and Croitoru, 2005; Plottu and Plottu, 2007). Use values are benefits derived from the actual use of ecosystem goods and services and are classified as "*direct use value*, *indirect use value and option value*". Non-use values, on the other hand, are benefits that are not linked to the actual use of ecosystem goods and services and consist of existence value and bequest value (Figure 1).

Figure 1. The components of total economic value



When estimating the economic value of any ecosystem service, we first consider whether there is a market for the good or service. If there is a direct market for the ecosystem service, the economic value of that service is estimated using the direct market price or shadow price. There are several difficulties in estimating the value of the erosion prevention function at a direct market price. This is because the erosion prevention function of forest resources is not a function that is directly traded in the market. Only the value estimation with shadow price over the prices of artificial fertilizers to be used to compensate for the nutrient content in the soil can be considered in this context.

On the other hand, for ecosystem services without a direct market, various economic valuation methods are used. Although several methods and approaches are used for valuation of different ecosystem services worldwide, not all methods and approaches are appropriate to estimate the economic value associated with erosion prevention function of forests, due to constraints in data and resource availability. Among these methods, those used to estimate the economic value of erosion prevention are shown in Table 3.

Table 3. Methods used for economic valuation of erosion prevention function

Stated Preference Methods	Contingent Valuation Method
	Choice Modelling
Revealed Preference Methods	Hedonic Pricing Method
	Production Function Method
Cost-Based Methods	Damage Avoided Cost Method
	Replacement Cost Method
	Preventive Expenditure Method
	Opportunity Cost Method

2.1.Stated Preference Methods

Stated preference methods refers to “a group of approaches that estimate the value of ecosystem services” by utilizing comments made by specific respondents regarding their preferences among a range of transportation choices. Usually, the alternatives are the researcher's developed descriptions of transit scenarios or circumstances. Stated preference methods by definition need specially created surveys to collect data (Kroes and Sheldon, 1988). These methods involve the elicitation of responses to predefined alternatives given in the theoretical scenarios in the form of ratings, rankings or choice (Boxall et al., 1996). Most used stated preference methods are contingent valuation method and choice modelling.

2.1.1. Contingent Valuation Method

The contingent valuation method (CVM) is a stated preference method that is based on surveys and is used to elicit people's projected future behavior in hypothetical markets. A hypothetical market where the good or service in issue can be traded is outlined in a contingent value questionnaire. The good itself, the institutional setting in which it would be supplied, and the mode of financing are all defined by this contingent market (OECD, 2018). People's willingness to pay for the benefit in question or their willingness to accept of a potential loss of benefit is assessed by creating a hypothetical market for an environmental good or service (Engo, 2010).

The CVM was first put forth by Ciriacy-Wantrup in 1947. Ciriacy-Wantrup believed that preventing soil erosion produced some "extra market benefits" that were in the nature of public goods. As a result, one method of estimating these benefits could be to ask people if they would be willing to pay for them using a survey method. The first application was undertaken by Davis (1963) valuing the benefits attached to outdoor recreation by estimating the benefits of goose hunting through a survey among the goose-hunters. This approach became popular when the existence and option values were recognized in environmental economics literature, particularly in the 1960s, as significant parts of the total economic values (Venkatachalam, 2004).

Currently, CVM is used to estimate the economic value of all use and non-use value components of different ecosystems. In this context, CVM is frequently utilized in estimating the value of different functions of forests. For instance, the most utilized method worldwide in estimating the value of soil conservation, erosion prevention, air pollution reduction, and water quality improvement and recreation functions of forests is CVM. In this context, CVM has been applied to the economic analysis of off-site effects of soil erosion such as “testing for the existence of a hypothetical bias in CVM surveys using soil conservation as a case study, evaluating the community support for government and personal expenditure on soil conservation and total economic value of the external effects of soil erosion” (Colombo et al., 2003).

