HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES

Ph.D. dissertation

ASSESSING LAND USE/COVER CHANGE AND VISUAL LANDSCAPE QUALITY IN THE LAKESHORE AREA

A CASE STUDY OF LAKE VELENCE, HUNGARY

Cai Xuecheng

Budapest, Hungary

2022

The PhD School

Name: Hungarian University of Agriculture and Life Sciences

Landscape Architecture and Landscape Ecology

Discipline: Agricultural Technology

Head: Dr. László Bozó

University professor, DSc, MHAS

MATE Institute of Horticultural Science

Department of Soil Science and Water Management

Supervisor: Dr. Zsombor Boromisza

Associate professor, PhD

MATE Institute of Landscape Architecture,

Urban Planning and Garden Art

Department of Landscape Protection and Restoration

....

Approval of the School Leader Approval of the Supervisor

Table of contents

Abbreviations

CA-Construction area

CLC-CORINE Land Cover

DE-Duration effect

DVI-Degree of visual impact

GIS - Geographic Information Systems

ha – hectare

km- kilometer

km^2- Square kilometer

LMBA-Landscape metrics-based assessment

LS-Landscape sensitivity

LU/LC- Land use/land cover

LULUC-Land use/land cover change

m – Meters

m^2 - Square Meter

MC-Magnitude of the land cover change

MMU-Minimum Mapping Unit

P-View point

SBE-Scenic Beauty Estimation Method

S-Site

T-Time

USDA- U.S. Department of Agriculture

VD-Vegetation degradation

VIA-Visual impact assessment

VLQ-Visual landscape quality

VPBA-visual perception-based assessment

VRMS -Visual resources management system

1 INTRODUCTION

The main objectives of this dissertation are to study the processes of land use/land cover change in the shore area of Lake Velence, and the visual landscape quality of the lakeshore. Lakeshore development and anthropogenic pressures are the main variables and drivers affecting lakeshore land cover and landscapes, specific impacts and changes will be explored in this thesis through a series of quantitative studies. This thesis will apply multiple methods to assessing land use change and visual quality in the study lakeshore area. The study integrates spatially explicit datasets, as well as other relevant variables in the field of visual landscape quality assessment. The first part of the study would present the current status of and threats to lakeshore land by mapping, analyzing and detect changes in LU/LC over a 30-year period. In the second part, public perceptions and attitudes toward the lakeshore scenes will be investigated, and a mixed methods approach will be used to evaluate the visual impact of construction and lakeshore modifications on the lakeshore landscape.

Importance of this topic

Lakeshore can be one of the most valuable area in terms of the diversity of ecological services it provides habitat for species, recreation, harvestable resources, production and processing of organic matter, dissipation of wave energy, flood control, maintenance of water quality and dispersal corridors for flora and fauna (Strayer & Findlay, 2010). At the same time, it is also the area most exposed to the negative influences of anthropogenic stress (Furgała-Selezniow et al., 2020). The alterations to the lakeshore may result in essential changes to its characteristics (Latinopoulos et al., 2018). Excessive external intervention and human activity not only threaten the natural lake ecosystem, but also affect the natural aesthetic quality of the landscape along the waterfront.

Since the 1960s, the economic transition and policies have contributed to increased development and investment in the lakeshore areas of Hungary. As the tourism industry and economic potential of the lakefront has grown, human activity and speculation in the lakeshore area has also increased. In recent years, intensive development activities and the expanding tourism-oriented land use in the lakeshore areas of Hungary have raised the concerns of the local community and the European Commission. The 10 and 25 km buffer zones of the lake are rich in natural and geological values. ESPON[1] (2021) regional targeted analysis[2] has reported that land use on the lakeshore has changed due to the increasing number of built-up areas and construction sites, which poses significant risks to the ecosystem.

Importance of analyzing land use /land cover change

Land use changes in the lakefront could disrupt the ecological equilibrium state of the lake, particularly between natural habitats and extensive land use. It also has a negative impact on achieving long-term sustainability. In order to reduce the social, natural and economic impacts of land use change on future generations, it is important to understand how land use/cover processes change over time, beyond achieving sustainable management of land resources. In particular, monitoring and measuring LU/LC changes at the local scale are critical.

The analysis of the LULC change can provide a basis for understanding the observed land use change, clarifying trends in change, or guiding decision makers to address these changes and impacts in an effective manner. Describing and explaining the transition from one type of LUCC to another over a given period and within a given spatial entity can help to identify drivers and specific impacts. Both environmental assessments and projections of future land change trends require mapping and quantifying the magnitude and rate of land use and cover conversion from a certain time in the past to the present. Furthermore, in terms of sustainable land and landscape management, understanding the processes and factors influencing LCLU change is of particular relevance.

Importance of assessing the aesthetics of lakefront landscape

Lake shore zone are extremely fragile environments, not only in an ecological sense but in visual absorption (Smardon, 1988). Intensive development activities and external intervention may cause the risk of landscape resources degradation (Cui et al., 2021), and interrupt surrounding visual information and aesthetics (Krause, 2001). Hardened shoreline, embankment construction,

---

[1] European Spatial Planning Observation Network

[2] Targeted Analysis of Lake Balaton-Towards an integrated development, April 2021, conducted within the framework of the ESPON 2020 Cooperation Programme, partly financed by the European Regional Development Fund.

dynamic changes in land use, and other human intervention activities in waterfront areas, may produce effects on the characteristics and visual quality of the lakefront landscapes. The impact of human activities and lakeshore modifications on visual landscape quality and landscape aesthetics can be immediate, abrupt, and continuous. The visual quality of the lakeshore landscapes needs to be assessed through systematic assessment methods, the results of which can also provide guidance and useful Information for future planning initiatives and governance.

1.1 Research questions and objectives

The main objectives of this study are to reveal changes in land use and land cover in the lakeshore area from 1989 to 2019, and explore the possible drivers; to evaluate the aesthetic quality of different types of lakeshore landscapes and different states of the landscape, and to test different visual assessment methods.

The following questions are specifically proposed for study:

1) What is the land use/cover of the shore area of Lake Velence at different time periods （1989，2009，and 2019）? What are the spatial distribution patterns of land use/cover in the lakeshore area?

2) What are the specific changes in land use/cover classes in the shore area between 1989-2009, 2009-2019 and 1989-2019?

3) How does the share and variation of LU/LC types within different zones (0-30m, 30-100m and 100-200m) differ?

4) How has the shoreline and nearshore areas of Lake Velence changed during the last thirty years?

5) Comparing the shore zones of Lake Velence and Lake Balaton, are there any differences or similarities in the characteristics and variation of LU/LC between the two lakeshore areas?

6) Are there any significant correlations between the different land use/cover types in terms of change over a 30-year period?

7) What are the public's preferences for different types of lakeshore landscapes and shore revetments?

8) Are there differences in landscape preferences between the different participant groups (local residents and professionals)?

9) What visual landscape indicators are significantly associated with public preference for lakeshore scenery?

10) To what extent has the visual quality of the lakeshore landscape been affected by construction activities in recent years?

11) How to minimize the impacts of lakeshore development on land use/cover and the visual landscape quality?

Based on the research questions proposed, specific objectives that need to be addressed include:

- Mapping and detecting LU/LC in the shore area of Lake Velence in 1898, 2009 and 2019.
- Measuring the area and proportion of each LU/LC class in the lakeshore area.
- Investigating land use/cover change in the Lakeshore area over three different time intervals (1989-2009,2009-2019,1989-2019).
- Subdividing the 0-200 m lakeshore zone of Lake Velence to investigate specific changes in LU/LC within the different subdivisions (0-30 m, 30-100 m and 100-200 m).
- Comparing the LU/LCC of the two lakeshores (Lake Velence and Lake Balaton) and calculating the rate of area change and annual rate of change for each class of LU/LC from 1989 to 2019.
- Identify similarities or differences in LU/LCC trends between the two lakeshore areas (Lake Velence and Balaton).
- Analysing possible correlations between the LU/LC classes based on land use variation data over the period 1989 to 2019.

- Evaluate public preferences towards the different lakeshore landscapes and shore revetment types.
- Identify the relationships between the landscape preferences and visual landscape indicators.
- Assessing the impact of shore modifications and construction works on the landscape visual quality.
- Identify high probability and high impact visual impact elements of the Velence lakefront that occur during the construction phase.
- Put forward specific mitigation measures for sustainable lakeshore development and planning. Provide adaptive strategies and recommendations for the restoration and protection of lakeshore visual quality.

1.2 Research approaches and materials

In order to achieve the above research objectives. A large number of map datasets were collected for the analysis of land use and land cover change in the study. Landscape photographs were utilized as the base material for preference surveys and visual impact surveys (Appendix 1). In addition, field surveys and field recording materials were also essential. The detailed research materials are as follows:

- **Map datasets: Topographic maps or historical maps** from the 1980s； **Orthophotography and Aerial images** from 2009 and 2019. Collection of mapping resources for research sites over time through websites (e.g., Bing Aerial Maps, Google Earth) and local authorities. **Vector cadastral maps** from Open Street Map and Copernicus land monitoring service.
- **Field work records and on-site photographs.** Visiting study sites to verify areas that are not clear on maps and where land changes are evident. Taking and collecting photographs of hot spots and core areas.
- **Official announcements and documents**. Visit relevant institutions and governmental

website， obtain the information of the regional development situation and development background, especially the content of the tourism planning and the landscape condition changes over the past 30 years.

- **Research articles and regional target analysis reports.** Relevant research literatures and target analysis reports, knowledge of the study sites and previous research findings helped us to identify research questions and hypotheses.

Research approaches:

1) Multi-temporal analysis of land use and cover change

Mapping and analysis of land use/cover at different temporal points（1989, 2009 and 2019）in the study areas. Quantifying the dynamics of land use and cover utilization and changes over time through GIS-based applications

2) Accessing lakeshore landscape preferences and public perception through a photo-based survey

To identify which landscape features and visual factors shape the visual quality of the lakeshore landscape, a preference survey was conducted using 14 different lakeshore scenes.

3) Using a mixed methods approach to evaluate the visual quality of disturbed lakeshore landscapes.

To investigates how the visual landscape of the lakeshore is affected by modifications and constructions using both a landscape metrics based objective assessment and a photo-based perceptual assessment.

4) Statistical analysis methods: In order to test the results of the surveys and research hypotheses, statistical techniques and the following research methods will be used in the thesis：**Descriptive statistical analysis** (a measure of central tendency, a measure of range, variation and standard deviation), **Correlation analysis,** and **paired samples t-test**.

1.3 Structure of the thesis

This dissertation focuses on two main concerns, namely land use/land cover change in lakeshore areas and landscape visual quality. The objectives and procedures of the study were structured around these two themes (Figure 1.1). The thesis consists of the following seven chapters as are described below.

Chapter 1; **General Introduction** that presents a brief overview of the outlines of this research such as research hypotheses, research questions, research objectives, and the proposed approach.

Chapter 2; **Literature review,** containing a review of the scientific literature previously conducted on subjects relevant to this thesis. Specifically, the background to lakeshore development in the study area is presented and the impact of lakeshore development on the lakeshore environment is summarized. The methods used in past studies to analyzing and assessing land use/land cover change and the visual quality of the landscape are summarized. Limitations and gaps in relevant research are also presented

Chapter 3; **Study area description** provides a detailed description of the study area and identified shore zones. The description contents a geographic explanation of the study area, and a brief introduction of the development background of the study areas.

Chapter 4; **Methods and procedures** provides a detailed description of the methods used or developed for the research questions. It includes methods for mapping and analyzing land use/cover change, as well as methods for assessing lakeshore landscape preferences and a multiple assessment method for the visual impact of disturbed lakeshore landscapes.

Chapter 5; **Results and discussions** presents how the land use/land cover of the lakeshore areas has changed over the study time periods. A survey of public perceptions of the lakeshore landscapes and an assessment of the visual quality of disturbed landscapes will also be presented. In this chapter, a detailed and comprehensive discussion of the causes of the land use/cover change will be presented. Finally, the limitations of studies and strengths and weaknesses of applied approaches will also be discussed.

Chapter 6; **Conclusions and Recommendations** illustrates an overall conclusion about the highlights of the research findings, conclude the changes in land use/cover of the lakeshore area over the last 30 years and the impacts of changes on the landscape visual quality. This chapter will also provide recommendations and specific guidelines on the governance and preservation of the lakeshore area based on the findings.

Chapter 7; **New scientific results** will list the main findings and achievements in this thesis. A brief introduction and supporting data will be provided for each research finding. All results and findings have been analyzed and discussed in the above chapters.

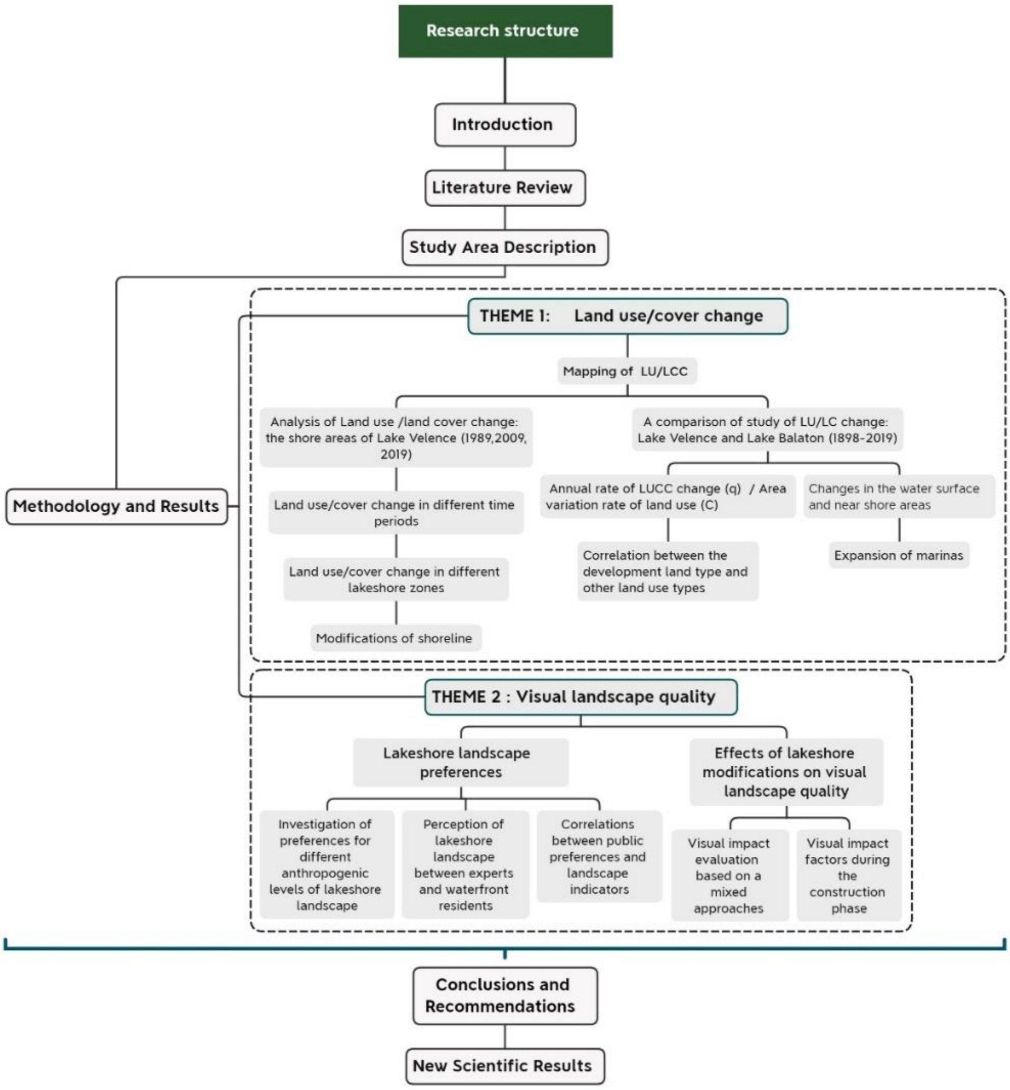


Figure1.1 Research structure flow diagram

2 LITERATURE REVIEW

2.1 Introduction

In this chapter, it is intended to summaries the theoretical and fundamental concepts about the object of study and the conclusions found in previous studies. It begins with the definitions of the terms, such as 'lakeshore' and 'lakeshore development', and outlines the socio-economic-historical background of lakeshore development. The impact of anthropogenic factors such as lakeshore development on the lakeshore environment from past studies will be summarized. After the overview, the causes and consequences of land use/cover will be described and appropriate modelling tools will be summarized. According to previous studies, the common approaches and indicators used for landscape visual quality and waterfront landscapes will be depicted. Lastly, the limitations of past researches will be discussed.

2.2 Shore zone and Lakeshore: Definitions

In broad terms, the **shore zone** is defined as **a specific area or a boundary area close to a watershed**. The shore zone is the area immediately adjacent to the shoreline where there is close and direct interaction between terrestrial and aquatic ecosystems (Strayer & Findlay, 2010; Dąbrowska et al., 2016) Scientists from different disciplinary backgrounds (e.g. geologists and ecologists) have defined shore zones in slightly different ways. The term 'waterfront' is also widely used in many studies to refer to the area where a body of water and land meet (Timur, 2013), for example, shore zone, coastal, riverside, lakefront, creek and streamside can all be collectively referred to as waterfront. The freshwater shore zone or lakeshore zone is considered to be a more specific type of waterfront zoning.

The shore zone as a management and planning concept refers to the shoreline, the nearshore and the area of land adjacent to the shoreline (Mitsova & Esnard, 2012; Pilkey & Young, 2005). The definition and zoning of the lakeshore provides a useful spatial context for land use planning and decision making because of its significantly closer to the water. cording to Jolanta et al.

(2016), the extent of the shore zone has been defined as the area extending from the riparian zone along the entire shoreline to the littoral zone (Figure 2.1).

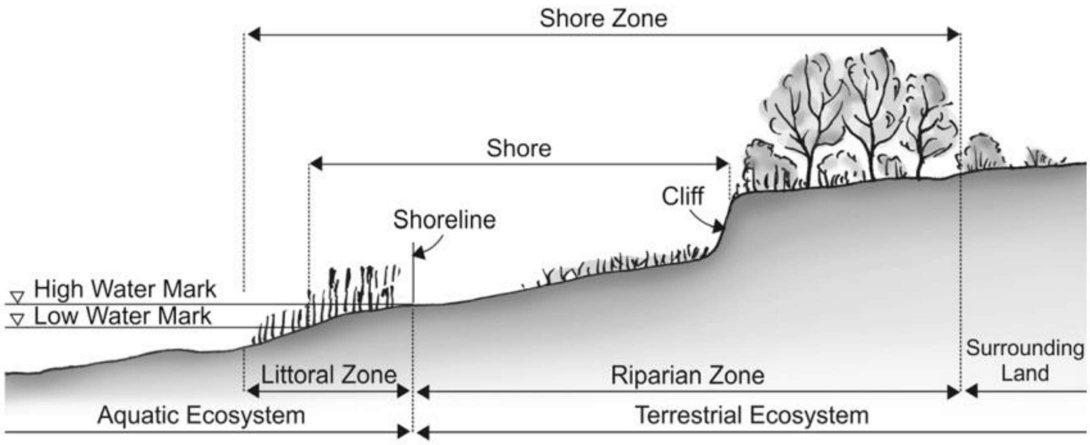


Figure2.1 Definitions of shore zones and boundaries, original from Jolanta et al. (2016)

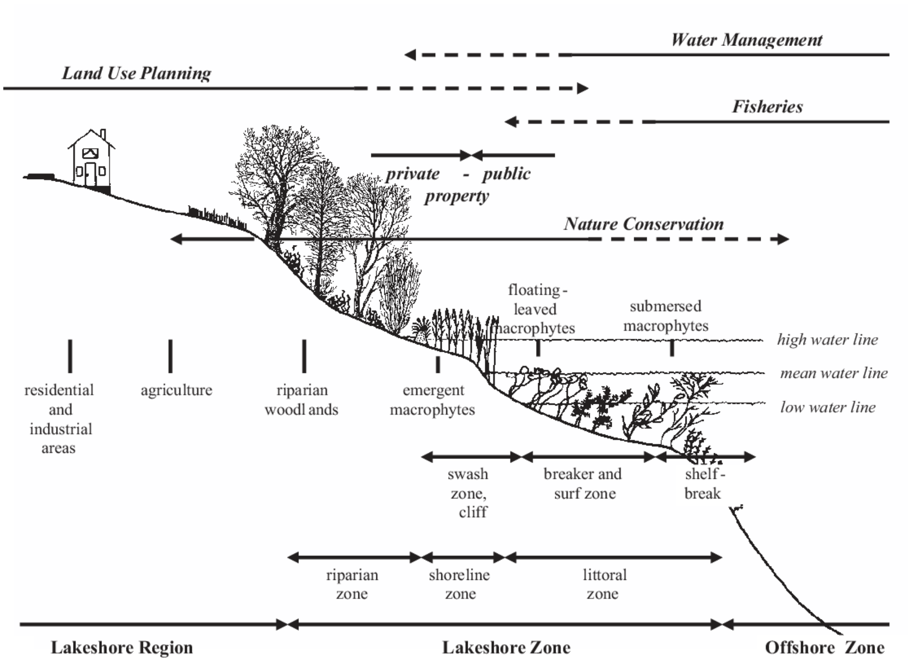


Figure2.2 Classification of the lakeshore zone (Ostendorp et al., 2004)

In addition, a study related to lakeshore hydrology presented a classification of lakeshore areas for planning and water management zoning (Figure 2.2), and give specific operational definitions of **lakeshore zone (including littoral zone, shoreline zone and riparian zones)**. The shoreline represents a thin line that separates water from land (Ostendorp et al., 2004). The definition of the **shoreline** is based on the true water datum (Mitsova & Esnard, 2012), which **generally corresponds to the mean high-water mark** (Robertson et al., 2004; Pilkey & Young, 2005)). The extent of the riparian zone is measured from the natural high-water mark of the lake, or from the outer edge of the wetland vegetation if the lake is surrounded by shrubs and other wetland vegetation (FPC, 1995).

The function of riparian zones in the environment is crucial as they act as buffers, trap pollutants and slow down the erosion of reservoir and waterway embankments (Dąbrowska et al., 2016). But it is essential that they are managed properly. The natural shore zones are the only habitats for many distinctive species of plants and animals, can contain highly diverse biomes as well as hotspots of biogeochemical activity (Strayer & Findlay, 2010).

2.3 Lakeshore development

Water bodies received many modifications and pressures during the 19-20 centuries (Dokulil, 2014; Schmieder, 2004), which are strongly related to the intensive use of shoreland and development activities (Furgała-Selezniow et al., 2020; Remenyik et al., 2013). Waterfront development (lakeshore development, riverside development and coastal development etc.) itself is a complex phenomenon (Ostendorp et al., 2004), which accommodates various policies and social needs. There are always contradictions and debates about planning purposes of waterfront development (Bruttomesso, 2001), and the attention between the environment and economic interest, the needs and tensions between the residents with the government, and the tourists (Papatheochari & Coccossis, 2019). In the 21st century, the waterfront has strengthened the attention to tourism development and turned local needs for recreational waterfront space to the external areas (Cheung & Tang, 2015). With the growth of development activities and tourism in the Great Lakes and coastal areas, their ecological and landscape values are increasingly concerned and discussed (Radomski & Goeman, 2001; Ostendorp et al., 2004; Cooke, G. D. et al., 2005).

Tourism-oriented lakeshore development

Lakes have rich ecological resources and valuable aesthetic values, usually recognized as attractive destinations for tourism, leisure, and recreational activities. The shore zone of the lake is a primarily attractive area for tourists. Some lake regions are popular because there provide opportunities for plentiful recreational activities, such as cycling and angling, etc. The recreational and aesthetic opportunities of the shoreline areas also make them attractive areas for human settlement and tourism development (Trial et al., 2001; Wehrly et al., 2012; Gong et al., 2017), with housing development often concentrated around the lakes (Schnaiberg et al., 2002; Wehrly et al., 2012).

Lake tourism is closely connected to the water-related development concepts, has specific infrastructure requirements (Furgala-Selezniow et al., 2006). “Water-related tourism” is defined as tourism in which the core attraction is water (Hall & Härkönen, 2006). But, water-related tourism is not just about sailing and swimming. It is a combination of land uses and water uses. It also covers recreational activities, resorts, and second home tourism (Papageorgiou, 2016). Water-based tourism often raises debates regarding the environmental impacts and conflicts with other human activities (Furgała-Selezniow et al. 2020). Papageorgiou (2016) stated that the water uses and infrastructure downgraded the visual quality of seascapes and landscapes.