2.1.2. Choice Modelling

Choice Modelling (CM) is “a family of survey-based preference modeling techniques that describe goods and services in terms of their attributes and of the levels that these take. Respondents are asked to rank, rate, or select their most favored alternative out of several descriptions of a good or service that are distinguished by their features and levels. People's rankings, ratings, or selections can be used to indirectly determine their willingness to pay by considering price or cost as one of the good's qualities. Similar to contingent valuation, CM can also measure all forms of values including non-use values (Hanley et al., 2001). The CM methodology is based on the ‘characteristic theory of value’ (Lancaster, 1966), which views goods as being a bundle of component attributes and their levels.

In CM surveys, respondents are asked a series of questions called a "choice set" to measure non-market values. Each question asks respondents to choose a preferred option from among several alternatives. One of the selection options is usually presented as a "status quo" or "no action" policy, while other "change" options are developed using variations in the levels possessed by component "characteristics " or "attributes". An attribute usually represents a monetary variable (called a payment vehicle) from which an implicit price can be derived (Choi et al., 2010).

In the early years, this method has been applied to tourism, cultural resources and environmental management in a wide variety of areas including marketing and transport (Choi et al., 2010). Nowadays, hundreds of studies are carried out worldwide every year using choice modeling in a wide variety of fields such as computer science, engineering science, social science, medicine, health science, statistics, business and environmental economics.

CM can also be used to “estimate the economic value of environmental goods, services and benefits”, just like CVM. In this context, there are several studies in which the value of the benefits obtained by preventing soil erosion has been determined using CM. For example; there are studies that determine the value of the benefits generated by erosion control and the value of the function of forests in preventing soil erosion and estimating the indirect use values for soil conservation, erosion prevention and flood protection.

2.2.Revealed Preference Methods

These are indirect techniques of valuation that calculate the economic value of non-market goods by using consumer surplus. In these methods, economic value is determined by taking existing markets for the goods or service as an example of a proxy market (Mundial, 2004). Proxy markets are markets for other goods and services related to environmental benefits. The products or factors of production bought and sold in these proxy markets are often complements to the environmental benefits mentioned. For example, for the economic value of air quality in a residential neighborhood, the housing market is a proxy market because housing is bought and sold in a real market.

The most commonly used revealed preference methods are: “travel cost method, hedonic pricing method, hedonic travel cost method and production function method”. Among these methods, hedonic pricing method and production function method can be used in estimating the economic value of erosion prevention function of forests.

2.2.1. Hedonic Pricing Method

The hedonic pricing method (HPM) is "a model based on the consumer theory of classical economics, which shows that each of the characteristics of heterogeneous goods provides a different level of utility or satisfaction to the consumer". The attributes that make up a product satisfy different needs of consumers and the level of utility or satisfaction of consumers changes after the consumption of each attribute. For this reason, the term "hedonic", which refers to the pleasure, satisfaction or benefit that arises after the consumption of goods and services, gives its name to the method used for this purpose (Çiçek, 2014).

The theoretical work on hedonic prices benefited tremendously from the application of two main techniques. The consumer theory of Lancaster (1966) served as the basis for the first strategy, while Rosen's (1974) model served as the basis for the second. The objective of both methods was to infer attribute pricing by analyzing the correlation between the number of attributes linked with distinct items and their observed prices (Chin & Chau, 2003).

Hedonic pricing method is used to estimate the cost of erosion. It is also used for benefits and costs of soil conservation. In the hedonic pricing method, the economic value of erosion is determined based on changes in the prices of land with different degrees of erosion. However, the applicability of this method is very limited.

2.2.2. Production Function Method

The economic value of ecosystem goods and services that go into making commercially marketed goods is estimated using the production function method. It is employed when an ecosystem's goods or services are combined with other inputs to produce a good that is marketed. The approach tracks how changes in ecosystem services affect the production process.