Figure2.3 Tourism development in the lakeshore zone

Note: The picture on the left shows the tourism accommodations developed on the shore zone of siofok, Lake Balaton, source from https://tgyoblog.wordpress.com/tag/furdovaros/. The picture on the right is the recreational areas developed on the eastern shore zone of Lake Velence.

2.3.1 Lakeshore development in Hungary

Lakeshore development may involve diverse combinations of land uses and planning purposes, residential, industrial uses (factories, harbors), commercial services (shopping mall, market), entertainment and recreational (parks, beaches, trails), and tourism-oriented uses (attractions and resorts). The most famous lakes in Hungary are Lake Balaton, Lake Tisza, Lake Velence, Lake Fertő, and Lake Fehér. Of these, Lake Balaton and Lake Velence have become the main recipients of national investments and the most popular destinations for lake tourism. The development of rural tourism in the lakeshore region over the last few decades has extensively stimulated recreational developments and estate investments. In recent years, the Hungarian government have continued to increase their investments and actions in the development of the lakeshore areas. Their main purpose is to promote recreational development potential and increase its tourist attractiveness. The lakeshore development and regeneration projects are mainly reflected in the reconstruction of littoral embankments and pavements, water treatment, and the increase of recreational areas, such as beaches and marinas.

2.3.1.1 Lake Velence

Lake Velence is a popular summer tourism destination for swimming and bathing, and the majority of the tourists prefer a day trip route to visit the lake because of the near distance from Budapest. From the 1930s, Lake Velence has started the development of tourism. The convenience of the newly operated M7 highway and railway connections with the capital and Lake Balaton region boost the day-trip tourism in lake Velence since the 1960s. The lake region attracts a large number of tourists to visit and spend holidays in the summer season. Affluent recreational areas and resorts around the lakeshore, especially the shore zone from Velence bay to Agard. These areas can also be defined as the developed areas of Lake Velence, where the shore zones are the most popular recreation destinations and the most active waterfronts for tourists.

The most serious interventions, that altered the semi natural condition of the shore at Lake Velence, go back the middle of the 19th century: the railway, built on the southern shore divided the lakeshore region (Papp, F., 1995). Since the 1970s, Lake Velence has undergone several major renovation projects (Szilágyi F., Szabó Sz. & Mándoki M., 1989; Gábor, 2016). Bank protection works and recreation development of Lake Velence have been mainly concentrated on the regions of Gárdony, Agárd, and Velence basin. The full length of the shore built with artificial shore-fortifications is approx. 17.7 km, accounting for 63% of the total length of the shoreline (Papp, F., 1995). Large scale bank protection works and lake basin control works carried out first of all in the region of Valence and Agárd, mainly based on placing the rip-rap on the embankment and vertical embankment wall construction. Large-scale sediment removal and lake scaping had fundamentally changed the characteristics and ecological state of lake and shore zone finally resulted in algae blooms, increased surface runoff in the shore zone and a loss of shore habitats (Pomucz & Csete, 2015). In the last 10 years, due to the planning contents, intensified recreational developments, and initial restoration project (Figure 2.4) formulated by the local authorities, the Lake Velence surrounding areas changing is remarkably (Boromisza et al., 2014).

Figure2.4 A complex renovation project in the shore area of Lake Velence

2.3.1.2 Lake Balaton

Lake is the core of a distinction' attractiveness at lake Balaton, Hungary (Hall & Härkönen, 2006). Tourism development in the region of Lake Balaton had already started in the 1840s. After the 1920s, Lake Balaton as a vacation destination increased its regional attention, which result in the speedy development of accommodations and entertainment facilities (Pálfi et al., 2015; Remenyik & Csilla, 2018; Bernát et al., 2020). In the 1930s, as the new mode of transport of railways was introduced and connected to the capital, it efficiently reduces the traveling time and distance between other cities and the lakefront destinations, which boost the visitor numbers and the development of tourism accommodations. Driven by economic reform and new policies launched in the 1960s, contributed to the growth of development and renovation projects in the lake region of Balaton. Nearly 60% of all the current private accommodations were built in the

1970s which has brought a negative change in the balance of natural and man-made environmental elements (Puczkó & Rátz, 2000). After 1990, there was a reduction in the number of visitors to Lake Balaton, combined with a reduction in agriculture, fertilisation and grazing of livestock. This has had a positive impact and improvement on the ecological status and water quality of Lake Balaton (Marton & Jónás-Berki, 2013).

Although the tourist number and guest nights of commercial accommodation are significantly declined at Lake Balaton from 2000 to 2015 (Remenyik & Csilla, 2018), Lake tourism and rural tourism still have great potential at lake Balaton due to the market development (Wettstein, 2013; Lőrincz et al., 2021). The fastest growing and popular branches of tourism in Lake Balaton are angling and yachting tourism. the number of yacht places increased to 12,000 by the construction between 2002 and 2012 (Buday-Sántha, 2007; Wettstein, 2013). Recent years, the authorities continue to invest in recreational development on the lakeshore (Figure 2.5) and the market potential of the Balaton lakeshore has attracted many foreign investment companies to undertake luxury condominium developments on the lakeshore (Figure 2.5).

Figure 2.5 Recreational development and resort development at Lake Balaton

Source: https://magyarepitok.hu/， March 11,2021. （a） shows a new bicycle path is being built at the southwest corner of Lake Balaton (about 10 kilometers of bicycle paths connecting Balatonberény with Vörs); (b) presents a new apartment resort development project in Balaton boglár started in March ,2020

2.3.2 Issues and benefits

Issues arising from lakeshore developments and modifications

Improper development can result in increased tensions on the lakeshore areas, and changed the physical feature, economic, and socio-cultural characteristics of the destination (Puczkó & Rátz, 2000). The negative impacts of tourism development can progressively damage the environmental resources it depends on (Dokulil, 2014). The growth of visitors and development of constructions in the lakefront zone will result in ecological unbalance in the Lake and an increasing number of complaints about lakeside congestion (Smith & Puczko, 2008). The expansion of second homes and tourism accommodations on the lakeshore threatens the water quality and lake ecosystems (Hiltunen, 2007; Rovira Soto & Anton Clavé, 2017), interrupted high aesthetic waterfront scenarios (Krause, 2001), and often causes irreversible changes in natural landscapes and heritage sites.

Extensive shore use includes constructions for settlements, traffic, industry and recreational facilities with a high percentage of soil sealing. This does not only result in complete substitution of the bioeconomic, but also affects the connectivity between littoral and terrestrial habitats. (Limnologica (2004). Recreation and tourism have impacts on the waterfront areas through a large number of facilities and tourists, resulting in habitat degradation, trampling, littering, and wildlife disturbance (Schnaiberg et al., 2002; Papageorgiou, 2016). Moreover, the tourism development in the lake region directly affects horticulture and declined agricultural land use and arable land use because farmers adapt to the needs of tourism by engaging in varying high-value tourism products (Liu et al., 2008).

Modifications of shorelines and littoral zone organize an increasing threat to the ecological condition and naturalness loss of lakefront (Carpenter et al., 2007). The changes in the vegetation cover, natural state, habitat quality, and the richness of species are negatively related to the developing activities in and around the lakeshore areas (Hall & Härkönen, 2006). The disturbance caused by tourism development affects not only water but also shorelines and catchments (Dokulil, 2014; Hatvani et al., 2020). Shoreline armoring could destroy shoreline plants that provide food for fishes (Radomski & Goeman, 2001), reduced habitat heterogeneity (Trial et al., 2001), and also reduced wetland areas that serve as hydrological buffer zones against flood events (Limnologica (2004).

The benefits of waterfront development in terms of socio-economic aspects

According to Doucet (2011), the most noticeable benefits of waterfront development are providing opportunities for new land uses and activities and the improvement of transport and social service. Tourism development and waterfront regeneration as an effective tool are beneficial for the local economic growth and increase the amenity for the neighborhood communities (Puczkó & Rátz, 2000). Tourism development generates economically beneficial impacts and mostly positive influence relevant social part in the lakefronts (Pomucz & Csete, 2015). Economic benefits are considered by residents to be the most significant positive impact of tourism (Rátz, 2002).Waterfront development as creation environments or new innovative uses area could stimulate the establishment of creative industries and social services, which can produce potential positive economic, social, and cultural additional effects for the broad local communities (Kostopoulou, 2013). Doucet and Van (2011) argued that the large lakeshore regeneration projects have bought quality of life improvements for the neighboring residents. The lakeshore developments have positive effect on the housing market and house price of the surrounding neighborhood (Oliva, 2006). Property-led development (like accommodations, hotels, tourism attractions, towels, shopping centers) in lakefront areas directly leads to the increased values of the resident's properties (Doucet et al., 2011; Remenyik & Csilla, 2018). In addition, Hall (2006) has concluded that the most noticeable benefits of tourism-oriented lakefront development are:

1) providing opportunities for new uses and recreational activities;

2) provide job and study opportunities

3) the improvement of transport and social services

4) new amenities

2.4 Land use/ land cover change

The terms land use and land cover are not synonymous and the distinction is noted in the literature so that they can be used correctly in the study of land use and land cover change (Arsanjani, 2013). ***land cover*** defines the physical or biological cover of the terrestrial surface, such as types of surface vegetation, water, soil, and other human-made structures, whereas ***land use*** is refers to the human purposes and human activities associated with that cover, such as farms, pastures, recreational or settlements (W. B. Meyer & II, 1994). Land use and cover change over time as both the natural and built environment are affected by pressures associated with the development process (Koomen & Stillwell, 2007). Land use relates to land cover in various ways and affects it with various implications (Briassoulis, 2020). Changes in land use may lead to changes in land cover, but the land cover may also change even if land use remains constant (W. B. Meyer & II, 1994; Bicudo da Silva et al., 2020; Tadese et al., 2020).

The reason for emphasizing the link between land use and land cover change is that the environmental impacts of land use change are, to a large extent, mediated by land cover change. Land use and land cover change represents a qualitative change in the area of a particular type of land use/land cover (Valbuena et al., 2008; Batar et al., 2017). As such, their analysis requires an examination of the links between land use and land cover change at different levels of spatial and temporal detail. Detailed descriptions of the spatial and temporal dimensions are essential to the analysis of both types of change (Briassoulis, 2020). A multi-temporal analysis of LCLU change is needed to help understand the processes and patterns over a given historical period (Mendoza et al., 2011).

2.4.1 Causes and consequences of land use/land cover change

Land use/cover changes are increasingly recognized as the result of the interaction of agents and forces. Land use/cover change is increasingly seen as a result of the interaction of agents and forces (Bakker & van Doorn, 2009). It is a complex process that results from the interaction between multiple drivers and factors at different spatial and temporal scales (Valbuena et al., 2008). With regard to the drivers/causes of land use/vegetation change, they can generally be classified into two main categories: socio-economic drivers and biophysical drivers (Briassoulis, 2020). Socio-economic drivers include social and economic variables, land policies and development plans, strategies, political factors, local culture, population dynamics, etc. Biophysical drivers encompass the characteristics and processes of the natural and geographical environment. All these drivers can influence human activities and have interactions with each other.

Industrial activity and development have contributed to the concentration of population in urban areas. This is referred to as urbanization. Studies have shown that human activities and development actions are also growing in natural mountainous areas (Bicudo da Silva et al., 2020), river basins(X. Chen et al., 2010; Tadese et al., 2020), and lake areas (Gong et al., 2017). Among these are changes in natural areas and multiple pressures from land change that directly threaten natural environment.

Land use/cover change can cause serious environmental issues, such as loss of biodiversity, threats to habitats quality (He et al., 2017), climate changes at local and regional scales, altered local hydrological characteristics (Deng et al., 2015), and increase the pollution ratio of the territory. Furthermore, land-use change can lead to severe land degradation and desertification processes, it has a significant impact on the condition of natural ecosystems and the supply of ecosystem services (Hourdequin & Havlick, 2016).

2.4.2 Modeling and analysis of land use/ land cover change

In the literature on land use/land cover change modeling, models can be classified and evaluated according to the following criteria (Briassoulis, 2020): purpose (description, interpretation, prediction, impact assessment); set (spatial, land use, temporal); dynamics; underlying theory; model specification; data used (spatially explicit & non-spatially explicit). The main categories of models can be broadly classified as follows.

- statistical and dynamic models
- spatial interaction models
- optimization models

- integrated models
- equation based models, spatial land-use allocation model

Land cover change is a consequence of complex processes that require delayed reflection in spatial and temporal analysis (Verburg and Veldkamp 2001). Spatio-temporal data models allow us to quickly generate land cover statistics for any given time step (Katalin 2013). Monitoring of land cover conversion can be carried out by simply comparing successive land cover maps. However, detecting subtle changes within land cover categories requires a specific representation of continuous changes in land cover and land properties in space and in time. The analysis of multi-year time series of land attributes, their fine-scale spatial patterns, and their spatial evolution has provided broader insight into land cover change (Eric 2003).

The development of geographic information systems (GIS) over the last 20 years has opened up new possibilities of managing and manipulating spatial data sets. Almost all parameters used in land use/land cover change models have a spatial dimension and much of the data can be efficiently organized using GIS (Agarwal, 2002; Bicudo da Silva et al., 2020; Deng et al., 2015). Geospatial modeling can produce accurate results to help planners and policymakers achieve better landscape governance and sustainable land management (Arsanjani, 2013).

2.5 Visual landscape quality

From the latter half of the 20th century, the dominant view of landscape studies saw landscape aesthetics as a separate field of study, a socio-cultural value separate from other considerations (Jorgensen, 2011). Visual environmental as an important resource has attracted the attention of environmental and agricultural departments, while the systemic visual landscape quality assessment was developed and progressed (Daniel, 2001; Krause, 2001). Landscape aesthetics is commonly investigated for many years (Aoki, 1999; Aoki Y., 2013). In the 1970s, the U.S. Department of Agriculture (USDA) has developed the Scenic Beauty Estimation Method (SBE)，which provides quantitative measures of aesthetic preferences for assessing the scenic beauty of forest landscapes and forestry planning (Daniel & Boster, 1976). The SBE model established a systemic rating scale for landscape aesthetic values for measuring the perceived scenic beauty of the landscapes and based on perceptual judgments (observers' ratings) about landscape photographs. Bishop and Hull (1991) have described the necessity of visual resources management system (VRMS). The VRMS could effectively assess and predict the visual quality, and facilitate land use management and planning practice. But, the landscape aesthetics is not valued or acknowledged as having importance for public, and hardly ever considered in the process of landscape planning, due to being seen as subjective (Ewald, 2001).

It is clear that the visual landscape quality is one of the essential components of landscape study and plays a critical role in environmental management and planning policies (Krause, 2001; Keleş et al., 2018; Spielhofer et al., 2021). The visual landscape quality assessment has been used in a wide range of landscapes (forests, mountain landscapes, waterfronts, scenic spots, rural landscapes, coastal zone, heritage sites). The main applications of visual quality are providing a basis for landscape management strategies (Bishop & Bruce Hull, 1991), landscape enhancement (Ewald, 2001; Spielhofer et al., 2021), and development plan politics. Assessment is not a tool designed to resist changes that may influence the landscape. Rather it is an aide to decision-making, it is a tool to help understand how the progress of landscape and the resulting potential risks (Krause, 2001; Carys Swanwick et al., 2002).

Visual impact assessment

Since the 60s, landscape visual quality assessment(VQA) and visual impact assessment (VIA) have become a vital research composition component in the field of landscape architecture and environmental science (Palmer, 1983a; Wu et al., 2006). Visual impact relates to the changes in the views of the landscape and the effects of those changes on visual amenity and visual receptors. Visual impact assessment (VIA) predicts and assesses the intensity of potential aesthetic or visual impacts of developed projects or proposed development activities in a particular area (Canter, 1996). This is accomplished by evaluating how the views and visual zone may be affected by changes in the visual content or changes in features because of the introduction of new elements and loss of the existing elements in the landscape (Institute & I.E.M.A, 2013). Common visual elements , such as color (Qi et al., 2013), texture (Ulrich, 1977), volume uncoordinated, and occlusion of the visual zones might cause significant visual impacts in the landscapes. VIA has been widely used in studies of the visual impact of large sized objects in the landscape, such as; wind farms, power stations, and hydropower plants, etc. (Spielhofer et al., 2021; Wróżyński et al., 2016). It is also often used in site selection of new architecture or farm buildings in rural areas (Hernández et al., 2004a), to estimate the scenic beauty (Frank et al., 2013; Schmid, 2001), to evaluate the visual impact of the highway construction (Jiang et al., 2015) and exposed pit mines (Misthos et al., 2020). In recent years, a number of researchers have focused on the visual impact of tall buildings on the lake landscapes and have argued that specific mid-range views can be effective in limiting the visual impact of tall buildings (Lin et al., 2018). Some studies evaluated the aesthetic value of waterfront landscapes with varied embankment types from the perspective of landscape preference (Hu et al., 2019).

2.5.1 Approaches for assessing visual landscape quality

Generally, there are two approaches commonly used to assess the visual quality of the landscape. Both approaches are generally recognized that landscape quality is a matter of the interaction between the physical landscape feature and the visual perception process, but different in the conception of the importance of the landscape and the receptor (Daniel, 2001).

- **The expert assessment method** emphasizes the characteristics and changes of the landscape, like the landscape attributes, landform, and land-use patterns.
- **The perception-based assessment** focus on the receptor's perceptual experiences and reactions, with subjective cognitive attributes.

In recent years, several studies have also been defined the perception approach as the subjective approach and the expert approach or metrics-based approach as the objective approach (de la Fuente de Val et al., 2006a; Frank et al., 2013). The perception-based assessment method is used widely in landscape preferences and scenic beauty estimation (Li et al., 2021), and dominated the field of landscape aesthetic assessment research. While the expert assessment is mainly applied in environmental management practice.

Early landscape assessment was mainly based on expert evaluations, predictive programs, and the landscape perception of the public (Canter, 1996; Palmer, 1983a). Over the past two decades, some studies discussed the availability and strength of these two approaches. Daniel (2001) stated that compared to the expert approach, the perception-based approach has a higher level of reliability. Surveys of residents and other sensitive receptors involved in a project can be applied to determine social attitudes, values, and perceptions regarding how the landscape reconstruction is conducted (Dokulil, 2014; Purcell et al., 2002). However, studies have shown that differences in participants' gender, occupation, and living environment may influence judgments about the landscape aesthetics. Considering the limitations and shortages of objective approaches (perceptual judgment) in environmental management, some scholars believe the objective method required necessary simplification and improve the applicability in planning progress. Frank (2013) expressed that the landscape metrics-based assessment is an effective method for environmental impact assessment and landscape aesthetic assessment, and can provide the informative context of the survey sites and a reference to evaluate the physical landscape conditions, land-use change, and landscape characteristic. Spatial landscape metrics-based assessment has played an important role in landscape aesthetic assessment (Wu et al., 2006; Brabyn & Mark, 2011; Jiang et al., 2015). Landscape spatial indicators offer the advantage of usability, which may have a positive impact on landscape preference studies where evaluation results can be obtained more easily and quickly by referring to landscape metrics (de la Fuente de Val, Atauri and de Lucio, 2006; Dupont et al., 2017). Fuente (2006) has explored the relationships between landscape visual quality and landscape structural properties and revealed that there are positive correlations between the landscape structure indices and the scenic beauty in mountain landscapes. Bamberger (2012) argued that there is rarely a single assessment method that can fully capture all the complexity of a project functioning in a physical space.

2.5.2 Indicators for assessing visual landscape quality

Risen social concerns for the degradation of the landscape quality and landscape characters have generated the importance of the visual aesthetic quality as an essential aspect of the landscape planning practices and management (de la Fuente de Val et al., 2006). Bishop and Hulse (1994) proposed that the predictable visual impact model required reliably predicted variables (landscape features) and responses (visual quality). Tveit (2006) believes that it is necessary to characterize the visual landscape as an object to interpret and analyze the effects of the landscape changes, but the scarcity of operational landscape indicators of visual quality is one of the main challenges.

Landscape classification plays an important role in landscape assessment (Carys Swanwick et al., 2002), the landscape types identified by classification could thus be used as the basis of a landscape evaluation (Blankson & Green, 1991; Bishop & Hulse, 1994). It has continued to develop over the last decades as an important approach for making judgments, and provides objective appraisal criteria based on the physical features of the landscape (Alexander, 1974). Visual landscape character recognizes the fundamental visual information by the landscaping and the perception processes (Tveit et al., 2006). Most visual evaluation metrics are related to the physical characteristics and state of the landscape (Palmer, 1983).

The basic elements of the landscape's physical characteristics are the form of the territory and the naturalness, pattern, and human artifact (Palmer, 1983). The physical characters of landscape (landform, land use patterns, landscape features) represent key criteria of the visual landscape quality in the past decades (Hahn et al., 2018). The aesthetic value of a landscape increases with the complexity of the topography forms (Ramos & Pastor, 2012). The landscape visual quality and landscape preference has strong interaction with the spatial pattern indexes (Jiang et al., 2015) Landscape heterogeneity and heterogeneity might be important factors that affect the visual aesthetic quality (de la Fuente de et al., 2006), the landscape heterogeneity positively corrected with the landscape preference and the recreational value (Hahn et al., 2018).

Some studies have discussed the important role of naturalness and vegetation in the landscape preferences (Frank et al., 2013), as well as the wildness (Arriaza et al., 2004) or type of vegetation (Wang et al., 2016), and identified the increase of vegetation coverage (tree cover density) has positive effects the preferences in barren areas (Jiang et al., 2015). Wang (2016) concluded that the landscape types significantly influence the judgment consensus of public receptors, the consensus increased with a well-maintained landscape or a large vegetation coverage landscape. Tveit (2006) reviewed the literature about the visual quality assessment and identified the nine concepts for assessing visual character and visual quality: stewardship, coherence, disturbance, historicity, visual scale, imageability, complexity, naturalness, and ephemera. As the development activities and interference increase, the factor of stimuli (Dupont et al., 2017) has also become a common indicator in visual quality assessment surveys.

Reviewed the literature and studies on the visual landscape quality and scenic beauty, the visual quality of the landscape is usually correlated to or affected by the following five main attributes: physical landscape attributes, biotic characteristics, visual perceptual elements, visibility, and visual impact factors. Moreover, each distribution has different indicators and parameters (Table 2.1).

Table 2.1 Visual landscape components and indicators used in previous literatures and references

Attributes and components	Indicators	References
Physical landscape characteristics	land use patterns (forests, recreational land, urban, farm)	Palmer,1983; Gabrielson and
	landform /types of topography (mountains, flat land, hills, composite forms)	Palmer, 1983; Wang,2016
	landscape pattern	Gonzalo 2006
	complexity	Tveit,2006; Gonzalo 2006
	heterogeneity and homogeneity	Thomas Hahn 2018
	coherence/ unity	Gonzalo 2006; Couturier,
Biotic characteristics	wildness /naturalness	Couturier, 1996; Arreaza, 2004, Frank 2013
	type of vegetation (grass, shrubs, trees)	Wang,2016; Arriaza 2004
	percentage of vegetation cover	Wang,2016; Arriaza 2004
	landscape diversity	Frank,2013
Visibility and Viewsheds	depth of visual basins/range of visible relief	Palmer,1983; Bishop 2003;
	visual range (open, close, semi open)	Wang,2016
Perception and visual component	visual diversity and visual richness	Tveit,2006
	color diversity	Gonzalo, 2006
	color contrast	Arriaza 2004; Dupont et al., 2017
	ground surface texture	Ulrich, 1977
Visual impact elements	maintenance, stewardship	Tveit,2006; Wang, 2016
	disturbance	Tveit,2006
	human activities	Ramos and Pastor, 2012
	stimuli	Dupont et al., 2017

Specific indicators in the study of waterfront landscapes

Distinguished from other types of landscapes, waterfront landscape (lakefront, riverside, coastal zone) has its unique landscape features and visual characters according to the integration of the water element and the aquatic plants. Therefore, the waterfront landscape is selected as a separate research object to review its visual landscape characters.

Studies have discussed the relationship between the water level and the aesthetic level of the landscape (Sargentis et al., 2005), the water-related characteristics (watercolor, visual water quality, and water clarity) with the landscape preference (Schirpke et al., 2021). Sargentis (2005) stated that the lake scenery is significantly more valuable when the water level is higher when compared to the lower water lever lake landscape. Schirpke (2021) indicated the high presence of algae and low land cover is the primary negative impact factor for the aesthetic value of the lake landscape, but the participants have a clear preference for blue and clear water.