Changes in production and consumption may be utilized to provide value for the integrity of the basis of natural resources when these other economic activities have a market value. The indirect contribution of environmental services to economic output is reflected in these production impacts. Examples of effects on production include flood damage and water shortages caused by the loss of forest watershed catchment protection; and loss of revenue and employment resulting from the extinction of species (Abila et al., 2005; NRC, 2004).

Environmental problems such as erosion and flooding have a significant impact on the productivity of soil-based products. For this reason, the productivity effect of the erosion and flood prevention function on production through the change in environmental quality can be analyzed and thus the economic value of these functions can be estimated. In other words, using the production function method, we can estimate how qualitative and quantitative changes in environmental inputs change the supply and prices of marketed products, and the economic benefit of protecting ecosystem services can be estimated by their contribution to the market value of products.

2.3.Cost-Based Methods

Cost-based methods “estimate the economic value of ecosystem services based on the cost of avoiding the loss of ecosystem services, the cost of restoring ecosystem services, and the cost of providing substitute services”. These methods do not take into account people's willingness to pay for ecosystem services. Instead, they assume that the costs described above are useful for estimating value. The rationale for this assumption is that "if people are willing to accept a certain cost to avoid the damage caused by the loss of ecosystem services or to regain ecosystem services, then the value of these services is at least as high as the cost that people are willing to accept". These approaches are explained below (Abila et al., 2005; King & Mazzotta, 2000):

2.3.1. Damage Avoided Cost Approach

This approach attempts to estimate ecosystem services' value by taking into account the costs incurred to prevent damage from the loss of ecosystem services. It measures the advantages that an ecosystem provides by using the value of the protected property or the cost of taking preventative measures. Ecosystem benefits are estimated using the damage cost avoided method, which takes into account the cost of actions taken to avoid damages or the value of property protected. For instance, if a wetland prevents flooding on nearby property, the benefits of that protection might be assessed based on the costs incurred by property owners to keep their assets safe from floods or by the losses that would otherwise be incurred. The value of damage resulting from the loss or irreversible degradation of the environment (for instance, the costs of destruction to homes, roads, bridges, and farms caused by flooding) can be used for estimating the value of environmental services in terms of losses avoided and costs saved (Abila et al., 2005; King and Mazzotta, 2000). This approach is mostly used in valuation studies on issues such as flood control, soil fertility, and ensuring the continuity of water quality.

2.3.2. Replacement Cost Approach

The replacement cost approach is a method of accounting that assesses the potential costs of repair or replacement of productive assets that have been lost or degraded as a result of project impacts or poor management in order to estimate the value of environmental benefits. Based on the costs of either replacing ecosystem services or recovering the ecosystem to the extent that it is able to once again provide the service, the approach assesses economic values. The approach estimates the value of an ecosystem or its services by calculating the cost of replacing them. The value of environmental services that can be reproduced by technological or artificial means is expressed by these replacement costs. They stand for the costs that are avoided due to the existence of naturally occurring ecosystems and the services and functions they provide (Abila et al., 2005; King and Mazzotta, 2000; IUCN, 1998).

This approach is often used to calculate the cost of pollution. For instance, it can be used to estimate the cost of pollution of water resources and air pollution, as well as the value of the watershed protection and soil erosion prevention benefits of forests. However, this approach is insufficient to determine the value of unique historical and cultural assets and unique natural areas that are difficult to restore (Dixon & Pagiola, 1998).