Yazici (2018) evaluates the potential differences of visual landscape quality of wetland landscapes by the items of water property size, plant existence, topographic diversity, neighbors' views, natural elements, cultural existence. Wang (2016) Concluded that three main predictors are water, flowers, and trees, which could enhance both the aesthetic preference and restorative potential in urban waterfront parks (Wang et al., 2016). In waterfront landscapes, people have the consensus that riparian plants can be visually pleasing elements (Ramos & Pastor, 2012; Yazici, 2018), are essential in the landscapes. Receptors preferred a balanced stream landscape between wilderness and human control, upland trees cover, and well maintained in the riparian zone, which could potentially enhance the attractiveness of urban stream landscapes (Hu et al., 2019).

Although the studies on the aesthetic values of waterfront landscapes are rare, the related outcomes (Table 2.2) show that except for the above general visual landscape characters, the waterfront landscape required other specific visual evaluation indicators and attention on the water elements and shores.

Table 2.2 Visual indicators and elements used in particular in waterfront landscape studies

	Indicators	References
Exceptional criteria for waterfront landscapes	presence of water	Ramos and Pastor, 2012
	percentage of water surface /presence of water	Wang,2016; Arriaza 2004
	shape of shore line	Wang,2016
	water color and clarity	Schirpke, 2021
	water movement and water amount	Arriaza,2004
	lake shape	Schirpke, 2021

2.5.3 Tools and techniques used for assessing visual quality

Earlier, visual quality assessment was mainly based on photo surveys. Researchers used a set of landscape photos to show participants or conduct field interviews with the community to obtain the evaluation results. Landscape image does not only comprise its spatial and structural parts but also the formal visual and cultural aesthetic expression of the landscape (Krause, 2001). Approaches that utilize photography and internet surveys to evaluate how the visual quality of landscapes and preference are viewed in some of the national parks from a public perspective has been applied (Sevenant & Antrop, 2009; Ziółek et al., 2004). Primary assessment of landscape preferences is generally taken on the basis of photos of the selected viewpoints (Wu et al., 2006). In some cases, different types of landscape photos will be collected for evaluation, like artificial structures, agricultural landscapes, and wild landscapes (Wu et al., 2006). Those photos should be collected at the same location, unified perspective, same season (Institute & I.E.M.A, 2013). Afterward, based on the survey of observers' preferences to evaluate and rank the visual quality and landscape aesthetic value (Arriaza et al., 2004). Studies aiming to assess landscape preferences through statistically methods are widely used in urban parks (Maikov, 2013) urban stream (Hu et al., 2019) and varying rural landscapes (Sevenant & Antrop, 2009). Those studies proved; the preference results can be presented more accurately through statistical analysis.

Later on, except photographs, satellite images, and land use maps were also applied to evaluate the landscape aesthetics (Frank et al., 2013). Recently, Dupont (2017) applied saliency maps and photographic landscape simulations to verify and assess the visual quality of constructions in the landscape. A saliency map is an efficient tool for preliminary decisive and design tool, especially in assessing the interference of size and color of new elements.

While, due to the application of geographic information systems (GIS) and remote technology in the 1990s, the potential of scientific quantitative visual analysis research by using GIS and three-dimensional landscape simulation (3D model) was gradually reflected (Bishop, 2003). 3D visualization models are often used to predict site selections by simulation (Hernández et al., 2004b; Wróżyński et al., 2016). Bishop and Hulse (1994) concluded that the GIS-based approach as an available and cost-effective method could replace the expert and public assessment to provide the prior visual quality assessment. These GIS-based methods have produced models for assessing visual quality and visual impact, especially used to accurately monitor and evaluate the viewshed (Brabyn & Mark, 2011; Swetnam et al., 2017) and the visibility (Swetnam et al., 2017; Yang et al., 2007) in a virtual environment from the digital elevation model (DEM). It is also broadly used to measure the physical landscape elements like land uses (Ramos & Pastor, 2012), Shannon's Diversity Index, Shape Index (Frank et al., 2013), the number of patches, and patch diversity in a landscape mosaic (de la Fuente de et al., 2006).

2.6 Limitations of previous research

In Hungary, several studies have examined land use/land cover changes in lake catchments (Jordan et al., 2005; G. Y. Chen et al., 2012; Kertész et al., 2019), river basin (Dezso et al., 2005), and marshland along the lake (Németh et al., 2021) based on spatial analysis and statistical database. However, specific quantitative research and spatial analysis of the LUCC processes in the buffer zone of the lake is still missing in Hungary.

When reviewing the researches on the impacts of shore development, the studies are often in an urban context and examined with usually an emphasis on the social, economic, cultural, governance aspects (Papatheochari & Coccossis, 2019). In the lakeshore area, studies have discussed and highlighted the negative impacts of shoreline housing and cottage developments

(Lindsay et al., 2002; Stedman & Hammer, 2006; Brauns et al., 2011), discussed the impacts of lake tourism development on the build-up areas (Boavida-Portugal et al., 2016), analysis the human pressures on lake regions (Furgala-Selezniow, G. et al., 2012), and monitoring the effect of urbanization and population growth on the riverside agriculture (X. Chen et al., 2010). However, the research about lakeshore development and its impacts on the sector of physical characteristics and aesthetics are still rare.

There are many studies that have assessed the landscape quality of urban waterways (X. Chen et al., 2010; Moran et al., 2016) and streams through public preference and participation (Hu et al., 2019). Yet, few studies focus on the visual aspect of lakeshore landscape (White et al., 2010). Studies examined the environmental and ecological impact of tourism and human activities on the fragile lakeshore and coastal zone, specifically discussing the impact of human activity on lake habitats and the ecological quality of the nearshore zone (Li et al. 2020; Papageorgiou 2016). And examined the influence of lakeshore modifications on flora and fauna (Radomski & Goeman, 2001; Lindsay et al., 2002; Brauns et al., 2011). But, the impacts of intervention activities on the landscape aesthetic and aspects of visual amenities in lakeshores are still insufficiently recognized. In particular, the impact of the developing projects and intensive construction activities on the visual quality and the aesthetics of the lake landscape are rarely investigated. And the impact of shore modifications driven by development on the visual quality and aesthetics of the lake landscape is hardly mentioned.

Based on the summary of past research methods, research priorities and findings, the main research gaps can be considered as the following three aspects: (1) **Research on the spatial analysis and monitoring of the LU/LC changes in lakeshore zone of Lake Velence is a vacant.** (2) **There is a lack of specific methods and metrics for assessing the aesthetic value of lakeshore landscapes.** In previous studies of landscape aesthetics, researchers have developed a number of assessment methods for agricultural landscapes, forest landscapes and urban parks. But few articles have focused on waterfront landscapes, especially lakeshore landscapes. (3) **Concerns and studies on the visual quality of lakeshore landscapes are rare.** In addition, visual impact assessment methods in past studies have not addressed disturbed lakeshore views.

2.7 Summary

Lakeshore development covers a wide range of discussions on social, cultural, economic, and ecological aspects. This chapter briefly reviewed the process and background of lakeshore development in Hungary and also summarized the issues and interests associated with lakeshore development. Economic and property interests often play a unique role in waterfront development proposals. Most of the negative concerns about the impacts of waterfront development are mainly in the ecological and environmental components.

Additionally, this chapter reviewed the methods and tools used in the analysis of LU/LC change and visual landscape assessment. Demonstrated a classification of the main attributes that affect the quality of the visual landscape, and identified the relevant indicators of each category branch. However, some of the indicators are still in a testing phase, the visual indicators required more experiments to approve their availability and the connection with landscape aesthetics. According to the reviewed studies, more verification surveys between the visual landscape quality and landscape metrics could promote the development of visual indicators. Also, it is necessary to develop more specific indicators for different types of landscapes.

3 STUDY AREA DESCRIPTION

3.1 Introduction

In this chapter, the importance of the study areas and why they were chosen will be explained, as well as an introduction to the specific definitions of the lakeshore zone. Also, this chapter will detailed introduce the study areas in terms of their geographical location, environmental characteristics and development context. In addition, some of the issues arising from development projects in the study lake areas will be briefly described.

3.2 Identification of the study area

This thesis focuses on the study of the shore area of Lake Velence. The focuses of all studies in this thesis are on the lakeshore zone and nearshore areas. In a slight difference to the definition of the shore zone already summarized in Section 2.2, the term **lakeshore zone** used in this thesis for specifically means **the strip of land within 200 meters of the shoreline** (Figure 3.1), which is also referred to as the buffer zone. All subsequent quantitative analyses of land use/cover change were assessed and measured within 200m of the lakeshore area.

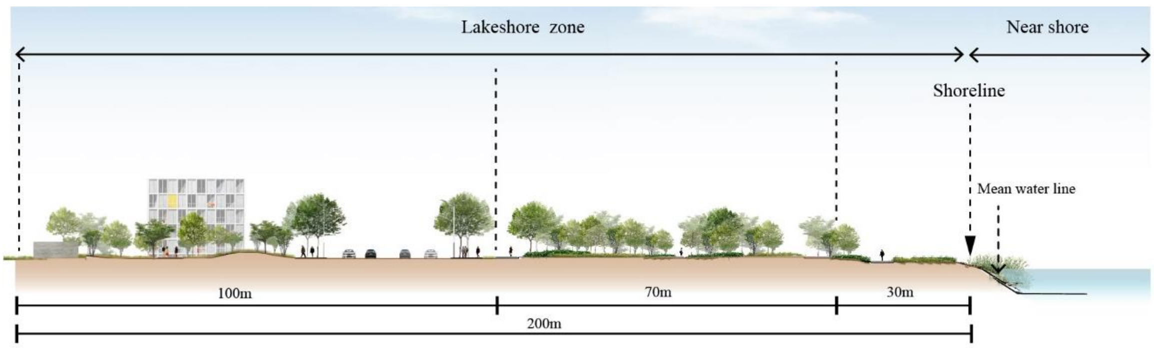


Figure3.1 Identification of the study shore zone

To examine the lakeshore area at different distances in more depth (Table 3.1), the 0-200m lakeshore area was subdivided into **three zones (0-30m, 30-100m, and 100-200m shore zone)**, and for a comparative study of land use/cover change in different zones (Figure 3.2).

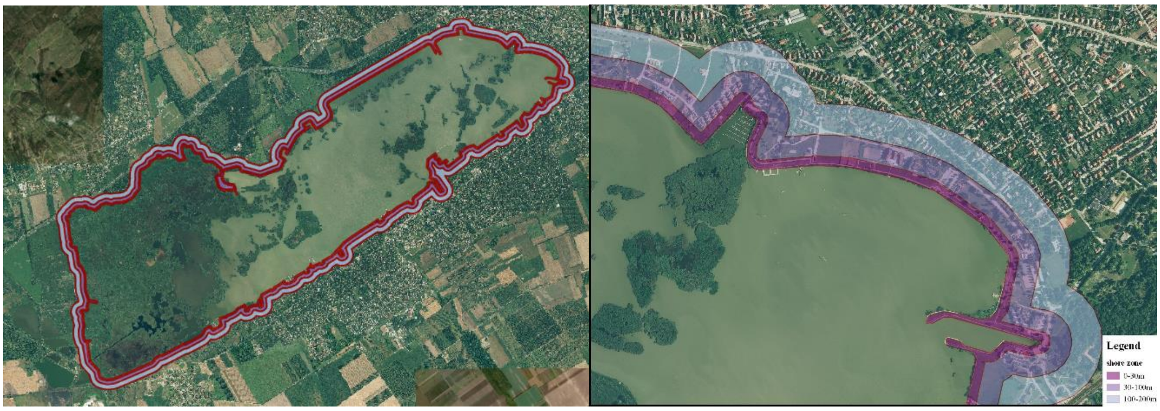


Figure3.2 Zoning of the Velence Lakeshore

Table 3.1 Lakeshore zoning and corresponding studies

Study shore zones	Area of shore zone（ha）	Studies
0-200m	627	1) LU/LC status in the shore area of Lake Velence 2) LU/LC changes in different time period (1989-2009,2009-2019,1989-2019)
0-30m	109	Comparing land use/cover status in different shore zones
30-100m	227	Comparing land use/cover changes in different shore zones
100-200m	290	Comparing land use/cover change in different shore zones
0-100m	321	1) A comparative analysis of LU/LC change in different lakeshores (Lake Velence and Lake Balaton) 2) Integrated analysis of LU/LC changes in the two lakeshore areas 3) Landscape preference survey and Visual impact assessment

With regard to the land use change study section, the shore area of Lake Balaton will also be studied with the aim of comparing and analysing the change with Lake Velence. The shore areas of the two largest natural lake in Hungary (Lake Velence and Lake Balaton), can be considered as ideal case study areas. This is because both lake areas have experienced similar socio-economic development policies and they have been affected by intense tourism pressure and expansion of facilities in the last decades. To investigate the land cover status and changes in the two lakefront areas over a thirty-year period, the zone most affected by tourism development, i.e., the **0-100m lakeshore zone** was selected for measurement and analysis (Table 3.1). Consequently, the total study areas for assessing the LU/LCC encompass approximately 3.20 square kilometers of the lakeshore zone of Lake Velence and 22.63 square kilometers of the lakeshore zone of Lake Balaton (Table 3.2). With regard to the study of landscape aesthetics, all the landscape viewpoints and scenes used for evaluation were also located in lakeshore areas close to the shoreline.

Table 3.2 A comparative study of the shores of Lake Balaton and Lake Velence

Study lake	100m shore zone	Water surface	Lakeshore length	Study period
Lake Velence	3.20 km²	37.67 km²	28.5 km	1989,2019
Lake Balaton	22.63 km²	592.65 km²	235 km	1989,2019

3.2.1 Lake Velence

Lake Velence is the second large natural lake and one of the popular tourist destinations in Hungary *(*Figure 3.3*)*. It is situated at Fejér county and the foot of the Velence Hills, between Budapest and Lake Balaton, 90 km from Lake Balaton and 45 km from Budapest (Gábor, 2016). It is a shallow lake with an average depth of 1.62m. The surface area of the lake is 24.17 km² (Szilágyi F., Szabó Sz. & Mándoki M., 1989). The whole area of Lake Velence is 26 km^2.The open water area is 16 km², and the reeds take around 10 km² with stable and floating reed islands (Gábor 2016). On the western part of the lake is a nature conservation area of 4.2 km2 belonging to the competence of Ramsar Convention, having an extraordinary landscape character with floating marshes and meadows. The western basin is covered by emergent macrophytes, the eastern basin is dominated by the open water-surfaces. Along the southern and eastern shores of the lake, settlements were developed nearly continuously since the earlier of the 20th century (Boromisza et al., 2014). The development of Lake Velence produced the eastern and southern regions rich in land use, varied revetment types, and diverse lakeside landscapes. These changes not just affect the ecological conditions and land use of the lakeshore, but strongly influence the aesthetics and visual connections. It also results in the regionalization and segmentation of the lakeshore landscape.

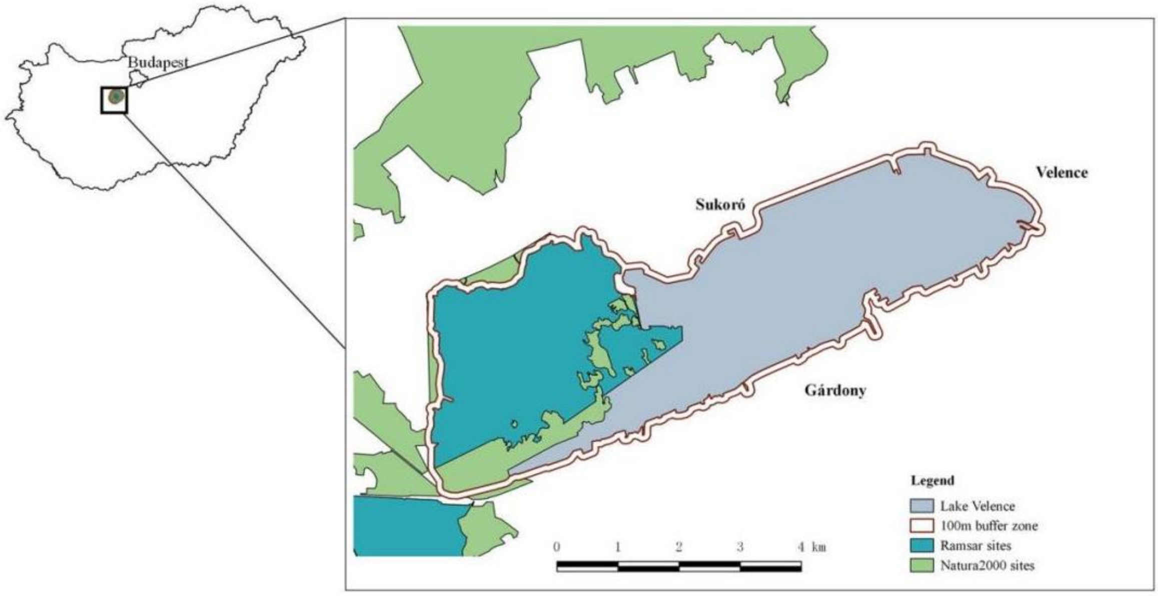


Figure3.3 Geographical location of Lake Velence

3.2.2 Lake Balaton

Lake Balaton is the largest lake and the largest freshwater lake in central Europe, and the most popular holiday destination in Hungary. It is located on the border of the south-central Transdanubia region in western Hungary. Lake Balaton has a surface area of 596 square kilometres, an average depth of 3.2 metres and a catchment area of 5,775 square kilometres (Bernát et al., 2020). It is part of the Natura 2000 Reserve and retains a wealth of natural resources and high scenic aesthetic value (Figure 3.4).

Lake Balaton is widely recognized for its inherent lake landscape resources and recreational value. By decades of lakefront development in lake Balaton, increasing tourism activities (swimming, yachting, fishing, etc.) have been considered as the most pollution factor on the lake environment. Like other lake regions in Hungary, the issue that has recently attracted extensive attention is the deterioration of water quality in the Lake Balaton region. Since the lake and water is the base resource of the tourism industry, it has to withstand excessive pressure and pollution from the overwhelming visitors and tourism activities in the peak season (Puczkó & Rátz 2000). In the Lake Balaton Region, the settlement structure is very fragmented and there are no bigger cities in the lakeshore (Wettstein, 2013; András et al., 2022). Concrete shore walls and building belts were developed around the lake, which directly led to the fragmentation and the loss of semi-natural land (Buday-Sántha, 2007) .

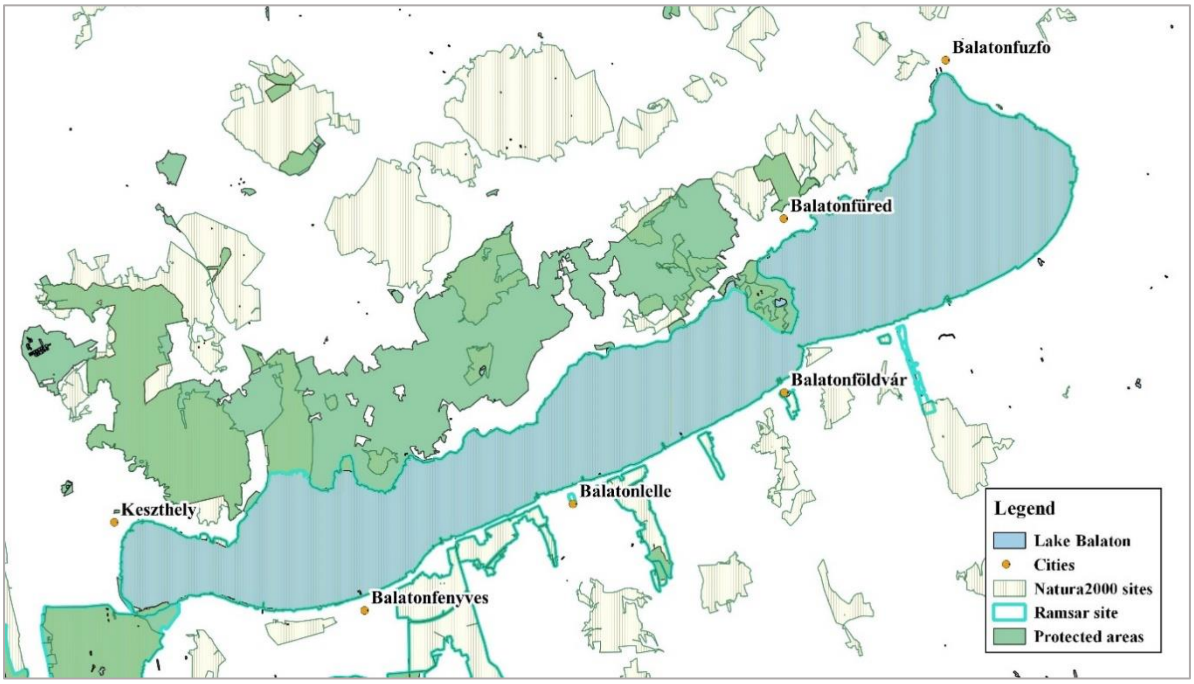


Figure3.4 Lake Balaton

4 METHODS AND PROCEDURES

This chapter will introduce detailed methods, procedures and tools for assessing land use/cover change and landscape visual quality of the lakeshores. Three main research sub-sections are included. The first section focuses on the methods used to mapping and analyzing land use/cover change in lakeshore areas, the second on assessing lakeshore landscape preferences through a photo-based approach, and finally, on the new multiple methods designed for visual impact assessment and used in practice to evaluate the visual impact of lakeshore modifications and constructions.

4.1 Mapping and analysis of LU/LC change

In order to understand the characteristics and magnitude of land use and land cover change in the lakeshore area, this section describes the methods and procedures for mapping and testing land use/cover in the lakeshore area, and presents the formulae for quantifying the magnitude and annual rate of LU/LC change. Firstly, the LU/LC types in the Lakeshore area need to be classified and described. Secondly, changes in LU/LC were detected by mapping and comparing land cover in 1989, 2009 and 2019. Afterward, the annual dynamic rate of LULCC and the area change rate of LU/LC were analyzed and calculated based on the map datasets of the three periods.

4.1.1 Classification of land use / land cover

According to the field survey and ancillary geographic information of lake regions, the first step of the study was to extract the classes of the land use/land cover according to the CORINE Land Cover classification. Ten general categories of land use and land cover were identified for application in this study (Table 4.1). In order to specifically analyses land use/land cover change associated with tourism development. I re-classified and integrated the ten categories of LU/LC into three main types of land use: **Tourism development area** (included the recreational area, accommodation areas, and other tourism facility area), **Urban development area** (comprises settlement area, transport land and bare land), and **Undeveloped area** (mainly refers to the vegetation-covered areas, like plantation areas, forests, semi-natural area, and water area).

Table 4.1 LU/LC classification and description of each class

Main classes	Class	Description
Tourism development area	**Tourist accommodation area**	land occupied by hotels, summer houses, farm houses, resorts, second home.
	Recreational area	camping areas, beaches, parks, footpaths, fireplaces, sport fields
	Other tourist facility area	water management authorities, shipyards, shopping mall, land occupied by marinas, water equipment rentals, restaurants and catering facilities, factory
Urban development area	**Transportation land**	main roads, railways, parking areas
	Urban area	urban and town areas, group of residential buildings, settlements.
	Bare land	Construction filed, barren, stockpiles
Undeveloped area	**Agricultural land**	rangeland arable land, permanent crops, pastures and meadows (homogenous, intensively cultivated grasslands), heterogeneous agricultural areas
	Forests	forest land, forest composition, lands with tree canopy density>50%
	Semi-natural area	wetlands, marshland, scrub, herbaceous vegetation associations, extensively cultivated biodiverse, semi-natural grasses, young woodland
	Water area	Inland water, pond

4.1.2 Data collection and mapping

First, three vector layers were created in GIS software represent LU/LC 1989, 2009 and 2019. Afterward，drawing of the study lakeshore zones (Described in detail in section 3.2) from the base maps. Third, using the dissolve tool in GIS, the geometries and data from the CORINE land cover (CLC 1990, 2018) was superimposed onto the mapped lakeshore strips.

The initial vector layers therefore consist of many polygons covering the different land use types based on the CLC classification. CLC uses a Minimum Mapping Unit (MMU) of 25 hectares (ha) for areal phenomena and a minimum width of 100 m for linear phenomena. The thematic accuracy (CHA) of CLC 1990 is $\leq$ 85%, and the CLC 2018 is $\geq$ 85%.

Considering that the CLC maps are not sufficient for a fine study of 200m strip areas, two types of reference map data (topographical maps 1989 and 30-meter high-resolution orthophotos at 2009 and 2019) were prepared for **manual validation.** Specifically, by checking whether the polygonal areas match the actual land cover and accurately correcting the initial CORINE land cover data (validating the data against the LU/LC classification defined in sub-section 4.1.2). The historical topographic maps and imagery were pre-processed and merged prior to the revision of the CLC maps. All land cover maps digitized on a scale of 1:10,000. After digitization of the raster image, the vector layers consist of various polygons overlaid with different identified land use types (Figure 4.1).

And finally, the area of digitized polygons and percentage of each land use category are measured, these are the fundamental parameters for the calculation of the dynamic rate of LULC change. All reference maps (topographic maps 1989) and imagery (high-resolution orthophotos 2009 and 2019) resources are from private collections. All mapping and measurements were based on QGIS 2.18 software and calculated in the WPS Office Excel software.

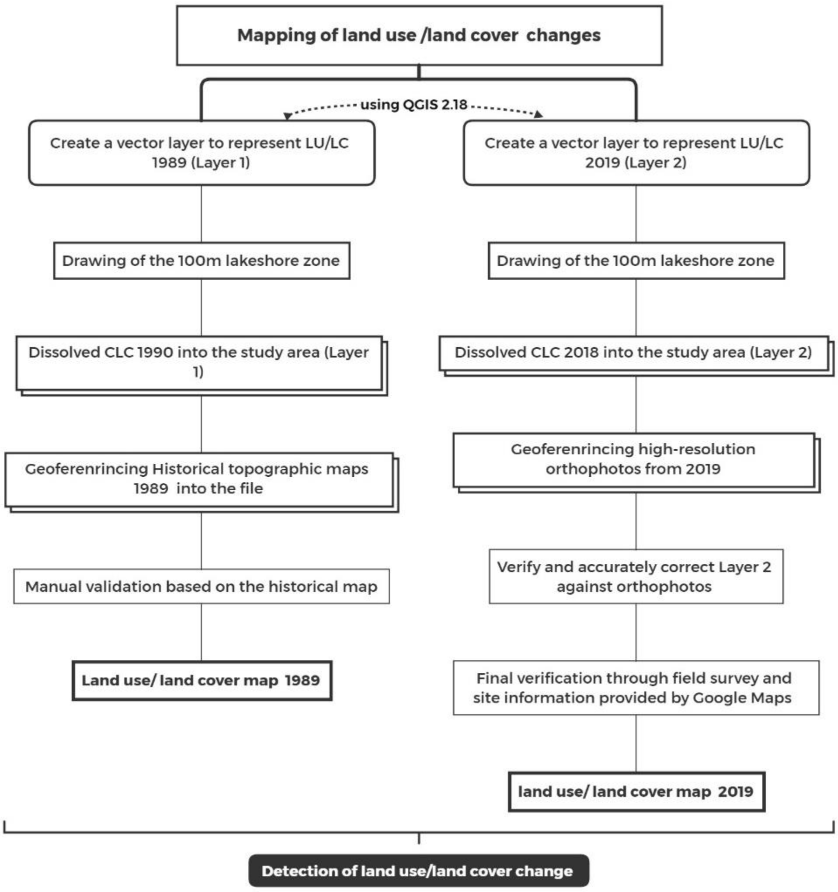


Figure4.1 Flow chart of mapping land use/ land cover changes

4.1.3 Qualifying Land use change processes

Land use dynamic degree as an important index of land-use change can used to represent the annual variation rate of the land use type. According to the previous land use /land cover researches (Batar et al., 2017; Furgała-Selezniow et al., 2020), The degree of change for each class of LU/LC were calculated by the modified formula described as:

$$q = \left(\frac{1}{t2-t1}\right) \times ln\left(\frac{A2}{A1}\right) \times 100\% \qquad \text{Equation 1}$$

Where *q* is the dynamic degree of the land use /land cover, express the annual rate of the change for each class in the study area; *A1* and *A2* are the areas of land use/land cover type, respectively at the corresponding time t1 (1989) and t2 (2009 or 2019).

In addition, to examine the magnitude of the land-use area change in the study period, the area variation rate of land use has been considered, which calculated by the following formula:

$$C = \frac{A2-A1}{A1} \times 100\% \qquad \text{Equation 2}$$

Where *C* describes the area change rate of the land use/cover between t1 and t2, *A1* represents the area of the land use classes at t1， *A2* represents the area of the land use types at t2.

4.1.4 Statistical analysis

To compare the significance of changes in area occupancy by land use type at the two study time periods (1989 and 2019), a **Wilcoxon signed rank test** (also called the Wilcoxon signed rank sum test) was used to detect statistically significant differences in LU/LC between the study time slices. Wilcoxon signed rank test is a non-parametric method developed by Frank Wilcoxon (1945). The purpose of the test is to determine whether two sets of paired data (independent samples) are statistically different (Wilcoxon, 1945). The Wilcoxon W test statistic is simply the sum of the positive ranks, but to calculate the p-value (Asymp. Sig), SPSS uses an approximation to the standard normal distribution to give the standardized (Z) test statistic and the resulting p-value.

In order to find out the correlation of changes between each LU/LC class, a **Spearman's rank correlation coefficient (r_s)** was applied to detect a statistical association between LU/LC types.

Correlation analysis is based on the ranking of the data. The x and y variables are ranked and the rank of x is compared with the rank of y. The correlation coefficient（r_s）is calculated according to the equation：

$$r_s = 1 - \frac{6\sum D^2}{n(n^{2-1})} \qquad \text{Equation 3}$$

Where D is the difference between ranks, and n is the number of pairs of data. Spearman’s returns a value from -1 to 1, where: +1 = a perfect positive correlation between ranks, -1 = a perfect negative correlation between ranks, 0 = no correlation between ranks.

4.2 Assessing public aesthetic preferences toward lakeshore landscapes

This section is dedicated to investigating the public's aesthetic preferences for different lakeshore landscapes and the relationship between visual elements of the landscape and perceptual evaluations. As can be learned from the detailed description in section 3.3，earlier intervention programmers and tourism developments in the lakefront area have led to different levels of artificiality in the lakefront landscape and a diversity of berms. The study consists of an aesthetic assessment and preference survey of 14 different lakeshore landscapes (shore with different levels of development and landscapes with different types of revetments) through public participation. The study comprised three main components: (1) investigating public preferences and perceptions of various lakeshore landscapes; (2) examining the correlation between visual indicators of the landscape and public preferences (Appendix 2); and (3) exploring the differences in lakeshore landscape preferences between different participant groups.

4.2.1 Survey points and photograph selection

The preference survey was assessed on the basis of photographs of lakeshore scenery. The selected viewpoints are mainly distributed on the southern shore zone of Lake Velence and the bay of Velence (Figure 4.2). The photos were taken with a PENTAX K100D camera, in between July to August 2016. During this period, a total of over 100 images along the entire shoreline taken. I selected 14 high-resolution representative lakeshore photos as the basis for this investigation. The 14 images/survey of the scenic spots were chosen to represent the different units of shore features, as well as the degree of development. The photographs were divided into four comparison view groups. The first three scene groups conducted a public preference survey on landscape scenes of different revetment types (Figure 4.3), and the last viewpoint group was to investigate the impact of different natural degrees of lakeshore on public perception and visual amenity. In addition, the perspective view of each group of comparative photos, the visual horizons, the distance between the shoot point and the water surface are similar (Svobodova et al., 2014).

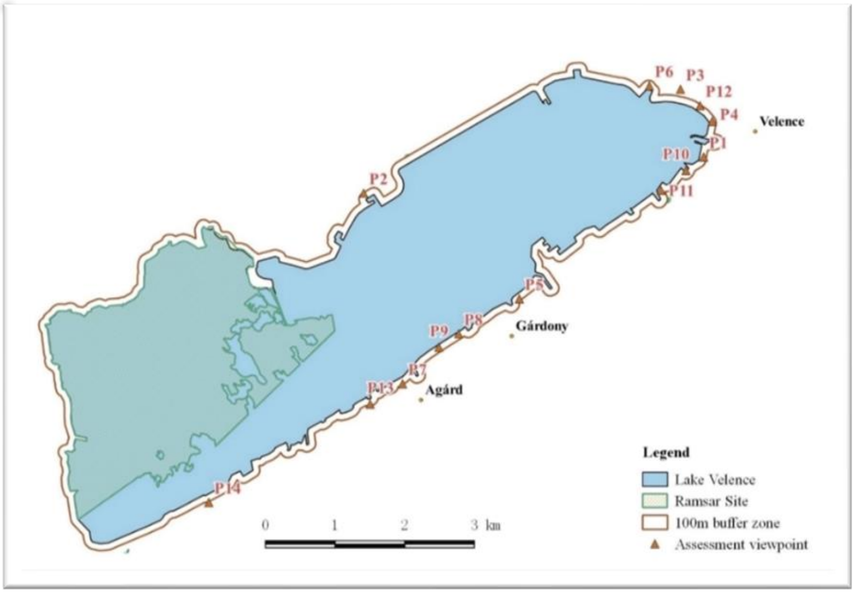


Figure4.2 Location of photograph points.

4.2.2 Questionnaire survey

I collected the public's preference judgments, opinions, and perceptions of the Lake Velence lakeshore landscape through an online questionnaire survey. I separately sent the online questionnaire to three different groups (outdoor enthusiasts, the local residence, and experts), mainly through social media communities. Additionally, I also sent it to several individuals by email. The contents of the questionnaire completed in July 2019, and all responses collected in October 2019. It divided into three sections:

The first part is a brief inquiry about the occupation background of the respondents and where they live. The second section was designed to investigate the public preferences of nine varying lakeshore landscapes, which with similar vegetation-covered but different revetment types and characters. It consisted of three groups, each of which contains three different comparison scenes (Figure 4.3). Participants need to choose from three different scene photos one of the best. Besides, the third part was regarding the preferences survey of the different extent of human influences of the lakeshore landscape (Figure 4.4). It contained five pilot sites. Participants will choose the best and the worst of the five sample photos. Behind each preference survey item will be accompanied by a brief interview, in which the respondents will be asked about the reasons for their choice, as well as their opinions (Appendix 4,6).

Figure 4.3 Three scene photograph comparison groups.

P1-P3=scene group1: a concrete revetment with partly sand slope, a shore with wooden groynes and timber piles, a natural beach with wooden groyne; P4-P6=scene group2: an well-organized shore with metal railings, a rip/rap bank slope with openly grassland, a shore restricted by aquatic plants and wooden fences on both sides of the pavement; P7-P9=scene group3: a rock slope revetment with unobstructed pavement, a rock slope revetment with obstructed pavement, a concrete revetment without sloping breakwater

Figure 4.4 Lakeshore scenes at different levels of development

Note: Comparison scenes of the third part: P10=an artificial shore background completely covered buildings, P11=a semi-artificial shore with partial buildings background, P12=a semi-natural shore with limited access, P13=a near-natural shore with the unobstructed pavement, P14=a natural shore partial covered with aquatic plants

Respondents

Respondents composed mainly of three groups (Appendix 3). The neighborhood residents and community groups living near the lake (group1). They are most concerned about the changes and renew of the lakeshore and most affected by the changes of lakeshore landscape; The experts (group2): the students in landscape architecture, the architects, and urban planner; Visitors and outdoor sports enthusiasts(group3), including bikers, kayakers, and hikers. The number of respondents who participated was 72. The actual valid responses were 65 (29 residents, 27 experts, 9 outdoor enthusiasts).

4.2.3 Data processing and Analysis

To evaluate the perceived scores and preferences results of lakeshore landscapes, a **Pearson correlation analysis** was performed to examine the relationships and relevance between public preference judgment consensus and landscape indicators. Previously, I have established and measured an applied landscape assessment indicators of partial study scenes by field survey (Table 4.2). Identify and characterize the landscape indicators based on the following considerations: the physical states (vegetation coverage area, human activities, the extent of human influences, density of riparian plants) and the condition of the landscape (visual range, naturalness, functionality, accessibility, maintenance).

To compare the preference differences between the experts (n=27) and waterfront residents (n=29), by using a Crosstabs analysis followed by the Chi-square test to examine the perceived votes of two participant groups. The results of Crosstabs perform shown that the cells have expected to count less than 5 in each group. Therefore, I used a follow-up to Fisher's Exact Test to verify it again.

Excel software (Microsoft Corp.) and SPSS software (v25.0, IBM Corp.) was used to perform the descriptive statistics, a general preferences analysis, correlation analyses and crosstabs analysis.

Table 4.2 Measurement of environmental indicators of five survey scene sites

Indicator	**Scene points**				
	P10	**P11**	**P12**	**P13**	**P14**
Naturalness	highly	semi artificial	semi artificial	near natural	natural /
Visual range	openness	semi openness	semi openness	semi openness	closure
Vegetation coverage (%)	10	30	40	60	80
Aquatic plants	no	no	middle density	low density	high density
Accessibility	free access	free access	inaccessible	limited	limited
Human activity	high extent	high extent	high extent	low extent	low extent
Maintenance	well maintained	well maintained	poorly maintained	well maintained	poorly maintained

4.3 A mixed methods approach to assessing the visual impact of lakeshore modifications on the lakeshore landscape

A mixed approach allows the strengths of different approaches to be captured and useful information to be integrated. An integrated approach that leverages different assessment tools and perspectives to help evaluate and monitoring the quality and changes of development activities and projects on the visual landscape. The adoption of a mixed approach can therefore generate new insights and comprehensive understanding through the results of different methods (Bamberger, 2012; Hattam et al., 2015). In this study, an objective landscape metrics-based assessment method (LMBA) and a subjective visual perception-based assessment method (VPBA) will be used to evaluate the visual impact of the construction and modification on the lakeshore landscape respectively. Both applied approaches considered the visual quality of the landscape as a matter of interaction between physical landscape features and visual perception processes, but with different attention to landscape quality and receptors (Daniel, 2001). The LMBA approach is first applied to quantify the magnitude of the visual impact and cumulative effect of the lakeshore landscape, which will be measured and calculated through a set of assessment indicators with the help of GIS tools and temporal-spatial datasets. The VPBA method will then investigate receptors' evaluations and perceptions of changes in the visual landscape quality of the lakeshore, and identify the impact fac-tors during the construction phase. Lastly, to compare the visual impact values assessed by the two methods and validate their relevance. The final visual impact level for each lakeshore site will be determined by combining the results of the two assessment methods. The specific steps of the study are as follows (Figure 4.5):

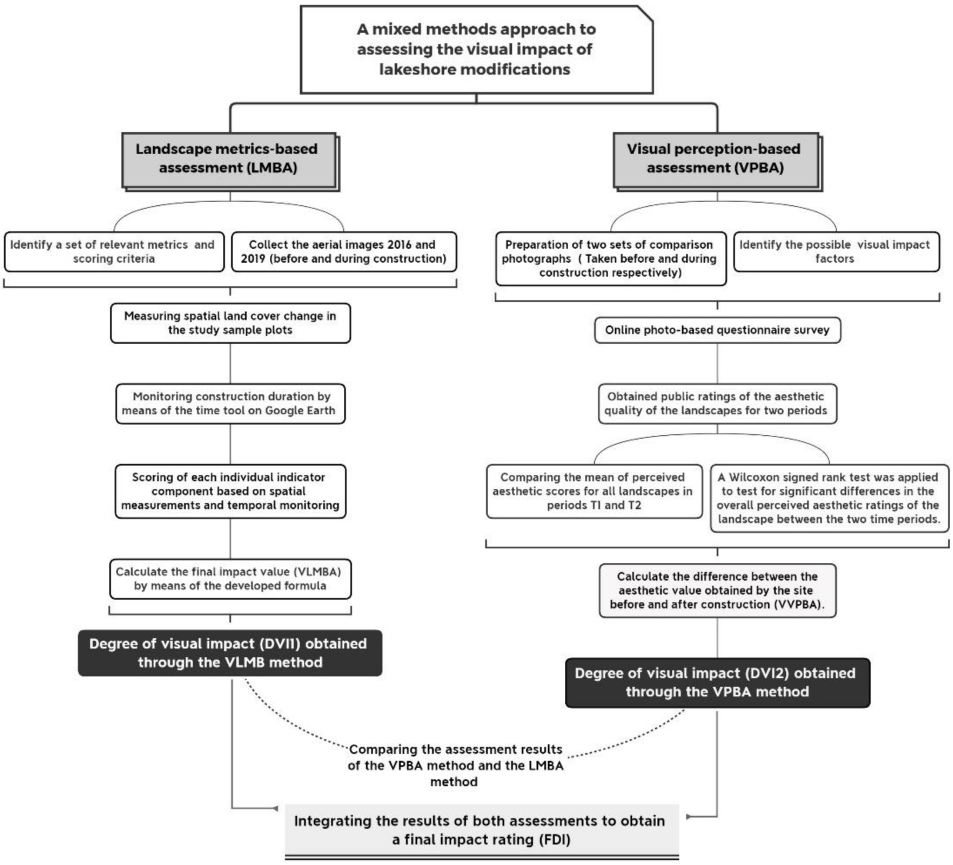


Figure4.5 Flowchart for assessing the visual impact of lakeshore landscapes

4.3.1 Project overview and study plots

In recent years, the Hungarian government and the National General Directorate of Water Management (OVF) have continued to increase their investments and actions in the development of the lake areas. This has directly led to an increase in built-up areas and construction activities in the lakeshore areas, as well as changes in the shoreline. Continued growth in tourism development and construction activity has resulted in over 50% of the shore area of Velence being highly artificial and intensively used. The development of Lake Velence is focused on the creation and broadening of tourism infrastructure and structures (Gabor, 2016). According to an official online announcement from the Hungarian water authorities (https://magyarepitok.hu/) in May of 2016, Lake Velence will carry on a comprehensive waterfront revitalization program starting at the end of 2017, with a tender fund for 14 billion forints from EU funds within the framework of KEHOP (Environmental and Energy Efficiency Operational Program). The project was expected to be completed in 2021. A total of 29 kilometers of shoreline will be renovated in the Lake Velence Complex Shore Renovation Program initiative. A new waterfront promenade and tailings pond will be created, dredging of the lake bottom will also take place, and emphasis will be placed on the development of recreational services and recreational lands (e.g., additional bike paths and beaches).

Six representative plots along the lake were selected as sample sites for the visual impact assessment (Figure 4.6). Each of the selected study sites underwent different types of construction operations and modifications during the lakeshore reconstruction program, including pavement renewal, tailings disposal, embankment reconstruction, bank wall demolition, material stockpiling, and construction of a new promenade. All of the study plots are located in a 100m riparian area along the shore of Lake Velence, which were semi-natural land or low human activity areas before modification. The standard dimensions of all study plots were 100 m wide x 300 m long and are shaped as strips along the lake. The camera points for the ground-level photographs used for the public participation survey are situated in the middle of each plot. (Figure 4.7).

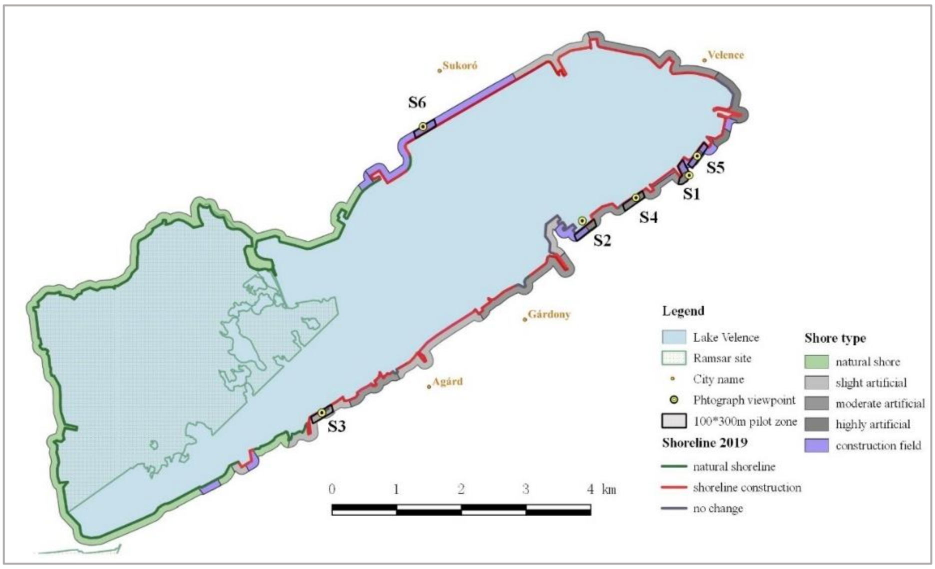


Figure 4.6 Location of the study plots for the lakeshore visual impact assessment

Site No.	S1	S2	S3
Field survey photo			
Type of modification	**Pavement Renewal** (Upgrading of the pavement, and excavate a new drainage ditch)	**New tailing pond field** （Carry out dredging and excavation work）	**Reconstruction segment of embankment and pavement**
Site No.	**S4**	**S5**	**S6**
Field survey photo			
Type of modification	**Demolition site** （removal the obsolete facilities and hard structures）	**Stockpile field** (Strip sod and Stockpile stone field site)	**New promenade construction segment**

Figure4.7 Field survey photos of the study sites

4.3.2 Landscape metrics-based assessment

A set of relevant metrics was applied to measure the visual impact of the construction and lakeshore modifications. The selection of metrics focused on the spatial effects of the interferences on physical landscape conditions and land cover changes, and the cumulative impacts caused by the time span of construction.

According to previous studies, naturalness (Frank et al., 2013), landscape structure, and vegetation cover (Wang et al., 2016) as the essential criteria for the assessment of landscape aesthetic quality, correlate with scenic beauty, landscape preference, and visual landscape quality. Furthermore, Institute & IEMA (2013) concluded that minor impacts on highly sensitive areas may be more critical than major impacts on less sensitive areas. Landscape sensitivity plays a crucial role in assessing visually disturbed landscapes. Slight disturbances can have a significant adverse impact on high sensitivity and naturalness.

I analyzed and measured the spatial land cover of the study sample plots by using a GIS tool (QGIS 2.18 software) and reference the 20m resolution aerial imagery and raster orthophotography in 2016 and 2019. The standardized dimensions of all study plots were 100 m wide x 300 m length and shaped as a strip along the lake (Figure 4.6). Firstly, I digitalized the land cover map of the plot before and during construction by drawing polygons on two time-representative vector layers (2016 and 2019). The land cover analysis and measurements consisted mainly of built-up area, patch area, bare land, and grassland. Afterwards, I calculated the difference in vegetation cover and the exposed construction area between the two-time slices. These differences represent the magnitude of land cover change. Additionally, I monitored the duration of construction and disturbance conditions at the study sites in the 2016-2022 timeline through field surveys and the historical imagery tool in Google Earth software.

Each of the individual indicator component has independent evaluation standards (Table 4.3), with four classes of rating scale from1 to 4. The state of the landscape and naturalness level in pre-construction determine the scoring of the corresponding degree of the landscape sensitivity. The parameters obtained from the geoprocessing survey and monitoring are the basis for the corresponding scoring for each indicator (Table 4.3). The impact value calculated for each study site through the landscape metrics-based assessment (V_{LMBA}) can be described by the following formula:

$$V_{LMBA} = S_{LS}(\sum S_{MC}) \times S_{DE} \qquad \textbf{Equation 4}$$

Where S_{LS} is the score of the sensitivity of the target area. S_{DE} represents the length of the construction duration. S_{MC} means the magnitude of the land cover changes, which was a combination of the degree of the exposed construction area (S_{CA}) and the degree of vegetation degradation (S_{VD})

Table 4.3 Metrics for visual impact assessment of lakeshore modification

Categories	Landscape indicators	Description	Score(S)
Landscape sensitivity (LS)	Sensitivity /Site condition before construction	low sensitivity (highly artificial lakeshore)	1
		slight sensitive (semi artificial	2
		moderate sensitivity (semi natural lakeshore)	3
		highly sensitive (nature conservation)	4
Magnitude of the land cover change (MC)	Exposed construction area /bare land (CA)	small area	1
		medium	2
		medium -large	3
		Large	4
	Vegetation cover degradation area (VD)	<20%	1
		20%-50%	2
		50%-70%	3
		>70%	4
Duration effect (DE)	Duration of construction work	temporary (<6months)	1
		medium term (6-12months)	2
		medium-long term (12-24months)	3
		long term (>2years)	4

4.3.3 Landscape visual quality evaluation based on public perceptual attributes

An online photo-based questionnaire survey was conducted to involve participants in assessing the visual aesthetic quality of lakeshore landscapes under different conditions. The aesthetic value of the lakefront landscape was evaluated by the participants utilizing ground-level photographs from two different periods (T1=before construction, T2= during construction). The difference in values of the aesthetic evaluations between the two time periods can therefore indicate the degree of influence of external interventions and modifications on the visual quality.