2.3.3. Preventive Expenditure Approach

The preventive expenditure approach attempts to estimate the value of environmental services based on the cost necessary to prevent the damage caused by the destruction of environmental services. This approach aims to determine the cost or benefit value of environmental resources by trying to observe how much individuals, communities or society will spend to prevent environmental damage. In doing so, it indirectly calculates the benefits of environmental resources. Therefore, it is also considered as a proxy calculation method for the demand for environmental protection. For example, the cost of building breakwaters or flood barriers in a wetland to reduce coastal erosion and damage to infrastructure can be used as a proxy to estimate the value of woodlands in that area (Abila et al., 2005)

2.3.4. Opportunity Cost Approach

Based on the income lost from the best possible alternative use of the area, the opportunity cost approach estimates the value of an area (IUCN, 1998). Opportunity cost is a measure of the best possible use of a given set of resources assuming they weren't used for the reason for which they are being cost. These costs can be divided into three components. First component is the direct costs. For instance, natural resource extraction needs labor, materials, etc. The external cost is the second component of the opportunity cost. The external costs result from the fact that changes to any one of the components of the natural resources affect the other components as well as the effectiveness of other economic activities. Deforestation, for instance, may cause siltation of rivers and reservoirs as well as soil erosion. Third component arises from intertemporal considerations regarding exploitation of nonrenewable resources will make these resources unavailable in the future (Pearce and Markandya, 1987).

Examples of cases where cost-based methods can be used include (King and Mazzotta, 2000):

- “Valuing water quality improvements by measuring the cost of controlling wastewater discharges
- Valuing erosion protection services of a forest or wetland by measuring the cost of removing eroded sediment from downstream areas
- Valuing wetland water treatment services by measuring the cost of water filtration and chemical treatment
- Valuing fish habitat and nursery services by measuring the cost of fish breeding and stocking programs”.

2.4.Comparison of Economic Valuation Methods

Table 4 summarizes the above-mentioned valuation methods and approaches used for economic valuation of erosion protection function of forests and the advantages and limitations of each methods. Since these methods estimate value from different perspectives and have different advantages and limitations, it is very difficult to say which method gives the most accurate result. Still, it can be stated that it is more practical to apply cost-based methods in estimating the value of the erosion prevention function of forests.

Table 4. Comparison of economic valuation methods

Method	Approach	Advantages of the method	Limitations of the method
Contingent Valuation	Willingness to pay/accept amount of people under the hypothetical markets	Can be used for all use and non-use values estimation.	Based on hypothetical market and scenarios Many sources of bias.
Choice Modelling	Implicit prices derived from people's choose form preferred options	Can be used for all use and non-use values estimation	Based on hypothetical market and scenarios, Many sources of bias
Hedonic Pricing	Difference in property prices that can be attributed to the different degrees of erosion	Based on real data of housing market	Difficult to state the exact effect of the erosion prevention on housing prices
Production Function	Market value as an input in the production process	Include easily available and real market data	Difficult to gauge the impact of changes in ecosystem services on production activities
Damage Avoided Cost	The costs avoided from the loss of ecosystem services because of erosion, flood, etc.	Easier to calculate the costs	Costs associated with damages avoided are assumed to be accurate measures of benefits
Replacement Cost	The costs of replacing ecosystem services	Easier to calculate the costs	Assume that the replacement of the ecosystem service is worth the investment
Preventive Expenditure	The costs of mitigating the effects of the loss of ecosystem services	Easier to calculate the costs	Overestimation potential of prevention costs
Opportunity Cost	The income lost from the best possible alternative use of the area	Easier to calculate the costs	Overestimation/underestimation of the possible alternative usage

3. CONCLUSIONS

Erosion and flooding, as critical environmental challenges, have far-reaching impacts on landscapes and ecosystems. The crucial role of forest resources in mitigating these negative externalities cannot be overstated. Forests play a vital role in stabilizing soils, reducing runoff, and preventing sedimentation, thereby significantly contributing to the reduction of erosion and flood damages. The study explores the various valuation methods and approaches used for economic analysis in estimating the erosion prevention function of forests. While some research focuses on valuation through physical measurements such as on-site and off-site damage of erosion, other studies directly estimate the value of soil conservation in monetary terms, employing socioeconomic studies or approaches like stated preferences, revealed preferences, and cost-based methods.

Estimating the economic value of the erosion prevention function of forests presents many difficulties, although there are various methods that have been utilized for this purpose. Since there is no direct market for these benefits, it is necessary to infer their economic value based on different methods. In addition, there is no standard methodology for determining value in this regard.

There are a limited number of studies conducted in this context both in our country and worldwide. In these studies, different methods are used depending on the condition of the study area. For example, since sedimentation will occur due to erosion in areas with dams, the economic life of the dams is negatively affected and cost estimation can be made based on the economic value of the energy that can be produced in the years of production lost in the dams. In addition, nutrients in the soil are also lost as a result of soil loss due to erosion. In such cases, the value is estimated depending on the cost to be spent for the compensation of nutrient loss.

In the HPM, the economic value of erosion is determined based on changes in the prices of land with different degrees of erosion. However, the applicability of this method is also very limited. In the replacement cost method, the value is estimated based on the costs of yield-enhancing products such as fertilizers required to compensate for the loss of soil nutrients due to erosion. However, since a one-to-one relationship cannot be established between the loss in nutrients and the loss in production, and since erosion adversely affects not only nutrients but also organic substances and the physical structure of the soil, the replacement cost method does not give accurate results.

In the production function method, the loss in the yield of the relevant products is valued depending on the market price of the product. However, this is mostly valid in the case of erosion in agricultural lands and income losses due to yield decline in agricultural products. CVM and choice modeling method are used based on the willingness to pay value. Studies using these methods aim to determine people's willingness to pay for soil conservation programs to prevent erosion.

Although the estimation of the erosion prevention function value does not give complete and accurate monetary results with the aforementioned valuation methods, it is still important in terms of raising awareness about the importance of this function by natural resource managers and both the people living in that region and the general public. At this point, it would be beneficial to encourage and popularize studies on the erosion prevention function of forests by the responsible institutions and organizations for the management of forest resources.

In addition, incorporating the results of economic evaluation studies into forest management plans can help decision makers make the right choices between different options and manage the area more effectively and efficiently. This will contribute to sustainable forest management. There is also a need to develop and test different modeling techniques in sample areas to estimate the costs of erosion. In this way, the most appropriate model that will provide more accurate estimates can be determined.

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LIGHTWEIGHT AND LIFE-GUARD FURNITURE DESIGN AGAINST EARTHQUAKE

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1. INTRODUCTION

The increase in human population over the last century has not been seen in the last 300,000 years. In some areas, this has forced people to live in densely populated cities. Between 33,000 and 150,000 years ago, the human population was estimated to be 10,000-300,000 people (Rogers & Jorde, 1995). The world population is currently around 8 billion, and it is expected to reach 9 billion by 2037 (Mcfarlane, 2023). This is a rapid increase. As the population has grown, so has urbanization. This resulted in the construction of larger and taller structures. As a result, the construction industry grew, and a diverse range of building materials were introduced. The durability of these building materials is still debatable. Because very serious earthquakes have been occurring in the world for billions of years (Kuzmin et

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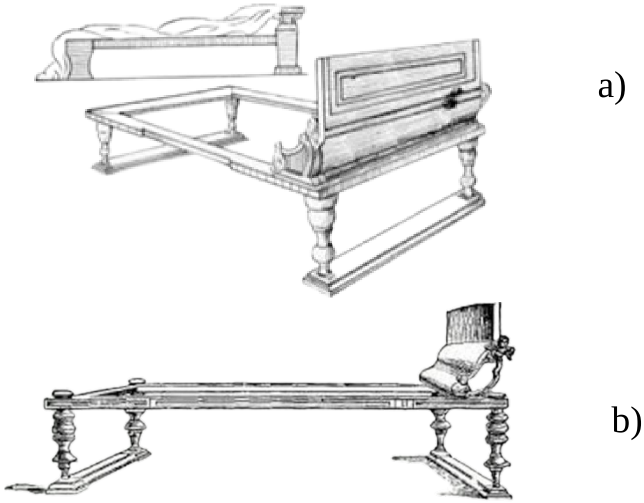
al., 2019; Kwiecień et al., 2022). These earthquakes cause serious damage to settlements. As a result of increasing urbanization in parallel with the increase in human population in the last century, earthquakes have become more destructive. Buildings that are not built resistant to earthquakes cause the death of tens of thousands of people. Since life in crowded cities is very unlikely to return to rural life, it is essential to take precautions, especially against earthquakes, in urban life (Arya, 2018; Mathur & Goel, 2015; Spence & Coburn, 1992).