Six sets of comparison photographs were applied to the questionnaire survey (Figure 4.8), taken in June 2016 and late May 2019. All photographs used were intended to accurately record changes in site conditions and visual content, before and during construction. Each group of comparative photos was taken with the exact viewpoint and at the same angle. Considering that the color contrast and weather conditions in different periods may affect the photos, each group's overall tone and sky color were edited by Photoshop software.

Figure 4.8 Comparative photos of the lakeshore before and during construction

Note: a =T1 (before construction), b=T2 (under construction).

The first part of the questionnaire is about the basic information of the receptors (occupation, living place, and tour experiences in Lake Velence). Afterward, according to the comparative photographs at different times (Appendix 8), respondents were required to rate the scenarios on a scale from 1 (least beautiful) to 5 (very beautiful). In the final session, participants were asked to vote for three main negative factors for each site from a list of 10 visual impact elements (Table 4.4). Overall, the visual influences were grouped into four main categories: land cover change, intrusion of volumetric objects, exposure of high-contrast building materials, and surroundings.

I sent the questionnaire via email and Facebook local groups individually to the participants. A total of 52 valid responses were completed. Among them, 80.41% of the respondents have been to lake Velence once or more times. The participants consisted of three different representative public group, including 37.5% of the planning and landscape professionals, the residents around the lake and neighborhood association (41.35%), and the tourists and outdoor enthusiasts (21.15%).

Table 4.4 Categories of potential visual impact elements

Code	Element	Category
LC1	Damaged vegetation, plants degradation	Land cover change
LC2	Unpaved pavement, granular base, bare ground	
IV1	Stockpile of construction materials (soil, sand, gravel, rocks)	Invasion of volumetric objects
IV2	Machine (excavator)	
IV3	Public facilities (roadblock, iron fence, pole, trash bin)	
EM1	Hard paving (cement pavement, concrete shore wall)	Exposure of high-contrast building materials
EM2	Plastic cloth cover	
SE1	Water	Surrounding environment and other factor
SE2	Buildings	
SE3	Other factors	

4.3.4 Comparing and integrating the assessment results of the VPBA method and LMBA method

Construction operations and shore modifications as an intensely human activity interfere with or disturb the natural lake landscape to some extent. Based on the preliminary assessment results, I found no clear positive visual impacts from construction operations and shore modifications at all survey sites in Lake Velence, either from public assessment or from landscape metrics-based assessment. In the VPBA approach, the potential of impact values depends on the mean difference of the aesthetic ratings between the two periods (before and during construction operation), which is on a scale from 0 (no impact) to 4 (highest negative impact). The final impact values of the LMBA method range from 0 (no impact) to 128 (highest negative impact), describing the possibility of impacting the visual quality of the lakeshore under modification.

To compare the evaluation results and to verify the differences between the two methods mentioned above, I grouped the range of final impact values for the two evaluation methods into five levels: a (no impact), b (minor negative impact), c (moderate negative impact), d (significant negative impact) and e (major negative impact). The degree of visual impact is determined by the range of grade values corresponding to the final assessment values for each survey site (Table 4.5).

Once the degree of visual impact (DVI) has been assessed by the methods described above, it is assumed that each impact level has been assigned a value from 0 to 4, with 0 representing a and 4 representing e. By combining the results of the two methods, the final degree of impact (F_{di}) can be obtained. The specific equation can be expressed as:

$$F_{di} = Dvi1 + Dvi2 \qquad \textbf{Equation 5}$$

Where Dvi1 indicates the degree of visual impact obtained through the landscape metrics-based assessment method, Dvi2 represents the impact rating obtained through the visual perception-based assessment method. The final calculated impact value (F_{di}) can also be divided into five levels (from A to E). A means no impact, E represents the highest impact level (Table 4.5).

Table 4.5 Definition of visual impact degree of two assessment approaches

Range of V_{VPBA}	**Range of V_{LMBA}**	**Impact description**	**Degree of visual impact (Dvi)**	**Final degree of impact (Fdi)**
T1-T2=0	0	no change	a (0)	0=A
T1-T2=0.1-1	1-32	slight negative impact	b (1)	1-2=B
T1-T2=1.1-2	32-64	moderate negative impact	c (2)	3-4=C
T1-T2=2.1-3	65-96	significant negative impact	d (3)	5-6=D
T1-T2=3.1-4	97-128	major negative impact	e (4)	7-8=E

Note: V_{VPBA}=The aesthetic value difference between the two periods obtained through perceptual evaluation. V_{LMBA}=Total impact value based on landscape metrics assessment.

4.3.5 Statistical analysis

The Wilcoxon signed rank test was applied to test for significant differences in overall perceived aesthetic scores for all survey sites at both time periods (pre-construction and during construction) and to test separately for significance of differences in perceived scores for each survey site at both time periods. In addition, a non-parametric method, the Spearman's rank correlation coefficient (rs), was used to examine the correlation between the assessment results of the two methods (visual perception-based assessment and landscape metric-based assessment). All the above statistical analyses were performed using the software SPSS (v25.0, IBM Corp., Armonk, NY, USA).

5 RESULTS AND DISCUSSIONS

5.1 Introduction

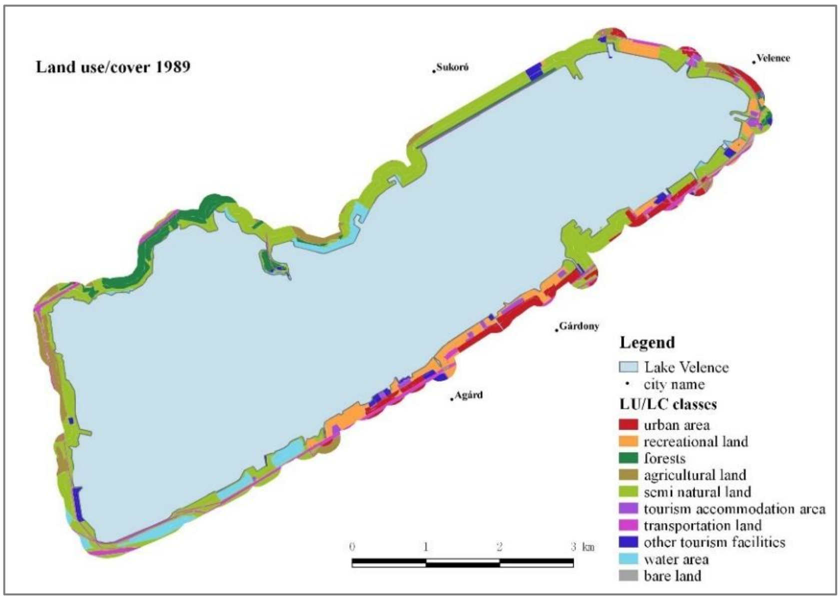
This chapter presents the findings of the assessments through a number of studies on land use/land cover change and visual landscapes in the lakeshore area. The chapter specifically consists of five sub-sections. Subsection 5.2 will specifically describe and demonstrate the status and changes in land use/cover in the delineated shore areas of Lake Velence in 1989, 2009, and 2019. Sub-section 5.3 will show the LU/LC change characteristics of the shore of Lake Velence and the shore of Lake Balaton over a thirty-year period. And the similarity of LU/LC change characteristics between the two lakeshores will be summarised. Public preferences for different lakeshore landscapes and different lakeshore berms will be presented in Section 5.4. In the last sub-section, the assessment results of the visual impact of the construction and lakeshore modifications on the lakeshore landscape through different assessment methods will be presented, as well as a discussion of the usability of these methods.

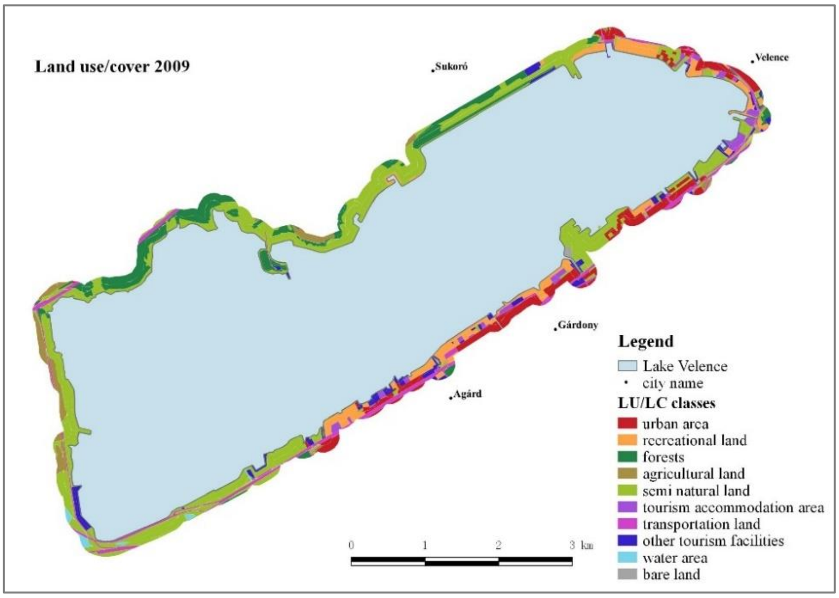
5.2 Land use /land cover change in the shore area of Lake Velence

This section will focus on land use and cover in the 0-200m shore area of Lake Velence and the processes of land cover change from 1989 to 2019. In addition, this section will discuss land use change on the shore of Lake Velence during different time periods. And, in order to understand land use change in zones at different distances from the lake shoreline, the 0-200m lakeshore is subdivided into three zones to specifically analysing the change in each zone. This section specifically contains: (1) demonstrate land use/land cover of the 0-200m lakeshore zone in 1989, 2009, and 2019; (2) Analysis of LULC changes in the shore zone between the time periods 1989-2009 and 2009-2019; (3) Identify LULC variations and linear trends in different shore zones; (4) A description of the changes in the lake shoreline and nearshore areas.

5.2.1 Land use/ cover status

Fig. 5.1 depicts spatial distributional pattern of land use/cover of the 0-200m shore zone for the year 1989, 2009, and 2019. The land use and cover maps show that undeveloped lands (semi natural land, water area, forests, and agricultural land) are mainly located in the western and northern parts of the lakeshore, while land for tourism development (tourist accommodation area, tourism facilities area, and recreational land) and urban area (settlements, bare land, transportation land) are mainly located in the eastern and southern parts of the lakeshore. From 1989 to 2019, semi-natural land accounted for the largest proportion of all land types in the lakeshore area.





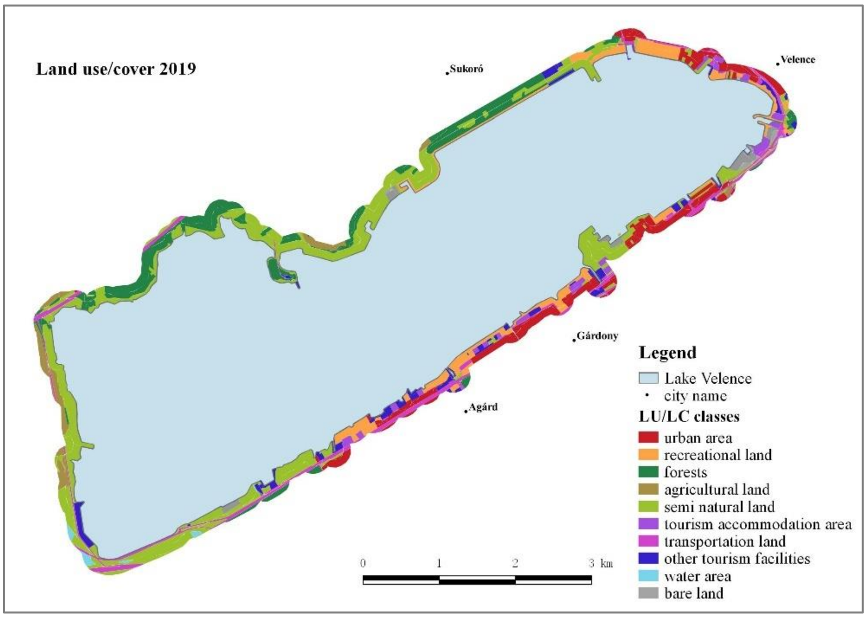


Figure5.1 Land use/cover status of the 0-200m shore area in 1989, 2009, and 2019

Based on the measurement of the area of each LU/LC class (Table 5.1, Appendix 9), the data reveal that in 1989, about 44.47% (277.8 ha) area of 0-200m lakeshore zone was over occupied by semi-natural land, 14.35% under tourism related land use/cover, 8.26% under urban area, 8.72% under forest land, 7.34% under water area and 0.16% under bare land. By 2019, the area under these land categories was found about 37.43% (236.18 ha) occupied by semi natural land, 18.18% under tourism related land use/cover, 12.14% under urban area, 15.36 under forest land ,0.71% under water area and 1.98% under bare land.

Table 5.1 Area of land use/cover classes in 1989, 2009 and 2019

LU/LC Class	1989		2009		2019	
	Area (ha)	% of the total area	Area (ha)	% of the total area	Area (ha)	% of the total area
Tourist accommodation area	11.17	1.79%	15.67	2.48%	19.12	3.03%
Recreational area	59.07	9.46%	60.76	9.63%	63.57	10.07%
Other tourism facility area	19.38	3.10%	27.87	4.42%	32.03	5.08%
Transportation land	54.29	8.69%	55.60	8.81%	57.97	9.19%
Urban area	51.61	8.26%	68.59	10.87%	76.62	12.14%
Bare land	1.01	0.16%	1.80	0.29%	12.51	1.98%
Agricultural land	44.51	7.13%	27.38	4.34%	25.86	4.10%
Forest area	54.44	8.72%	84.72	13.43%	96.94	15.36%
Semi-natural area	277.80	44.47%	280.00	44.37%	236.18	37.43%
Water area	45.85	7.34%	4.66	0.74%	4.45	0.71%

5.2.2 Land use/cover change in different time periods

Detecting changes in land use/cover area by type over two time periods (1898-2009 and 2009-2019). The results indicated that there are notable differences in land use/cover change during different time periods in the 0-200m lakeshore zone (Figure 5.2). During the time interval between 1989 to 2009, there was a significant decrease in water area (-6.66%) and agricultural land (-2.76%). At the same time, the dominant growth occurred in forested areas (4.78%), followed by urban area (2.69%) and tourist accommodation area (1.29%).

Between the years 2009 and 2019, a sharp decrease of the semi-natural land was observed in the lakeshore area (Figure 5.2; Appendix 14), by -7.50%. In contrast, increases were observed in forest land (2.06%), bare land (2.01%), and urban area (1.27%). Besides， as the proportion of water and agricultural land in the lakeshore area was already very small since the 1980s, after significant reduction and conversion between 1989 and 2009, the area of water surface and agricultural land remains almost unchanged since 2009.

Comparing the land use changes between the two-time intervals (1989-2009 and 2009-2019), the similarities can be seen in the growth of forests, urban area and tourism related land use. Different from the first-time interval, the land use/cover change between the 2009 and 2019 time period shows a dramatic decrease in semi-natural land and a notable increase in bare land and grey field land during this period, which is mainly due to increased construction activities.

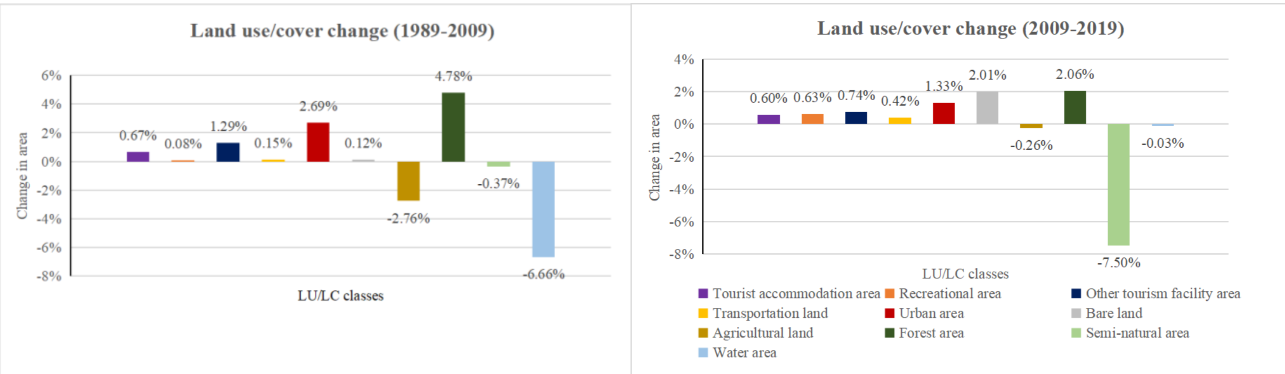


Figure 5.2 Land use/cover changes in the 0-200m shore zone in different time period

In general, the change in occupancy of each land use type between 1989 and 2019 is shown in Figure 5.3, with forest and urban land increasing by 6.83% and 4.02% respectively. All tourism-related land uses (recreational area, accommodation area, tourism facility area) and bare land also increased notably. Over this 30 years period, semi-natural land, water area and agricultural land decreased by 7.87%, 6.69% and 3.02% respectively.

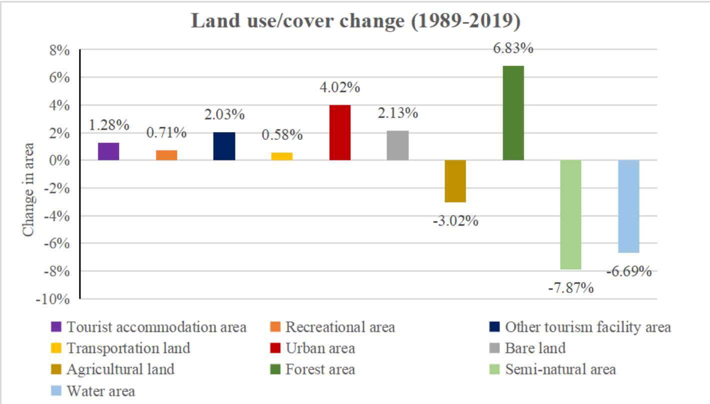


Figure 5.3 LU/LCC in the 0-200m shore zone (1989-2019)

The spatial distribution of land use/cover changes between 1989 and 2019 can be seen in Figure 5.4, where the afforestation is mainly concentrated on the northern part of the lakeshore, in the Sukoró precinct. Urbanization took place mainly in the east and south of the lakeshore, in the bay of Velence and Gárdony. It is also noteworthy that most of the increase in tourism-related lands and bare land (building construction sites) are distributed in the 0-100 m lakeshore area.

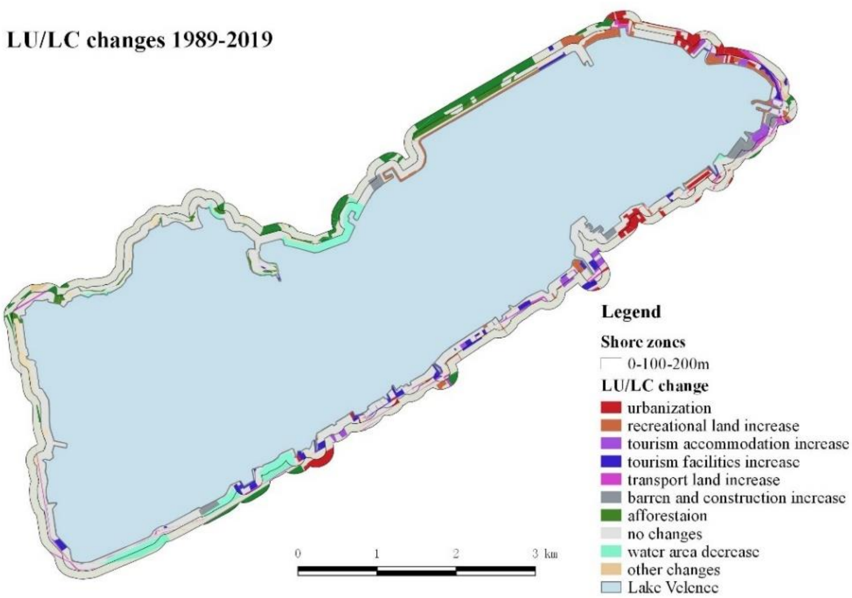


Figure 5.4 Detected land use and land cover changes from 1989 to 2019

5.2.3 Land use/cover change processes in different lakeshore zones

By analysing land use/cover changes in the three subdivided lakeshore zones (0-30m shore zone, 30-100m shore zone, 100-200m shore zone) at different times. As can be seen in Figure 5.5, between 1989 and 2009, semi-natural areas showed a significant increase in the 0-30m lakeshore zone and the 30-100m lakeshore zone (Appendix 9,10), mainly because the water areas within these zones were filled in during the same period and turned into semi-natural land. At the same time, change in the reduction of agricultural land is occurred within the lakeshore zone of 30m to 200m. The increase in woodlands and urban areas are mainly concentrated in the 100-200m lakeshore zone (Appendix 12).

From 2009 to 2019, semi-natural land has seen a dramatic decrease in all three lakeshore subzones (Appendix 14). At the same time, the area of bare land within the 0-30m and 30-100m zones has increased significantly due to increased construction activities. Figure 5.5 illustrates that the changes in land use and cover in the 0-30m lakeshore zone from 2009 onwards are mainly at the expense of semi-natural land conversion to recreational land, while the presence of a large amount of bare land also indicates that more developed land growth can come out in the near future.

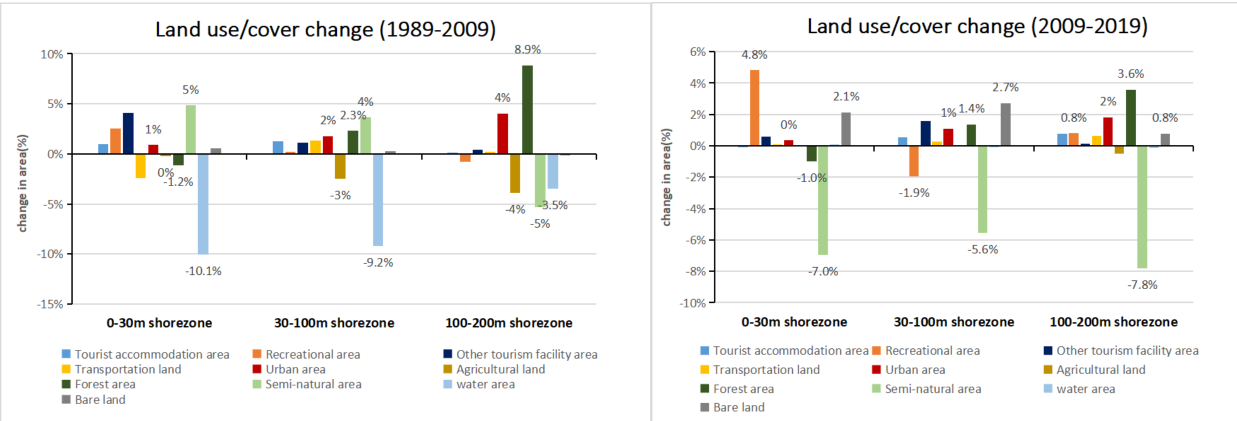


Figure 5.5 LU/LCC in the three zonal shore areas over different periods

Figure 5.6 (A) show a significant linear growth in the recreational land, tourism facilities area and bare land in the 0-30m lakeshore zone from 1989 to 2019. In the 30-100m lakeshore zone (Figure 5.6 B), there is no significant change in the proportion of land use/cover categories, except for a slight increase in tourist accommodation area and urban area. Land use/cover categories in the 100-200m lakeshore zone have changed more dramatically over the last thirty years than in the first two lake zones, with the Figure 5.6（C）displaying a clear linear decrease in semi-natural and agricultural land and a linear increase in urban land and forest land from 1989 to 2019.

Figure5.6 Linear trends in LU/LC change in different shore zones（1989-2019）, (A)0-30m shore zone, (B) 30-100m shore zone, (C)100-200m shore zone

5.2.4 Shoreline change

Figure 5.7 illustrates the morphology and natural shoreline distribution of the shoreline of Lake Velence in 1989 and 2019, Slight changes in the shape and length of the shoreline have occurred during this period. As Table 5.2 shows that the natural lake shoreline accounted for 55% of the total lakeshore length in 1989, decreased to 42% by 2019. The majority of the lake shoreline change is related to changes in land use. The hardened shoreline（vertical wall， riprap revetment, and concrete revetments）rose from 45% in 1989 to approximately 58% in 2019, of which 2% was man-made beach shoreline.