The most important of these measures is the construction of durable buildings (Housner & Jennings, 1977). The second precaution is to create safe environments against earthquakes. To make our houses more durable to earthquakes, the goods must have certain properties in the environment. One of the most important things in designing earthquake-safe is that the goods must be light. In addition, it is required to have some properties such as not having a sharp edge, not brittle, and not flammable (Czarnecki et al., 2020; Guimarães et al., 2023). There have been many changes in furniture designs throughout history (Figure 1). In these furniture designs, more emphasis is placed on visual beauty and comfort. Earthquake concerns were not included in the furniture design.

Figure 1. Examples of ancient furniture a) Egyptian style (BC: 2700), b) Roman style (BC: 500)



When designing furniture for earthquake-prone areas, it's crucial to ensure that the construction is lightweight (Sakuma, 2023a). Thus, the cabinet made of lightweight material will not cause any harm when it topples over, even if there are people underneath it (Figure 2). By utilizing materials such as wood or Cross Laminated Timber panels, it is possible to create structures that are easier to move and transport in the event of an earthquake (Fellin et al., 2022). Moreover, incorporating solid profiles into furniture production can provide secure areas for individuals in the event of a building collapse. For instance, the innovative Lifeshell concept, constructed entirely from wood, shields people during earthquakes. Similarly, the variable folding earthquake evacuation furniture utilizes folding connecting members and support members to offer a safe space indoors (Fellin et al., 2022). In addition, the incorporation of advanced safety systems into furniture and mobile equipment can significantly improve their ability to protect in the event of an earthquake (Galloppo et al., 2019). When combined with the use of lightweight materials and sturdy profiles in furniture design, these measures go a long way toward creating secure living environments for individuals during seismic activity.

Figure 2. Items falling over during an earthquake

(Vanolaycom, 2020)

Flexible and durable materials are important in furniture design for earthquake safety. These materials help prevent damage to furniture during tremors. Steel and aluminum provide durability, while wood is a flexible material that can minimize damage by deforming during an earthquake (Kumar, 2022). Using shape memory alloys (SMAs) in furniture design can also enhance earthquake resilience. SMAs, such as those used in the innovative superelasticity-assisted slider (SSS) system, can provide effective seismic protection for structures (Narjabadifam et al., 2022). By incorporating these flexible and durable materials into furniture design, the risk of damage during earthquakes can be reduced, ensuring the safety of occupants. Although the measures taken inside the houses after the earthquake were not sufficient, among the measures taken were; fixing furniture, using light materials, making changes in furniture dimensions and placement, wall panels, chandeliers/lamps, paintings and picture frames (Figure 7) has been reported (Ayrilmiş et al., 2015; Güler & Ulay, 2010; Ulay & Güler, 2010).

2. SECURED FURNITURE DESIGNS

Securing furniture to walls or floors is a crucial step to prevent injury during earthquakes. However, there are many other important factors to consider in ensuring furniture safety and functionality. Ergonomic design, for instance, is essential for promoting comfort and avoiding musculoskeletal disorders. Professionally designed furniture should support the body's natural posture and minimize physical strain to create a healthier living or working space. Additionally, choosing sustainable and environmentally friendly materials is crucial for both the safety of the environment and the well-being of individuals using the furniture. Opting for non-toxic materials can significantly reduce harmful chemical exposure and create a healthier indoor environment. Moreover, using sustainable materials supports responsible consumption and production practices, contributing to global efforts towards environmental conservation and reducing carbon footprint (Henifin, 1982; Kalınkara et al., 2017).

Furniture prototyping allows for a comprehensive evaluation process for aesthetics, ergonomics, comfort, structural integrity, and sustainability. At this point, teaching furniture design becomes important. Teaching furniture design goes beyond imparting skills specific to a particular vocation. It serves as a platform for developing essential skills across various design disciplines, promoting sustainable design and social responsibility. The integration of students from different design disciplines presents significant learning opportunities but also poses challenges due to differences in skills, technical knowledge, design methodology, and workshop proficiency. Furniture prototyping is an effective way to overcome these challenges and enhance critical thinking skills, problem-solving ability, and creativity. In conclusion, furniture design education promotes transferable skills while encouraging responsible consumption and production practices and supporting global environmental conservation efforts (Vere, 2011, 2008).

Adjustable furniture modules can adapt to the needs of a space both before and after earthquakes. While it is important to secure furniture to prevent movement during seismic events, the versatility of adjustable furniture modules can also be instrumental in improving safety and functionality. (Galloppo et al., 2019).

During emergencies, the preference for lightweight and portable furniture designs is high due to their ease of evacuation and movement. These designs are crucial for public safety management and the development of effective evacuation strategies (Six, 2023). Unfortunately, current pedestrian movement models cannot account for the impact of emotional differences on movement patterns, which limits the effectiveness of crowd evacuation simulations (Zhang et al., 2023). To address this challenge, a sensor-based pedestrian movement simulation and evacuation method is proposed. This method leverages image sensors to gather data and an emotional perception model to link pedestrians' emotional states with their movement characteristics. Additionally, a lightweight single image super-resolution (SISR) network called TCSR is suggested. TCSR achieves comparable performance to larger convolutional kernels with fewer parameters (Wu et al., 2023). These advancements in lightweight and portable designs significantly enhance the simulation effect of pedestrian movement and increase evacuation efficiency. Consequently, they play a pivotal role in emergency situations.

Furniture manufacturers play a pivotal role in ensuring the safety and resilience of their products, particularly in regions susceptible to seismic activity (Figure 3). Compliance with established safety protocols and the acquisition of certifications attesting to the earthquake-resistant attributes of their designs are imperative in this context. Accredited certifications offer consumers the confidence that the furniture they are acquiring has undergone rigorous testing and validation to withstand seismic forces. This aspect assumes heightened significance as it empowers consumers to make informed choices, opting for furniture options deemed safer in seismic environments.

Figure 3. Earthquake proof table by arthur brutterand ido bruno

(Rose Etherington, 2024)

The adherence to safety standards and the procurement of certifications underscore the manufacturers' dedication to producing furniture of superior quality and reliability capable of enduring seismic events. Such endeavors contribute significantly to enhancing consumer safety and well-being by mitigating risks associated with structural failure during earthquakes.

3. SOME LIGHTWEIGHT FURNITURE DESIGNED FOR EARTHQUAKES

The role of furniture in mitigating injuries during earthquakes can not be overstated. It is essential to prioritize the design of furniture used in communal spaces. Specifically, locations like schools and nurseries demand extra attention in furnishing design. Bookshelves and tables utilized in these areas ought to be lightweight and possess superior mechanical properties to guarantee effortless usage and a secure environment during seismic activity.

A recent study delved into the effects of shaking on human movement and behavior. To conduct this research, the team utilized data from the strong motion recorded during the 1995 Hyogo-ken Nanbu earthquake to develop a human body model. Additionally, they performed a static loading test on a bookshelf to determine its friction coefficients and create a seismic response analysis model for furniture. These models were ultimately integrated into a physical simulator to evaluate the risk of injury to humans in a building. By inputting floor responses calculated by seismic response analysis of an RC super high-rise building into the simulator and applying the head injury criterion, the team was able to assess the extent of potential harm to individuals (Sakuma, 2023b).