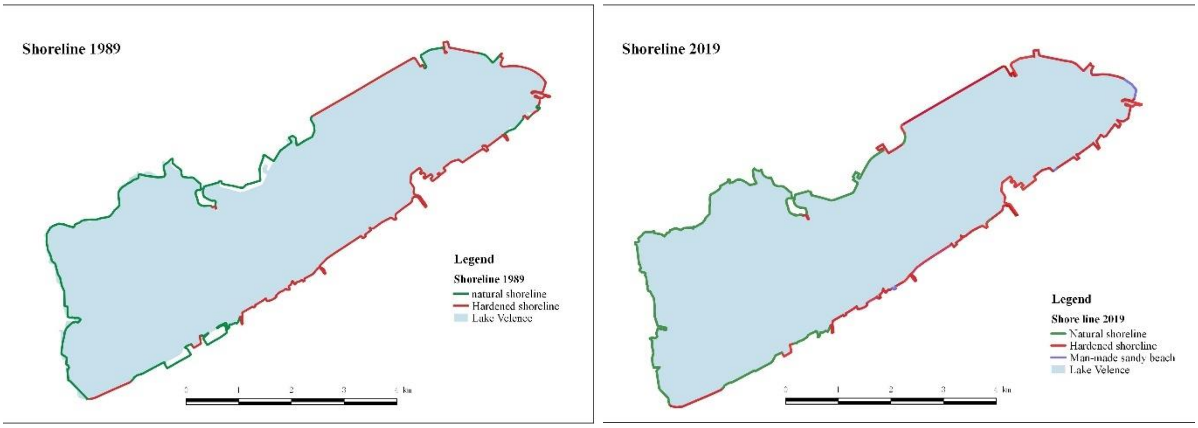


Figure 5.7 Shoreline of Lake Velence in1898 and2019

Several renovation and dredging projects since the 1980s have resulted in changes to the shoreline and nearshore areas of Lake Velence. Shore infilling area and retreat area are mainly in the western natural conservation area (Figure 5.7, Appendix 16), with the infilling areas about 57.72 ha in the nearshore zone and 31.77 ha of retreated area. In addition, the reclamation operations have altered the soils and sediments on the lake bottom or in other areas of the lake, and these activities have also directly modified the morphology of the shoreline of Lake Velence. The new infill areas are basically occupied by semi-natural land and habitats for birds and wild animals.

Table 5.2 Percentage of different types of shorelines in 1989, 2009, 2019

Shoreline type	**1989** % Of total length	**2009** % Of total length	**2019** % Of total length
Natural shoreline	55%	42%	42%
Hardened shoreline	45%	57.39%	56%
Artificial Sandy beach	0	0.61%	2.0%

5.2.5 Summary

This section presented the land use and land cover changes on the 0-200m shore zone of Lake Velence in 1990, 2009, and 2019. Also, study compared the changes in each land use type over the three time periods, and the results illustrate that the main changes from 1989 to 2009 show a decrease in agricultural land and water area. The decrease in semi-natural land becomes prominent during the period 2009-2019. In addition, the changes in the three subdivided lakeshore zones over the three decades were analyzed. The results illustrated that tourism-related land use (recreational area, tourism facilities, and tourism accommodation land) showed a significant increase in the 0-30m zone, forest land and tourist accommodation areas show a slight increase in the 30-100m zone, and the 100m to 200m zone showed a significant increase in urban land and forest cover.

5.3 A comprehensive study of LU/LC changes on two lakeshores: Lake Velence and Lake Balaton

As the two most representative natural lakes and domestic tourism destinations in Hungary, it is necessary to compare the parameters of land use/cover change in the two lakeshore areas and to investigate the changes in land cover associated with tourism development. The analysis of land use/land cover change is carried out by examining changes on land cover maps over time, measuring the area of change, and calculating the magnitude of LULC change. This section will present the degree of LULC change over a 30-year period for the shore zones of Lake Velence and Lake Balaton. Specifically including (1) describe the land use/land cover of the two lake areas in 1989 and 2019, and present the annual dynamic rate of change (q) and area change rate (C) for each LULC classification during this period. (2) Introduce the similarities or differences in land use/cover change between the two lakeshores; (3) An integrated analysis of the two lakeshores and a description of the correlation between the different types of LULC; (4) Illustrate the amount and distribution of marina growth in the nearshore areas.

5.3.1 LU/LC change and area change rates for the two lakeshores between 1989 and 2019

Table 5.3 shows that the condition of the land use /land cover of the 0-100m shore zone of Lake Velence from the beginning time 1989 to 2019 (Appendix 17). In 1989, more than the half proportion of total lake shoreland was occurred by semi-natural land (55.23%), followed by 14.44 % of recreational area and 8.59% of forests. While the proportion of the semi-natural land has fall to 48.27%, the recreational area hardly changed to 14.36%, forest land has increased to12.73 % in 2019.

The most notable change of the land area of the LU/LC classes in the shore zone from 1989 to 2019 was the decline of the agricultural land, with -7.55% of change rate per year, and -97.13% of area variation rate. And the increase of tourism accommodation area (*q*=1.6%, *C*=69.39%) and other tourism facility area (*q*=2.77%, *C*=66.79%). Unexpectedly, although new beaches have been built along the lake, recreational activities and water sports facilities become richer， in fact, the total area of the recreational land has not obviously changed during the study period.

Table 5.3 indicated that the area of the tourism development area (tourism accommodation area, recreational area, tourism facility area, etc.) and urban development area (settlements and transport land) have separately increased 5% and 3% of the total area, but the undeveloped area (plantation areas and semi-natural land) has decreased 7% of the total area, between the 1980s to 2019.

Table 5.3. LU/LCC in the 0-100m shore zone of Lake Velence (1989-2019)

LU/LC Classes	**1989**		**Area (ha)**	**2019**	**Change of land use area between 1989 and 2019**		**Annual rate of the change (q)**	**Area variation rate of land use (C)**
	Area (ha)	% Of the total area	Area (ha)	% Of the total area	Area (ha)	%	%/year	%
Tourist accommodation area	8.95	2.80	15.16	4.74	6.21	1.94	1.60	69.39
Recreational area	46.21	14.44	45.94	14.36	-0.27	-0.08	-0.02	-0.58
Other tourism facility	13.28	4.15	22.15	6.92	8.87	2.77	1.55	66.79
Transportation land	16.89	5.28	19.2	6.00	2.31	0.72	0.39	13.68
Urban area	13.12	4.10	20.82	6.51	7.7	2.41	1.40	58.69
Agricultural land	15.36	4.80	1.27	0.40	-14.09	-4.40	-7.55	-91.73
Forest area	27.49	8.59	40.72	12.73	13.23	4.13	1.19	48.13
Semi-natural area	176.72	55.23	154.47	48.27	-22.25	-6.95	-0.41	-12.59

The table 5.4 shows the land use and land cover changes in the 0-100m shore zone of Lake

Balaton from 1989 to 2019. In 1989, the share of semi-natural land (34.42%) on the shore zone of Lake Balaton was the most prominent, but by 2019 the urban area dominated with 26.42% of the total area due to the dramatic decline of semi-natural areas to 22.76% of the total area. Additionally, I observed a significant increase in the area of forest land in the lakeshore area, from 9.66% of the total area in the 1980s increased to 15.57% in 2019 (Table 5.4).

The results show that recreational land use and water-based tourism facilities have increased significantly throughout the shore zone of Lake Balaton over the last 30 years. Compared to land use and land cover in the 1980s, the rate of change for tourism facility land use increased by 44.34% in 2019. However, the area variation rate of semi-natural areas decreased 33.18%. Large-scale tourism infrastructure and recreational lands have replaced and occupied a large proportion of semi-natural lands (wetlands, meadows, and shrubs) along the lake.

Table 5.4 LU/LCC in the 0-100m shore zone of Lake Balaton (1989-2019)

	LU/LC Classes	**1989**	**2019**	**Change of land use area between 1989 and 2019**		**Annual rate of the change (q)**	**Area variation rate of land use (C)**
		% Of the total	% Of the total	Area (ha)	%	%/year	%
Tourism Dev.	Tourist accommodation	4.25	5.31	24.89	1.06	0.71	26.33
	Recreational area	13.98	16.90	68.78	2.91	0.60	22.08
	Other tourism facility	3.53	5.04	34.89	1.51	1.11	44.39
Urban Dev.	Transportation land	6.42	6.47	2.73	0.06	0.06	1.91
	Urban area	23.98	26.42	60.41	2.44	0.32	11.31
Un dev.	Agricultural land	3.77	1.52	-49.72	-2.25	-2.72	-59.22
	Forest area	9.66	15.57	135.20	5.91	1.48	62.83
	Semi-natural area	34.42	22.76	-254.31	-11.65	-1.22	-33.18

The most notable LU/LC change from 1989 to 2019 is represent in the increase of forest land, with a dynamic rate *(q)* of change of 1.48% per year, followed by the increase in the area of tourism facility (*q*= 1.11%， *C=44.39%)* and tourist accommodation area (*q*= 0.71%， *C=26.33%)*. However, the notable decline of the land area of LU/LC in the shore zone from 1989 to 2019 was the agricultural land (*q*= -2.72%, *C*=-59.22%), the semi-natural land (*q*=1.22%, *C*=-33.18%).

5.3.2 Changes in the main LU/LC categories on both lakeshores

The reclassification of land use and cover categories shows the change in the main land use categories from 1989 to 2019 for both lakeshores as seen in Figure 5.8 and Figure 5.9. Compared to 1989, the tourism development area (tourism accommodation area, recreational area, other tourism facilities areas) on the Balaton Lakeshore increased from 22% to 27% of the total area in 2019. The urban area (settlements and transport land) increases by 3%. However, undeveloped areas (woodlands, semi-natural lands and agricultural lands) account for 48% of the total area in 1989, decreasing to 40% by 2019.

Figure 5.9 shows the change in the main land use types on the 0-100m lakeshore of Velence from 1989 to 2019. Similar to Lake Balaton (Figure 5.8), the area of the tourism development area (tourism accommodation, recreation, tourism facilities, etc.) and the urban development area (settlements and transport land) both increased over the three decades, by 5% and 4% respectively. but the area of the undeveloped area (plantation area and semi-natural land) declined significantly, by 8%.

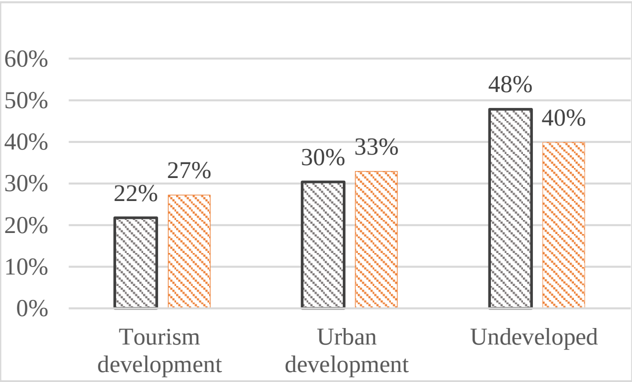


Figure5.8 Changes in the shore zone of **Lake Balaton**

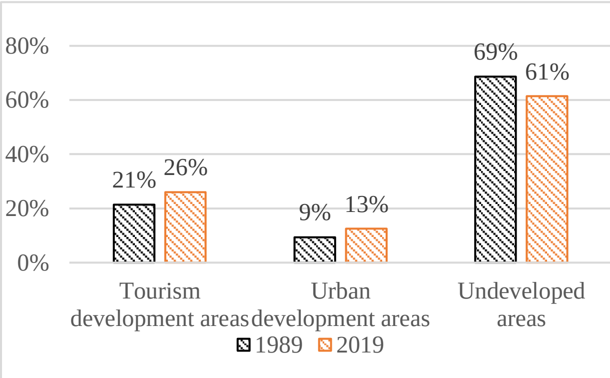


Figure 5.9 Changes in the shore zone of **Lake Velence**

The comparison of the main land use categories in the two lakes study areas shows a clear upward trend in the share of developed land (including settlements and tourism development areas) in the riparian areas of both lakes. At the same time, both lakeshore areas are facing a marked decrease in undeveloped land (mainly semi-natural land).

5.3.3 An integrated analysis of the LULC change for the two lakeshores

According to the Wilcoxon signature rank test, Figure 5.10 shows the statistical significance ($p < 0.01$) between all land use and land cover types for the two lakeshore areas (combined Lake

Balaton and Lake Velence) across time (1989 and 2019).

Table 5.5 illustrates in detail the overall changes in land use/land type for the two lakeshores. From 1989 to 2019, the area of agricultural land (C=-64.59%) and semi-natural land (C=-30%) in the lakeshores has decreased significantly. The decrease in agricultural land use is also evident in the shore areas of both study lakes, which may be due to the small share of agricultural land use in the lakeshore areas since the 1980s (3.87%).

Meanwhile, there has been a substantial increase in the area of forest land (C=59.62%) and tourism facility areas(C=46.21). In addition. the most notable dynamic annual rate of land use/land cover change is for agricultural land, which occupies -3.43% per year, followed by forest lands (1.59%) and semi-natural land (-1.16%).

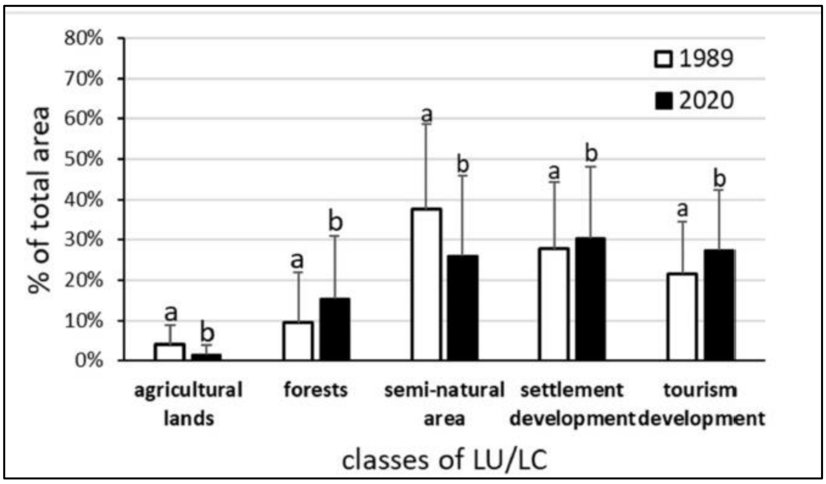


Figure5.10 Changes in land use/cover on the lakeshores between 1989 and 2019

Note: Data marked with the same letter (a or b) at two time period did not differ statistically ($p<0.01$).

Table 5.5 Magnitude of LU/LC change in the two study lakeshores between 1989 and 2019

	% Of the total area in 1989	% Of the total area in 2019	Change of land area (ha)	Area variation rate of land use (C)	Annual rate of the change (q)
Tourist accommodation area	4.07	5.24	31.10	28.81	0.88
Recreational area	14.05	16.58	68.51	18.02	0.58
Other tourism facility area	3.61	5.28	43.76	46.21	1.30
Transportation land	6.28	6.41	5.04	2.17	0.10
Urban area	21.50	23.94	68.11	11.37	0.39
Agricultural land	3.90	1.38	-63.81	-64.59	-3.43
Forest area	9.54	15.22	148.43	59.62	1.59
Semi-natural area	37.06	25.94	-276.56	-30.00	-1.16

According to the Spearman's rank test (Figure 5.11), significant negative correlations were found between changes in agricultural land and forest area ($p<0.01$, $r_s=-0.4$) and between changes in semi-natural land and forest area ($p<0.01$, $r_s=-0.54$). However, no significant correlations were observed from tourism development sites and semi-natural sites.

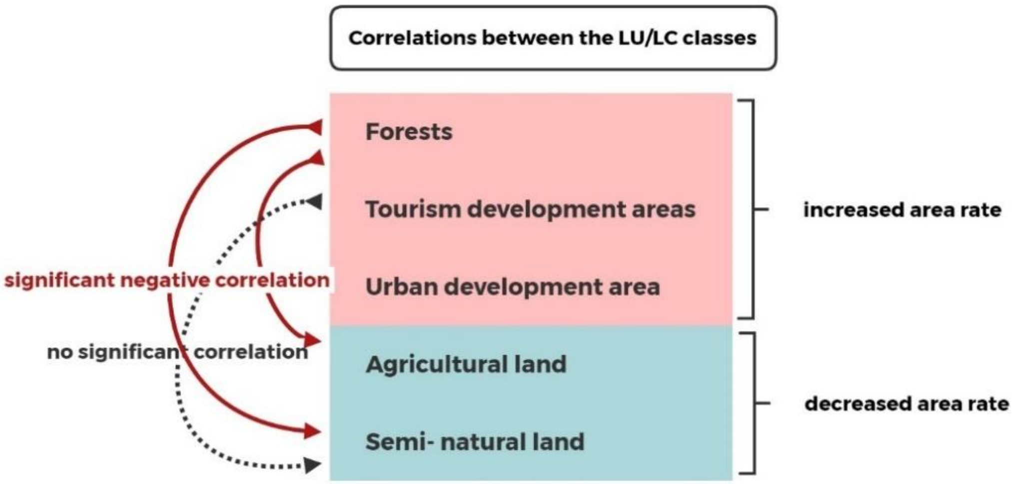


Figure5.11 Correlations between the classes of LU/LC

5.3.4 Expansion of marinas in nearshore areas

Driving by the development and popularity of water-based tourism in Hungary， and the growth of water-based recreation activities (such as boating, yachting, and sailing) have promoted the intensive development of marinas, piers, and harbors, as well as recreational land use. Over the past few decades, plenty of water sports facilities, shipyards, marinas, and ports have developed along the lake region of Hungary (Figure 5.12, Appendix 18), various sailing schools, and yacht clubs wildly dotted along the lakeshore zone.

In the 1980s, there were overall 28 marinas and 24 ports along the shore zone of Lake Balaton and Lake Velence, 18 of which marinas were located in Lake Balaton, and 10 in Lake Velence. At present, a total of 59 marinas and 27 boat ports were established along the shore zone of Lake Balaton and Lake Velence, seven of which have a capacity of over 200 berths. The marinas are evenly distributed over the entire shore zone of Lake Balaton and the southern shore of Lake Velence from Velence to Agárd. The number of marinas on Lake Valence has remained almost the same and has not changed noticeably in size over the last three decades, but the number of marinas on Lake Balaton has increased sharply from 18 in 1989 to 49 in 2019. And most of the original marinas in the 1980s have expanded in capacity and area. Difference to the distribution of marinas in the 1980s, most of the new marinas and expanded marinas are concentrated in the Keszthely region in the west of Lake Balaton, and the northeast Balatonfűzfő region.

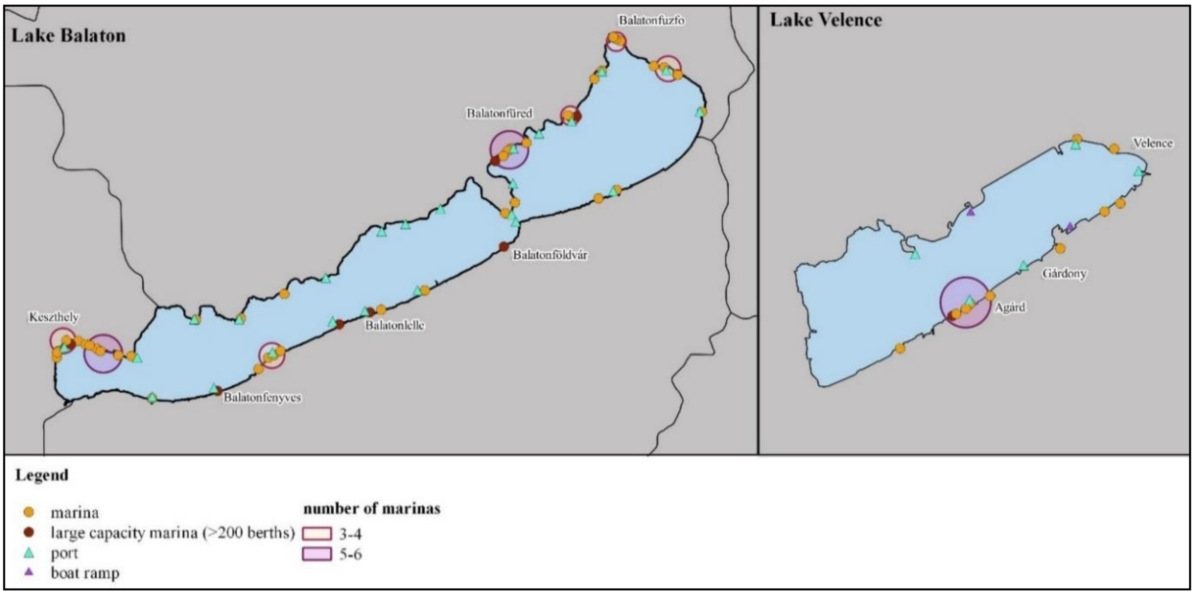


Figure5.12 Distribution of marinas and ports in the lake regions

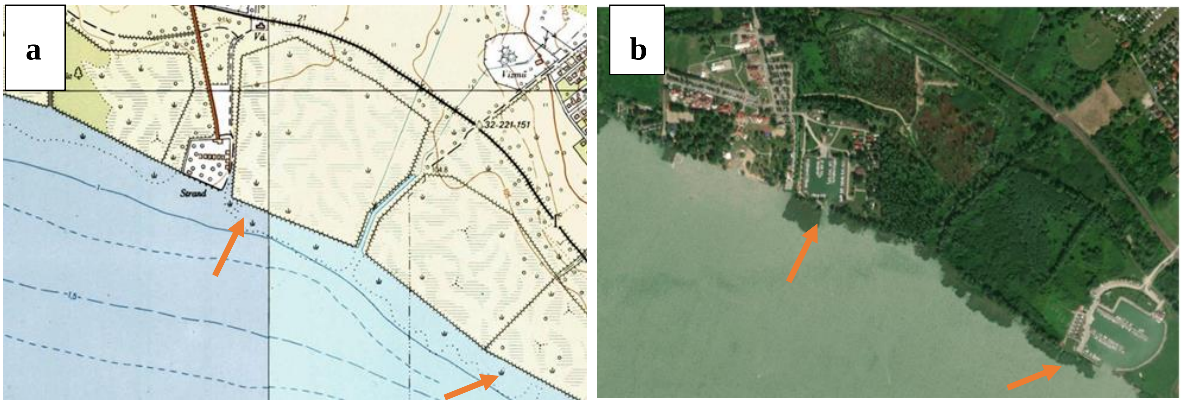


Figure 5.13 Marina expansion in the shore of Lake Balaton

Note: Lake Balaton (46°45'42.5"N 17°17'22.3"E: b, d) Arrows indicate (respectively) semi natural land (b -1989) transform into tourism development area (a, b – 2019).

Since 2000, the local government has initiated several development concepts that point to the necessity of investing in the development of boat ports and marinas to promote yacht tourism and fishing tourism in Lake Balaton (Buday-Sántha, 2007). The most emblematic new marinas of the last decade are the marina of Balatonfenyves and the Vonyarc Marina established in 2016. When completed, the marina of Balatonfenyves becomes the second-largest marina on Lake Balaton, covering an area of 4 hectares and able to accommodate 350 berths in the peak season. Although there has not been an apparent increase in the number of marinas on the shore zone of Lake Velence, the extension and construction of the piers and promenades have been particularly noticeable in recent years.

5.3.5 Discussions

The LULC change may occur due to direct or indirect human interventions (Etter et al., 2006; Tadese et al., 2020). The studies of the two lake areas of Balaton and Velence are not representative of land use change trends in all lake areas in Hungary, but they can reflect some similar common problems. For both lakeshores, the afforestation achievements of the last thirty years have been productive. However, both lakeshores are also under threat from various development activities. On the one hand, there is a lack of effective monitoring and management of the lakeshore areas, while on the other hand, the growth of tourism has led to a tendency for landowners to convert traditional agricultural land into more profitable uses.

5.3.5.1 Causes of LU/LC change in the lakeshore areas

The factors leading to land use and cover change are complex and multiple. For the land use changes in the two lakeshores analysed above, I argue that socio-economic drivers (social and economic variables, development strategies, political factors) are the main causes of LU/LC changes in the lakeshore areas of Velence and Balaton. Hungary went through a special period of economic and political transition from the 1980s to the 1990s, with changes in land policy and economic development plans, and these factors are the major causes of land use/cover change in the lakeshore areas.

Tourism development in the lakeshore area

Unlike in Eastern European countries such as Poland, this high level of development in the lakeshore areas of Balaton and Velence is similar to that observed in the Mediterranean coastal tourism areas. This may be due to the tourism attributes of the lakes within Hungary and the high tourism demands in the country. Land use and conversion is fundamental to the tourism industry and can be directly linked to its development (Boavida-Portugal et al., 2016). The development of tourism was seen as a top priority by the new economic mechanism that started in 1968. At the same time, lake tourism and holiday tourism became the main tourism products in Hungary

(Remenyik et al., 2013). According to the general organizational plan for the Lake Velence region issued by VÁTI[3], "In the Lake Velence basin, tourism takes precedence over agriculture. Every plan that goes against the interests of tourism must be closed or prohibited from expanding". (HRDUP, 1980).