A recent study delved into the effects of earthquakes on buildings and the design choices made by architects. The Durrës earthquake that occurred on November 26, 2019, caused significant non-structural damage to buildings of various ages, structural systems, and volumetric shapes. This article aims to explore the various types of damages caused by earthquakes and their underlying causes (Tuxhari et al., 2023).

The study revealed that the damages were linked to the architect's decisions and the corresponding conditions in the technical design codes. Elements such as the building's shape, structural regularity, seismic joints, cantilever volumes, parapets, stairs, doors, and more played a crucial role in the damage caused.

Tuxhari (2023) emphasizes the importance of early collaboration between architects and structural engineers in areas prone to seismic activity. While prioritizing the minimization of damages in the future, construction costs should also be optimal. The functional and aesthetic choices of buildings should not be limited, but instead should aim to create a safer environment for individuals in these spaces during earthquakes. For example, furniture such as bookshelves and tables in these areas should be designed to withstand strong shaking and minimize the risk of injury. By prioritizing the use of such furniture, a safer environment can be created for individuals in these spaces during earthquakes.

In the case of an earthquake, non-structural elements such as furniture, equipment, and mobile systems can either hinder or aid in the safety of vulnerable groups like children, the elderly, and the disabled. A study explored the potential to design smart security systems that can protect lives by renewing and transforming furniture and mobile equipment. In the article, earthquake-resistant projects and products are critically analyzed, life-saving strategies implemented and areas to be developed in the future are determined.The goal is to establish technical performance requirements for new collaborative concepts that can save lives during earthquakes. Study analyzes were conducted by the research team, collecting data from a variety of sources, including patent analysis, interdisciplinary research on health and psycho-physical stress during seismic events, and interviews with people who recently experienced earthquakes in central Italy. The results of this research demonstrate the promising potential for designing furniture and non-structural elements for earthquake safety, and suggest design strategies for developing life-saving systems from a systemic and collaborative perspective (Galloppo et al., 2019).

In regions affected by earthquakes, the process of securing historic structures can be challenging, requiring significant investments and lengthy lead times. An interdisciplinary and systemic approach to designing "anti-seismic" furniture for public spaces like schools and offices in high-risk areas could offer an alternative solution for safeguarding people. This approach would involve creating a network of intelligent and interconnected furniture that could serve as a life-saving passive protection system. The resulting furniture would be a valuable product-service that could aid in locating and rescuing individuals caught under debris, as well as monitoring the building. The "S.A.F.E." industrial research project, which stands for "Sustainable design of anti-seismic furniture as smart life-saving systems during an earthquake," is a part of this larger effort (Pietroni et al., 2021).

4. CONCLUSION

The increase in human population has forced people to live in more crowded cities. This situation also changed the city architecture and caused the use of materials that allow cheaper and faster construction. These materials used in building construction have advantages as well as disadvantages. For example, concrete is cheap and allows rapid building construction. However, since it is a heavy material and loses its hardness over time, it causes buildings to become flimsy.

Large-scale earthquakes have been occurring on Earth for millions of years. These earthquakes have become more destructive with the increase in urbanization. In this context, the construction of earthquake-resistant buildings has gained importance. In addition, furniture used indoors during an earthquake must ensure safety during an earthquake. It should not topple over during an earthquake, or even if it does, it should not harm people. In this case, the furniture used indoors must be earthquake safe. Recently, the number of researches on earthquake-resistant and safe furniture designs has increased considerably.

It is important that earthquake-safe furniture is especially lightweight. In addition to being lightweight, it must also have sufficient physical and mechanical properties to meet the need. Studies on this subject may create difference and awareness in furniture design. This issue needs to be evaluated and developed on an industrial scale rather than being a research topic. In this way, a new furniture design branch can be created and a contribution can be made to ensuring safety during an earthquake.

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