Lake Balaton and Lake Velence are the country's main natural tourist attractions and major destinations for summer tourism and holidays in the country. The development of tourism facilities and commercial accommodations on both shores of the lake was in full bloom as early as the 1980s. As can be seen from section 5.3.3, in 1989, over 50% of the land on the shore of Lake Balaton was developed and the shore of Lake Velence also accounts for 30% of the developed land. In the 1990s, suburbanization and the growing importance of tourism changed the size and structure of the towns on the shores of Lake Velence (Tamáska, 2006).

With the development of real estate and the value increase potential of the land, a large number of semi-natural areas have been transformed into tourism investment land for resorts and second homes (Lőrincz et al., 2021). The development of lake tourism has stimulated the growth of recreational activities and economic income for the local communities, and in particular the tourism infrastructures located in the nearshore zone have thrived in the last decades. Efforts to meet the demand for residential housing and related services and infrastructure, as well as the establishment of new industries, have also led to an increase in the area of settlements and transport land.

Afforestation

Afforestation on the shores of Lake Balaton and Velence has been a remarkable success over the last three decades (Figure 5.14). To harmonizing the tourism advise impacts on the lake, the regional planning plan of Lake Balaton increasing the size of the nature conservation areas (Wettstein, 2013). The main changes in Lake Balaton catchment between 1990 and 2012， include a continuous increase of the forest area and a remarkable on-going decrease of arable

1. [3] full name VÁTI Hungarian Regional Development and Urbanization Nonprofit Kft.

land (Kertész et al., 2019). With regard to the increase in forest land and the decrease in agricultural land, Dessel (2008) argues that this is linked to the collapse of the collective farming system. The de-collectivization of agriculture and the reduction of the rural population directly led to the gradual conversion of less fertile soils into permanent grasslands or forests (Dessel et al., 2008). Previous studies have concluded that afforestation as the most meaningful positive change in the lakeshore zone (Furgała-Selezniow et al., 2020), in addition to the transformation of built-up areas into other forms of LU/LC that are also beneficial for the lakeshore environment.

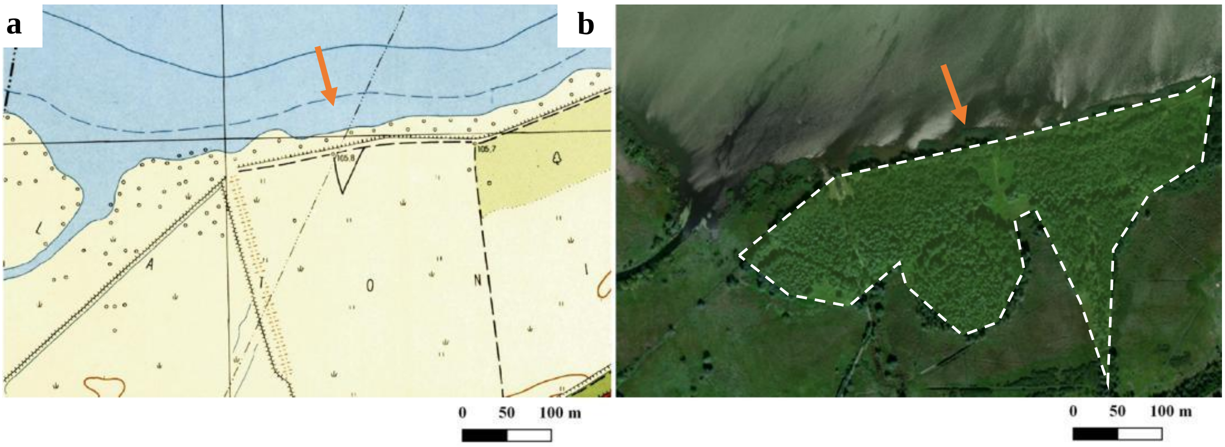


Figure5.14 Afforestation in the shore zone of lake Balaton.

Note: **a** represents the meadow land in the shore zone of Lake Balaton (46°42'23.9"N 17°16'11.2"E) in the 1980s, and **b** indicates the meadow landscape transformed into woodland in the 2019.

Land Privatization

Following the privatization of land since the 1990s, the lakeshore area was divided into a large number of small properties, and a large number of new owners was created, which leading to the abandonment of agricultural uses (especially vineyards) and an increase in floor space (Buday-Sántha, 2007). Some traditional agricultural land and vegetable gardens are being converted into tourist accommodation areas and real estate investments as residents are seeking more profitable returns on their land. At the same times, a considerable amount of fragmentation and vacant land has also been observed throughout the lakeshore areas of Hungary. Habitats and natural green spaces are affected by the fragmentation of neighboring construction areas (Boavida-Portugal et al., 2016).

Figure 5.15 New built-up area on the shore of Lake Balaton

5.3.5.2 Limitations of the LU/LC change analysis

Due to the lack of local scale map resources (high-resolution aerial imagery) the current LU/LCC analysis study period only focuses on changes and dynamics over a 30-year period, and compared the LU/LC of the two lakeshores between 1989 and 2019. If more map resources and spatial data become available in the future, I think it would be worthwhile to measure and analyzing LU/LC over a wider range of time periods, preferably every 10 years. It is possible to carry out an analysis and comparison of LU/LC changes in the two lakes over different time intervals (1989, 1999, 2009 and 2019).

In addition, the current study area does not include all of Hungary's lakeshores. Other lakes, such as Lake Tisza and Lake Fehér, were not considered in this study, due to the fact that they are artificial lakes and have a different development context and strategy than the two lakes studied above. Nevertheless, to adequately explain and describe the LU/LCC in the Hungarian lakeshore area, future studies could include other lakes in Hungary for investigation and analysis in order to explore the characteristics and rate of land cover change under different development strategies.

5.3.6 Summary

In this study, land use/land cover changes from 1989 to 2019 were analysed and compared for two lakefront areas (Lake Velence and Lake Balaton). The annual rates and area change rates of

LULCC in the study areas are presented in detail. Similarities in LULC changes were finally identified, as well as correlations between the classes of land use. The results show that from the 1980s to 2019, the shore areas of the two lakes have mostly seen an increase in land for tourism development and woodland, and a significant decrease in agricultural and semi-natural land. The near-shore areas of both lakes are also under pressure from the expansion of tourist facilities and marinas.

5.4 Public perceptions and preferences toward lakeshore landscapes

This section will present the aesthetic preferences and perceptions of the public (consisting of lakeshore residents, experts, and outdoor enthusiasts) for different levels of development of the lakeshore landscape, as well as the aesthetic evaluation of different riparian landscape types. The drivers and visual elements of the landscape that lead to preference bias and visual discomfort will also be presented. Finally, differences in landscape preferences between experts and lakefront residents will be discussed.

5.4.1 Public preference for lakeshores at different levels of development

According to the extent of human influences and different intervention levels, five representative photos from different locations along the Lakeshore were selected for evaluation, which divided into five typical types, from an artificial lakeshore landscape transition into a natural/ “wild” lakeshore P10=artificial lakeshore, P11=semi-artificial lakeshore, P12=semi-natural lakeshore P13=near natural lakeshore P14=natural/ “wild” lakeshore). Each of the pictures showing a different degree of naturalness and landscape features. As table 5.6 shows, the most popular landscape scene was the semi-artificial lakeshore (41% of respondents prefer P11), followed by the artificial lakeshore (26%) and the near-natural lakeshore (25%). However, both the natural / “wild” lakeshore (37% of participants dislike P12) and the semi-natural lakeshore (37%) are the least favored lake landscape scenes. Thus, the degree of naturalness and human intervention have a significant effect on aesthetic preferences in the lakeshore landscapes of Lake Velence. Both highly artificial shores and highly natural shores may be negatively evaluated because of the visual enclosure of the views and limited visual connections. Compared with a natural lakeshore completely covered with aquatic plants, respondents preferred an artificial lakeshore with a neat appearance, accessibility, and well maintained (Appendix 7).

Table 5.6 Perceived votes of five varying comparison lakeshore scenes

Scene points	Favorite		Least favored	
	votes	% Within group	votes	% Within group
point10	17	26	13	20
point11	27	41	1	1
point12	2	3	24	37
point13	16	25	3	5
point14	3	5	24	37
Count	65	100	65	100

Note: P10=an artificial shore background completely covered buildings, P11=a semi-artificial shore with partial buildings background, P12=a semi-natural shore with limited access, P13=a near-natural shore with the unobstructed pavement, P14=a natural shore partial covered with aquatic plants

5.4.2 Correlations between public preferences and visual landscape indicators

To find out the influences of lakeshore landscape factors on aesthetic preference judgments, investigate the correlations between landscape features and perceived votes (lakeshore scenery points 10-14) is required. As Table 5.7 shows that the perceived scores are significant positive correlated with accessibility ($r=0.82$, $p<0.01$), visual range ($r=0.81$, $p<0.01$), and maintenance state ($r=0.79$, $p<0.01$). However, it is negatively correlated with naturalness ($r=-0.46$, $p<0.01$), aquatic plants ($r=-0.79$, $p<0.01$) and vegetation coverage ($r=-0.4$, $p<0.01$).

The results reveal that the degree of naturalness, aquatic plant coverage, and vegetation coverage does not significantly affect aesthetic preferences in the lakeshore landscapes of Lake Velence. In particular, the natural / “wild” lakeshore type has dense vegetation and riparian plants. It provides a good condition for the habitat and the species of the lake, but the overgrown riparian plants may block the visual range, visual connections. To a certain extent, the closure of the visual zone caused visual unpleasantness. This result is coinciding with an earlier study, it pointed out that riparian plants can have mixed effects on the waterfront landscapes: the riparian plants can increase the visual attractiveness of the waterfront landscape but may also produce perceptions of an unsafe atmosphere (Purcell et al., 2002). Additionally, the following landscape characteristics could produce positive landscape preferences: a wide field of vision, access to the edge of the water, well planned, well organized and good maintenance.

Table 5.7 Correlations between perceived votes and landscape indicators

		1	2	3	4	5	6	7	8
1	Perceived votes								
2	Naturalness	-.46**							
3	Visual range	.81**	-0.03						
4	Vegetation coverage	-.40**	1.00**	0.02					
5	Aquatic plants	-.79**	.88**	-.42**	.86**				
6	Accessibility	.82**	-.78**	.39**	-.75**	-.96**			
7	Human activity	.46**	-1.00**	0.03	-1.00**	-.88**	.78**		
8	Maintenance	.79**	-0.05	.73**	-0.02	-.51**	.64**	0.05	

Note: N=65 **P<0.01.**Correlation is significant at the 0.01 level. For scene point 10-14

5.4.3 Public preferences for different revetment types of lakefronts

Early studies have suggested that people's aesthetic preferences are mainly due to the impact of vegetation (species of plants, plant color, seasonal effects) in the environment, followed by the environmental atmosphere etc. (Tyson, 1998). Therefore, this study grouped lakeshore landscapes with similar vegetation cover for preference assessment. These lakeshore landscapes differed mainly in terms of type of berms, type of shoreline (soft or hard shoreline), accessibility, landscape elements, applied paving materials, etc.

As table 5.8 shows, the P3 (the shore landscape with a natural beach and curved wooden groynes) is the most popular lakeshore type (57 % of participants voted) in the first group, fewer respondents chose P1 (28%), and the least favored was P2 (11%). Most of the respondents believed that scene P3 is the most natural and untouched one, the shape of the revetment is distinctive and the materials were natural. The perceptual reviews from the participants pointed out that P3 is more attractive because the beach is lovely, well-crafted, and makes people feel to be invited. P5 (a rip/rap bank slope with open grassland) received the highest perceived votes of group 2 (Appendix 5), nearly half of people (48 %) like point 5, 26% prefer P4, and the rest of 18% prefer P6. The general positive feedback about P5 including: it close to the water, has a good vision, no fences, a large grassy area with good usability, as well as a calm environmental atmosphere. In group 3, most of the people vote P7 (60%), followed by P8 (14 %) and P9 (12%). In comparison with the other two scenes, the shore condition and revetment type of P7 (a rock slope revetment with unobstructed pavement) have more advantages, due to the higher safety (the rock breakwater prevents the spread of water on the sidewalk, and accidentally falls) and better visual perception (the unobstructed shoreline and the rocks component looks more natural than the concrete embankment).

Table 5.8 Preference results of three comparison scene groups by vote

	Scene group1				Scene group 2				Scene group 3			
Scene points	P1	P2	P3	Invalid	P4	P5	P6	Invalid	P7	P8	P9	Invalid
Votes	18	7	37	3	17	31	12	5	39	9	8	9
% Within group	28	11	57	4	26	48	18	8	60	14	12	14

Note: n=65. P1=a concrete revetment with partly sand slope, P2=a shore with wooden groyne and timber piles, P3=a natural beach with curved wooden groyne; P4= a shore entire edge provided metal railings; P5= a rip/rap bank slope with openly grassland, P6=a shore restricted by aquatic plants and wooden fences on both sides of the pavement; P7=a rock slope revetment with unobstructed pavement, P8=a rock slope revetment with obstructed pavement, P9=a concrete bank without sloping breakwater.

The changes of the visual contents (such as color, texture, volume uncoordinated and occlusion of the visual zones) and features in the environment may influence visual amenity and landscape aesthetic value (Institute & I.E.M.A, 2013). Nevertheless, the perceived votes (Table 5.8) and the general perception statements reveal that these slight deviations and small-scale elements have no significant negative impact on the visual amenity and aesthetic preferences, in the case of P2 (temporary hut exist in the lakeshore), P5 (multicolor beach umbrellas in the environment) P6 (wooden fences in the landscape) and P8 (boats exist in the lakeshore). However, those elements may partially block the visual range or caused an obstructed pavement and grassland, and leads to a loss of landscape accessibility and functionality.

5.4.4 Preference differences between experts and waterfront residents

According to the professional background and residence of the participants, I selected two groups of most representative participants (experts and waterfront residents) and analyzed whether there are differences in their preferences for the lakeshore landscapes (Table 5.9). The results of the Fisher's Exact Test for all four comparative viewpoint groups showed no statistically significant differences between the two participant groups ($p1=0.71>0.05$, $p2=0.07>0.05$, $p3=0.32>0.05$, $p4=0.98>0.05$), which reveals that landscape preferences were roughly similar between the waterfront residents and experts (Figure 5.16).

However, as can be seen in Table 5.9, there is a significant difference in the proportion of aesthetic votes between Riverside residents and experts at points P4, P6 and P8. Other points, such as P1, P3, P5, and P9 also showed a remarkable difference. According to structured interviews and comments from the public, 41.7% of experts liked survey site P4 (A well-organized lakeshore with railings) because it appeared well-maintained, clean and organized and contained contemporary landscape and architectural design features. However, only 14.8% of waterfront residents voted for P4, mainly because they did not think it was possible to have any water sports and recreational activities in this place. Similarly, in the P8 (a rock slope revetment shore with colorful boats), 20.8% of waterfront residence and 8.7% of experts voted it, which also points out that experts are concerned about the visual impact and landscape beauty, while residents are more pay attention to recreation and practicality.

Figure5.16 The perceived vote count between experts and waterfront residents

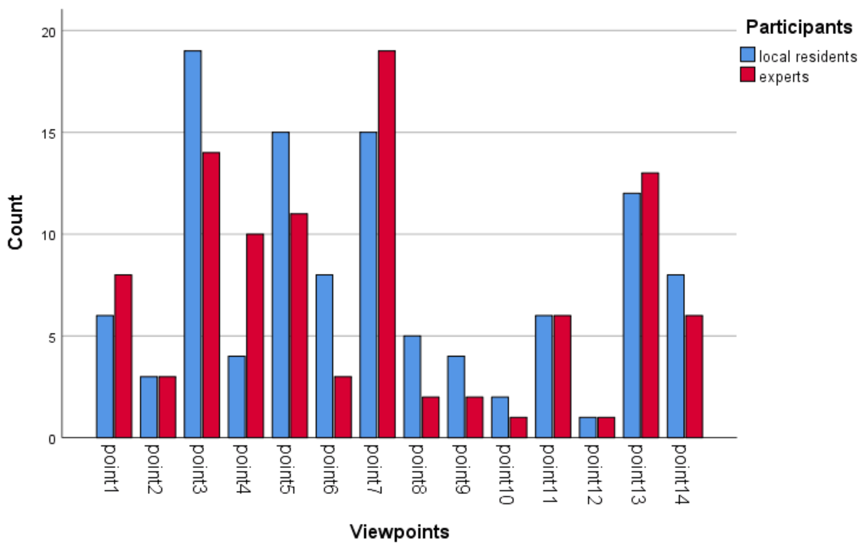


Table 5.9 Viewpoints * Participants Crosstabulation

		Waterfront	Experts	Total
group1	point1	21.4	32	26.4
	point2	10.7	12	11.3
	point3	67.9	56	62.3
	Count	28	25	53
group2	point4	14.8	41.7	27.5
	point5	55.6	45.8	51
	point6	29.6	12.5	21.6
	Count	27	24	51
group3	point7	62.5	82.6	72.3
	point8	20.8	8.7	14.9
	point9	16.7	8.7	12.8
	Count	24	23	47
group4	point10	6.9	3.7	5.4
	point11	20.7	22.2	21.4
	point12	3.4	3.7	3.6
	point13	41.4	48.1	44.6
	point14	27.6	22.2	25
	Count	29	27	56

Note: cells of each group have expected count less than 5.

5.4.5 Discussions

The evaluation of lakeshore landscapes and public aesthetic preferences are complicated due to the diversity of influencing factors and the different backgrounds of participants. Nevertheless, the evaluation method of public participation is a good detection method for the lakeside landscape design, provide valuable opinions and references to the relevant authorities and designers. Lakeshore landscape preferences investigation and assessment help us have a better understanding of the public's preferences and demands of lakeshore residents. Exploring the interactions between waterfront landscape features and landscape preferences can provide valuable information for decision makers and planners. Identifying similarities in landscape preferences between different participants can help to develop general guidelines for waterfront planning and design.

This study revealed that the main effect factors of preferences were related to the maintenance state, hydrophilicity, functionality, accessibility and construction materials in the environment. In addition, the scale of building, vegetation coverage, and the extent of the visual range, can also affect the evaluation results of the aesthetic preference in lakeshore landscapes. What are the acceptable range and comfortable proportions of building scale and riparian vegetation cover in the lakeshore landscapes for the public? further discussions are required in the future study.

5.4.5.1 The impact of man-made structures on lakeshore landscape preferences

Many researches has concluded that human structures and artificial elements have a negative impact on the visual quality of the landscape and public preferences (Acar et al., 2006; Arriaza et al., 2004). From this perspective, elements such as surface paving materials, enveloping elements, buildings and the number of structures is expected to have a negative impact on the visual quality of the landscape. However, in this study, the results show a somewhat positive relationship between human structure and landscape preference. Semi-artificial lakefront landscape is the most popular type compared to the wild lakefront landscape. This is because it appears to be more organized and maintained but not as dull as a highly artificial lakeshore. In addition, the findings in this paper show that the degree of naturalness, aquatic plant cover and vegetation cover are significantly negatively correlated with aesthetic preference for lakefront landscapes. The results of this study differ from previous studies.

5.4.5.2 Differences in preferences between the experts and waterfront residents

Vouligny (2009) argued that: experts have the ability to quantify the aesthetic value of a landscape because their judgement of landscape value is based on the intrinsic value and physical attributes of the landscape. However, residents' evaluation criteria are generally related to feelings, life experiences and their perceptions of the place (Vouligny et al., 2009).

In the survey of lakeshore preferences, there were no statistically significant deviations in the preferences of experts and waterfront residents for the 14 sample sites. However, a summary of the participants' perceptual statements in subsequent interviews indicated that waterfront residents are more concerned about the functionality of landscape, accessibility, maintenance, recreation, and pay less attention to visual beauty, while experts pay more attention to the design, aesthetic and order of the landscape. In addition, the responses show a shared strong demand from residents and experts for the usability and well maintenance of the lakeshore landscape.

Christian (2001) believes that the value ranking of landscape features and visual expressions can be carried out at the level of ecological and sustainable land use and planning, and that this ranking requires a combination of specialist judgement, informed opinions and public preferences. The findings in this section could remind designers and decision-makers of issues that may be overlooked in the planning processes, as well as the necessity of subsequent management and maintenance, which also provides new insights for our future research. Regarding the different opinions and preferences between the people who had a different gender and live environment, can discuss it more specifically in the future.

5.4.6 Summary

This section demonstrates public perceptions and preferences for different lakeshore landscapes. The landscape elements that influence landscape preferences are identified. Differences in preferences between the different participant groups are also discussed. The results show that the semi-natural type of lakeshore landscape is the most popular. There was no significant relationship between public preferences and man-made structures. Concerns differed between the different participant groups, but there were no statistically significant differences in aesthetic preferences.

5.5 Impact of lakeshore modifications on the visual landscape quality

As analysed in the section 5.2, there has been a dramatic increase in bare land and grey field on the 0-100shore zone of Lake Velence between 2009 to 2019. The hardening of the lakeshore is also becoming more severe. These status and issues are mainly caused by various construction projects and developments on the lakeshore. Intensive development activities and external disturbances in the lakeshore area have a direct impact on the visual quality of the lakeshore landscape. This investigation seeks to explain how the visual quality of the lakeshore landscape is influenced by the construction process and modifications. As well as stating what types of modifications and factors can have a significant impact on the lakefront landscape. The following sub-sections present the results based on the different assessment methods. The negative visual elements affecting the receptors during the construction phase will also be specified and enumerated. Lastly, the assessment methods applied in this study will be compared and their strengths and weaknesses will be discussed.

5.5.1 Evaluation results of the landscape metric-based assessment

The LMBA approach is primarily based on the objective identification of landscape characteristics, describing and measuring changes in landscape composition and quality through changes on a spatial-temporal scale. The main result of the assessment is a qualitative description of each of the landscape indicators listed in Table 4.3.

Among all the investigated sites, the results assessed with the LMBA method (Table 5.10) showed that Site 5 (stockpile site) received the highest negative visual impact value (VLMBA=-48), where is the most significantly impacted by the shore modifications and construction operations. Followed by Site 2 (tailings pond) and Site 6 (promenade construction site), with scores of -36 and -27 respectively. From the field surveys and examination of HD aerial photographs of changes in landscape features, it was found that these high impact sites have moderate to large land cover changes caused by construction operations. And all these scenes are in a continuous process of medium to long-term disruption.

Table 5.10 Measurement of landscape indicators for visual impact

Categories	Landscape indicators	S1	S2	S3	S4	S5	S6
Landscape sensitivity (LS)	LS	slight	moderate	slight	slight	moderate	moderate
Magnitude of the changes (MC)	CA	medium	medium -large	small	small	large	medium - large
	VD	20%-50%	50%-70%	<20%	<20%	>70%	50%-70%
Duration effect (DE)	DE	medium term	long term	medium term	temporary	long term	medium-long term
VLMBA	VLMBA	**-8**	**-36**	**-4**	**-2**	**-48**	**-27**

5.5.2 Visual impact assessment based on perceptual attributes

Based on the 52 participants' valid ratings and responses to the aesthetics of the survey sites at the two time periods (pre-construction and during construction), the Wilcoxon signed-rank test indicated that there were statistically significant differences in the aesthetic value of the landscape at all survey sites before and during construction (Z=-12.277，P value <0.01). As shown in Table 5.11, the perceived aesthetic scores and median scores at all survey sites during the construction period (T2) were significantly lower than the perceived aesthetic scores of the previous landscape (T1). The lakeshore modifications and associated construction activities caused a significant decline in the visual quality of the landscape. The most noticeable aesthetic means difference values between the two periods occurred at the stockpile site (S5), followed by the reconstruction site of the embankment and pavement (S3), and the new tailings pond site (S2). However, the smallest aesthetic difference value between the two periods occurred at the promenade construction site (S6).

It is observed from the perception-based assessment survey that the public's rating of the disturbed lakeshore scene is closely related to the visual quality of the pre-construction landscape. The more picturesque the scene, the more visually fragile it is, and any disturbance or intrusion can have a substantial visual impact. For example, S5 received the highest aesthetic rating (4.19) among all surveyed sites before construction (T1), but dropped dramatically to 2.1 during the construction (T2). In contrast, Site 6 was the least popular before construction, but it received higher scores than the other sites during the construction phase, thus producing the least difference in the visual quality of the landscape between the two time periods.

Table 5.11 Visual aesthetic ratings of the survey sites in different times

Sample site	T1 (Before)		T2(During)		Difference		Z	P value of Wilcoxon Signed
	Mean	Median	Mean	Median	Mean	Median	T2-T1	T2-T1
S1	3.58	3.5	2.00	2	1.58	2	-5.369[b]	0.000
S2	3.60	4	1.92	2	1.67	2	-5.321[b]	0.000
S3	3.65	4	1.79	1	1.87	2	-5.512[b]	0.000
S4	3.52	3.5	2.65	2.5	0.87	1	-3.611[b]	0.000
S5	4.19	4	2.10	2	2.10	2	-6.172[b]	0.000
S6	3.48	4	2.67	3	0.81	1	-3.060[b]	0.002

Note: N=52, the rating of the aesthetic value based on a scale from 1 (least beautiful) to 5 (very beautiful). [b] Based on positive ranks, $p<0.05$ indicates statistically significant change. S1=a pavement renewal site, S2=a new tailing pond field, S3= Site being reconstructed for embankment and walkway, S4=demolition site, S5=stockpile field, S6=new promenade construction site.

5.5.3 A comparison and integration of the evaluation results of the VPBA and LMBA methods

Spearman's rank correlation coefficient was computed to assessing the relationship between visual perception-based assessment (VPBA), landscape metrics-based assessment (LMBA), and applied landscape indicators in the LMBA. Table 5.12 illustrates the correlation between the result of visual perceptual assessment and landscape metrics-based assessment showing that there is no statistically significant correlation between the evaluation results. Interestingly, no significant correlation was also found between the results of the visual perception assessment and the indicators applied in the objective LMBA (landscape sensitivity, land cover change, and construction duration).

Comparing the visual impact evaluation results from the LMBA approach and the VPBA approach (Table 5.13), it was found that half of the sites had the same visual impact results obtained by the two applied assessment methods. Differences in the degree of visual impact assessment are reflected at S2, S3, and S6, and the visual impact degrees of S2 and S6 obtained from the landscape metrics-based assessment are higher than the visual perception evaluation. This difference is mainly due to the wider visual range taken into account according to the VPBA method, and the cumulative effect of construction duration. Participants' ratings are based on the immediate perception of incongruities and changes in visual zone.

Combining the visual impact values from the two assessment methods, Table 5.13 shows the final aggregate rating results (FDI), with Sites 2 and 5 receiving the highest visual impact grades, both rated D, implying a significant negative visual impact.

Table 5.12 Correlations between the VMBA, the VIBA, and the applied indicators

	V_{VIBA}	LS	MC	DE
V_{LMBA}	0.664	-.928**	.896*	.952**
V_{VIBA}	1	-0.447	0.539	0.674

Note: N=6, ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level.

Table 5.13 Impact level ratings for six survey sites based on different methods

Method	Degree of visual impact					
	S1	S2	S3	S4	S5	S6
DVI1	b	d	b	b	d	c
DVI2	b	c	c	b	d	b
FDI	B	D	C	B	D	C

Note: DVI1= degree of visual impact evaluated based on landscape metrics. DVI2= degree of visual impact of the assessment based on visual perception, FDI=final degree of visual impact from the integrated methods. The visual impact degrees from a class to e class (a or A=no change, b or B=slight negative impact, c or C=moderate negative impact, d or D=significant negative impact, e=major negative impact)

5.5.4 Visual impact factors during the construction phase

The public voted on the elements that negatively affected the change in the visual quality of the lakeshore landscape during the construction phase. According to the results received (Table 5.14), the highest percentage of factors contributing to the negative visual impact was the damaged vegetation (LC1) at about 22%, followed by 18.4% of the stockpiles (IV1), and around 17.4% of unpaved pavement or bare land (LC2).

Of the general visual impact categories (Figure 5.17), almost 39.4% of the negative visual impact votes was related to land cover change (LC), 34.5% of the impact categories was occupied by volumetric intrusion elements (IE), and high contrast material elements (EM) and other peripheral elements (SE) accounted for 15.5% and 11.9% of the total impact categories respectively.

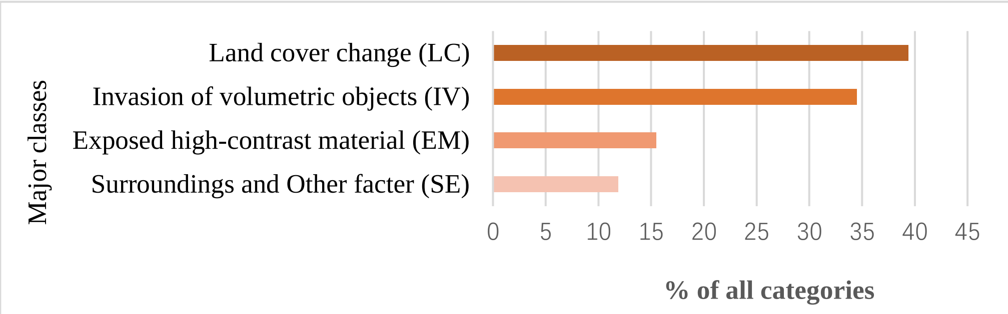
In follow-up interviews, participants expressed concerns about construction activities on the lakeshore, dissatisfaction with the loss of green space and the cluttered environment, and a number of local residents felt that the hardened shoreline is a serious problem, all of which seriously affects the visual amenity and peaceful atmosphere of the lake view.

Table 5.14 Percentage of the negative visual impact factors at the survey sites

Factor categories	Composition of negative factors at each site						Overall ranking
	S1(%)	S2(%)	S3(%)	S4(%)	S5(%)	S6(%)	% Of all categories
LC1	27.1	17.4	18.7	27	25.8	17.9	22.0
IV1	13.5	22.2	25.2	0	25.8	22.4	18.4
LC2	23.3	0	7.7	24.8	34.8	19.4	17.4
EM1	10.5	6.6	5.2	24.1	6.8	12.7	10.7
IV3	12.1	12.6	5.2	14.6	0	13.4	9.7
SE3	13.5	7.8	9	5.1	6.8	9.7	8.6
IV2	0	26.3	0	0	0	0	5.1
EM2	0	0	26.5	0	0	0	4.8
SE1	0	0.6	2.6	4.4	0	4.5	2.0
SE2	0	6.6	0	0	0	0	1.3

Note: land cover change (LC), invasion of volumetric object (IV), explosion of high-contrast material (EM), and surroundings and other factors (SE).

Figure 5.17 Ranking of major negative visual impact categories



5.5.5 Discussions

Modification and construction activities in lakeshore areas can directly lead to landscape fragmentation, vegetation degradation, dull landscapes, and an increase in artificial levels and hardscapes along the lakeshore. However, at the regional and local levels, there is a lack of effective regulatory systems and environmental protection regulations to curb developments and disturbances in the lake area and riparian zone. The assessment of environmental and visual impacts is often neglected. Lakeshore construction and development activities are temporary in nature, but can also have a significant visual impact on the lake area, which needs to be quantified through the development of a set of applicable assessment criteria and assessment tools.

5.5.5.1 Visual stimulation caused by lakeshore modifications

The visual stimulations (Figure 5.18) of lakeshore construction and modification on receptors is mainly reflected in the intrusion of incongruous objects into the scene (piles of construction materials and heavy equipment) and textural contrasts (e.g., granular base paving, turf scars from crushing operations). All these factors reduced the aesthetics and visual comfort of the lakeshore landscape and destroyed the connection between the receptors and the lakeshore landscape. The intrusion of new objects or colors disrupts the landscape content and structure of the natural lakeshore. And these stimulations reduce the visual quality by blocking or interrupting prominent lakeshore landscape axes and viewshed.

Figure5.18 Probability of the visual impact factors

5.5.5.2 Strengths and weaknesses of using a single method in VIA

The LMBA approach assesses visual landscape quality through changes in temporal-spatial information. Such remote sensing and geoprocessing methods allow for accurate physical measurements and regular monitoring of changes in land cover and landscape patterns through GIS software and spatial datasets. In practical terms, it is more reliable and efficient. The LMBA method can be used as a simple and cost-effective systematic assessment tool for preliminary estimates of the impact of development or modification on the lakeshore landscape. Planners and decision makers can use landscape indicators and calculation formulas to quickly estimate the potential visual impacts of a new project. However, one limitation of the LMBA approach is the measurement of small-scale visual distractors. In terms of spatial dimension and perspective, smaller-scale objects or temporary intrusions are difficult to capture with GIS-based tools or aerial imagery, such as construction materials and heavy construction equipment, which can have a strong visual impact at eye level due to incongruities in color and volume. Yet, they may have only a slight or no impact from an aerial perspective.

The VPBA method records and visualizes the landscape features and visual content of key landscape locations at different times through photography. The application of a visual perception assessment survey can collect and reflect receptors' intuitive sense responses and judgements on landscape change and visual stimuli. It also helps us to identify the main disturbing elements to the receptors of construction activities and sites. Nevertheless, individual perceptual differences exist in the visual impact of the receptors. Factors such as the angle, distance and landscape background (sky, water or green cover) of the shot in eye level photography may also affect the visual assessment results.

5.5.5.3 Overall appraisal of the LMBA method and the VPBA method

As mentioned above, the recognition of visual impacts at the aerial and eye levels is inconsistent. Planners cannot solely rely on aerial images or spatial landscape information to evaluate the visual impact of construction and modifications. Site surveys and ground-level photographs are still indispensable tools for assessing visual disturbance.

The differences in assessment results are mainly due to the different attributes and criteria of the two methods. According to the VPBA method changes in the physical landscape and a wider range of visual areas can be measured, as well as cumulative effects over time. Participants' ratings are based on direct perceived responses to in-congruities and changes in the visual area. Although in some locations the LMBA method has a relatively low level of impact due to the small size and short timescale of construction, high contrast surface materials and incongruities in the visual range can have a high visual impact on receptors. Visual disharmony and abruptness can result when a high brightness, color, and saturation material (e.g., concrete and red rock) dominates and is exposed in the shore area, or when the material does not fit in with the surrounding aquatic plants and natural lake scene. The findings of the LMBA method and the VPBA method for the evaluation of visual impact were not conflicting, but complementary and referred to each other. It is therefore important to combine the results of the two assessment methods to obtain a comprehensive evaluation reference value.

5.5.5.4 Directions for future research

I selected and applied sensitivity (LS）, exposed construction area (CA), area of vegetation degradation (DV), and duration effect (DE) as indicators for the LMBA method. And by evaluating six different lakeshore construction sites, the investigation showed that these evaluation criteria are applicable to measure the visual cumulative impacts of such construction activities that are highly correlated with land cover changes.

However, I also recognized that modifications and construction activities in lakeshore areas are not transient and are isolated, it often has a linear characteristic that leads to a continuous and a sequence of visual influence on the lake scenarios and the receptors. Linear construction operations, such as shore wall renewal, drainage ditches, promenade construction, and marina development, will require more specific criteria in the future to measure the visual impact of these modifications on the lake shoreline axis.

Since only six 300-m long lakeshore segments were selected for the current study, if the visual quality of the entire lakeshore or one side of the lakeshore needs to be assessed in the future, the coherence of the landscape will need to be considered as a metric. And it is possible to experiment with other types of evaluation formats, such as video presentations or inviting participants to evaluate visual impact by walking or cycling along the lakeshore.

The effects of human activities and lakeshore modifications on visual landscape quality and scenic beauty can be direct, abrupt, and continuous. Visual impact conditions on the lakefront landscape may change after construction projects are completed and visual impacts may be mitigated, or ongoing, additional negative impacts may occur with changes in land use and increased human activity. Thus, it is necessary to promote ongoing monitoring and tracking of the visual quality of the lakefront after construction of the lakeshore modification project is completed.

5.5.6 Summary

The work presented in this section assessed the visual quality of lakefront landscapes under construction phases, and tests and compares the usability of the LMBA method and the VPBA method for visual impact assessment of lakefront landscapes. The results of this study indicate that the visual quality of the landscape in the lakeshore areas degraded significantly during the construction phase. Visual stimuli, such as large-scale land cover changes and degradation of vegetation caused by construction operations are the main factors that significantly affected the visual quality of the lakeshore landscape. No significant correlations were found from the evaluation results of the two methods applied, but they contribute different perspectives and criteria for assessing visual impact of interventions and modifications on lakeshore landscape. The case of the Velence Lakeshore study shows that the results of **the two evaluation methods do not conflict**, but rather **complement and cross-reference each other**. These methods and templates may be useful for monitoring and assessing the visual quality and visual impact of other lakeshore landscapes with similar development contexts.

6 CONCLUSIONS AND RECOMMENDATIONS

This chapter provides a general summary of the assessment results of the above studies and identifies the potential problems that may exist and result. First, land use/land cover changes from 1989 to 2019 in the Lakeshore areas of Velence and Balaton will be presented, and the effects of developments and modifications on the visual landscape quality of the lakeshore will be summarized. Furthermore, this chapter will provide detailed recommendations related to land use and visual landscape protection in the lakeshore area, specifically providing appropriate guidance and mitigation measures for the issues identified in the dissertation.

6.1 Conclusions

The lakeshore area provides essential functions for economic, cultural and recreational uses as well as human settlement. Besides, as an ecological transition zone between land and water, the lakeshore area is important for the habitat of flora and fauna as well as for biodiversity. However, human intervention and various socio-economic drivers directly influence changes in land cover and visual landscape quality in the lakeshore area. The expansion of built-up areas and large infrastructure has altered the lakeshore land cover and contributed to the hardening of the shoreline, also threatening the natural character and habitats of the lakeshore. In the long term, negative impacts on ecosystems and landscape quality can lead to significant losses in economic and social benefits.

6.1.1 LU/LC changes in the lakeshore area

6.1.1.1 Lake Velence

The south-eastern and north-western shores of Lake Velence show a completely different state of land cover. The northern and western shores are primarily occupied by undeveloped semi-natural land (meadows, young woodland, shrubs). However, the northern and western lakeshores are mainly covered by dense residential and tourism-related land. The extensive land use forms were dominant in Lake Velence. 58% of the lakeshore are slightly pressured, 36% are highly pressured, 4% are pressured to a critical extend (Boromisza, 2012).

From 2009 to 2019, there has been a dramatic reduction in semi-natural land on the shores of Lake Velence. In the 0-30m and 30-100m lakeshore areas, the reduction in semi-natural land is replaced by a remarkable increase in bare land and tourism-related land uses. In particular, recreational land (artificial beaches, campsites) has seen the most prominent growth in the 0-30m lakeside area. During the same period, a large commercial integrated service center was built on the lakeshore of Velence Bay (Figure 6.1). The changes in the northern lakeshore area are mainly reflected in the alteration of parts of the semi-natural land by forests and young forests.

From 1989 to 2019, most of the Valence's shoreline has been strongly affected by various human interventions. The direct impact comes from shore modification works and dredging projects around the lake, as well as the expansion of the breakwater and jetty.

Nowadays, the construction of infrastructures and tourism facilities is still expanding, and the development of water sports facilities and new marinas is progressing. Some plots in the south shore area are now under construction and other semi-natural plots in the north shore area are now in a state of sale. The trend towards tourism-oriented land use in Lake Velence will therefore continue in the short term.

Figure6.1 LU/LC in the shore zone of Velence bay in 2019 and 1989

Note: a=Velence bay in 2019，b=Velence bay in 1989. The aerial images indicate the transform of semi natural land (b,1989) into an integrated recreational and commercial services area (a, 2019).

6.1.1.2 Lake Balaton

Lake Balaton region is generally considered to be the main destination attraction for summer holidays in Hungary. The tourism development area and settlements have occupied about half of the total area since the 80s. Port, marinas and marinas on Lake Balaton have been well developed since the 1980s. The growth of tourism accommodation and real estate along the shores of Lake Balaton has been remarkable after the 1980s, with the majority of new build up area being in the form of investment-oriented hotels and luxury holiday flats. The most notable areas for real estate development and commercial services are the Siófok region, the Zamárdi region and the Keszthely region in the north-west. The main reasons for this phenomenon are the increase in land properties along the lake and the profit maximization purposes of the different stakeholders over the last decades. Secondly, the desire for natural lake scenery and the demand for second homes by residents of large cities also led to an increase in building and transport land in the lakeshore area. As a result, settlements and built-up areas have continued to expand, despite the decline in population and visitors to the area after 1980 (Gábor, 2016; Lőrincz et al., 2021).

From 1989 to 2019, the new increased land for tourism development in the littoral area of Lake Balaton is mainly reflected in the development of recreational land uses (tourism facilities, artificial beaches and cycling paths) on the shore zone. Over the last 10 years, tourism development on Lake Balaton has continued to emphasise the enhancement of fishing and sailing tourism enhanced angling and sailing tourism, which has led directly to the expansion of water-based recreational facilities and marinas in the nearshore area， the Lake Balaton Lakeshore has seen continued growth in water-based recreational facilities and marinas.

By 2019, the land use and land cover change maps show an increase in built-up land and vacant land in the shore area of Lake Balaton. This implies that property development activities will continue to grow in the lakeshore area in the coming years if no regulatory intervention takes place.

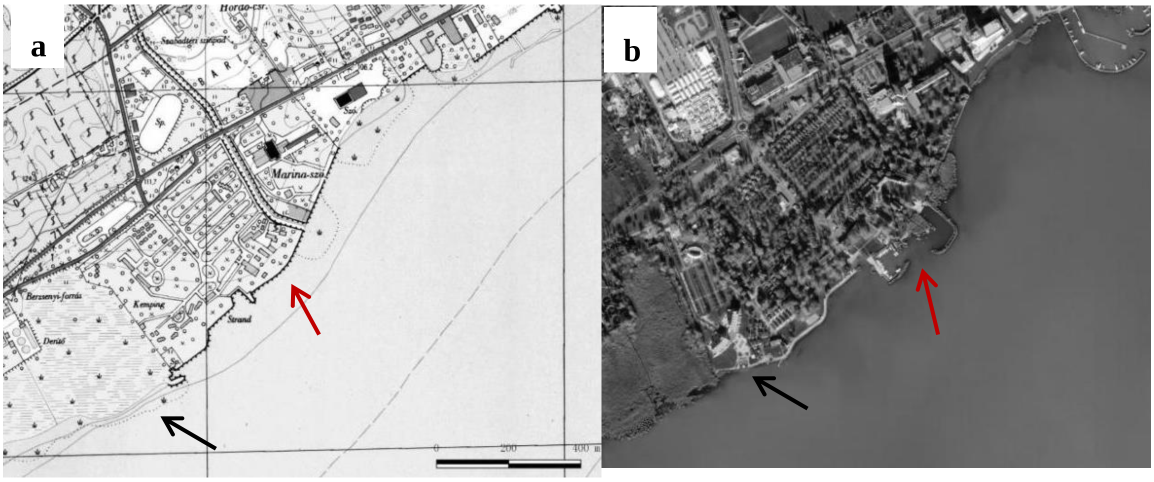


Figure6.2 Land cover change in the lakeshore area of Balatonfüred

Note: The loss of semi-natural area as a result of tourism development. **a** and **b** show the status of land cover in the lakeshore zone of Balatonfüred in 1989 and 2019. The black markers indicate the transformation of semi-natural land into tourism accommodation area, the red markers indicate the expansion of the marina.

6.1.1.3 Similarities in LU/LC change between the two lakeshores

There are similarities in land use changes in the lakeshore zones of Lake Velence and Lake Balaton. Land use and cover in the 0-100 shore areas of both lakeshores are severely influenced by tourism development. Between 1989 and 2019, the proportion of tourism-related land uses has increased significantly in both lakeshore areas, while at the same time semi-natural land (wetlands and grasslands) has decreased sharply. Lakeshore areas with high natural and landscape values are being squeezed.

This thesis considers the following major changes in land use/land cover in the 0-100m lakeshore zone of Lake Velence and Lake Balaton over the last three decades.

1) The increase in developed areas (recreational uses and settlements) at the expense of semi-natural land in the lakeshore area appears to be a great threat to the Lake Velence and Balaton Lakeshore area.

2) The development of tourism and residential areas in the lakeshore area is independent and occurs at different rates.

3) Forestation has produced remarkable results in both lakeshore areas.

4) Intensive recreational activities in nearshore areas and expanding tourism facilities (e.g.,

water recreation and yacht tourism) have put enormous pressure on water bodies and waterfronts. As a result, a large part of the natural shoreline has hardened and wetlands have been reduced.

Sustainable land use policies in lakeshore areas are essential for a balance between environmental and socio-economic aspects. Land use planning and developments in the lakeshore area should be prudent, especially in the riparian zone and littoral zone, and awareness of ecosystem services and sustainable tourism development must be raised.

6.1.2 Visual landscape quality of the lakeshore

The beautiful lake landscapes are indispensable resources for tourism on Hungarian territory. However, as the consequences of the authorities' encouraging and liberal policy towards waterfront development over the last decades, recreational land, large infrastructures, resort hotels and housing constructions and fortifications have been taking place in the shore zone of Lake Velence. The investment and social benefits are generally appreciated. However, the landscape character of the rural areas and the value of the diverse natural landscape elements of the lakeshore have not received similar attention and protection. There is currently a lack of awareness among the public and local authorities of the decline in the visual landscape quality and landscape aesthetics of the lakeshore in Hungary. In fact, the disturbances and damages to the lakeshore landscape and the loss of aesthetic appearance and natural values caused by lakeshore developments re often neglected or tolerated. The need for sustainable land use and landscape management can become apparent aesthetically (Nohl, 2001; Werner & Zander, 2001). Awareness of this necessity will be part of restoring the beauty of the lakeshore landscape.

6.1.2.1 Impact of land use/cover change on visual landscape quality

The study found that different land use/cover types on the lakeshore had an impact on public preferences and evaluations, which is strongly related to the appearance and functionality of the landscape. For example, lakefront recreational land is preferred over natural lakefront areas due to its availability, accessibility and good maintenance. Additionally, as Werner (2001) argued, i.e., more and more new land uses are invading the rural landscape, and these often result in massive installations and facilities causing great visual intrusion.

The findings through section 5.2 indicate that the diversity and natural beauty of the lakeside landscape is being replaced by the constant construction of man-made structures. As many of the semi-natural lands have been replaced by recreational land and build up areas. The opportunity to experience the naturalness of the landscape is greatly reduced by the systematic removal of natural or semi-natural structures from the landscape in shore zones. Examples include wild grassland or wetland, trails, natural water banks, trees and bushes in meadows, diverse vegetations. On the other hand, large-scale engineering elements and structures such as lakefront promenades, buildings, roads and power lines have been introduced. All these new objects blur the previously stark visual contrast between urban and natural landscapes.

Excessive land use and tourism-related development in lakeside areas is likely to cause long-term, irreversible damage to the natural waterfront landscape and scenic quality. They are empty and lifeless in their natural structure. A landscape filled with large engineered structures (roads, buildings, facilities and shore fortifications etc.) and artificial materials creates a sense of visual monotony and tedium. These intensive use areas are among the least aesthetically attractive landscapes, also called "plain" landscapes (Nohl, 2001) . Plain landscape will continue to be shaped by rational land use planning and management, but this will not be an aesthetic deficiency.

6.1.2.2 Effects of developments on the lakeshore landscape

Over the last few decades, human activity and tourism development have been continuously increasing in the lakeshore areas of Hungary. A number of structures with "urban character" and large functional elements have been introduced to the lakeshores. Although the socio-economic transformation processes of the last decades have not completely eliminated the rich natural and cultural landscapes of the Hungarian Lake areas (András et al., 2022). However, continuous development and lakeshore modification activities pose a threat to the aesthetics of the natural lakeshore landscape and the rural landscape. Lakefront developments may have several consequences: loss of naturalness, loss of rural structures, and loss of landscape diversity.

Loss of naturalness and rural structuring

Since **modern development structures** (buildings, touristic facilities, recreational structures, installations and so on) are often very densely changed the original lakeshore landscape form and cover huge areas. It is clear that the number of effective aesthetic elements in the natural landscape is steadily decreasing in the studied lakeshore area. Many of the original landscape elements that provided the visual symbolism and orientation of the region have been removed. The inclusion of man-made structures has created a new landscape type, somewhere between natural, rural and urban, where the naturalness of the lakefront landscape is being diminished. As a result, the visual information content in both natural and rural landscapes have been diminished in the lakeside area. For example, the shore of Velence Bay is representative of a highly developed lake shore, where the natural landscape and traditional architecture of the shores have been replaced by highly modern features (hotels, commercial services, beaches and promenade).

Loss of variety in lakeshore landscape

As the artificiality of the lakeshore and the group buildings increase, other landscape forms, such as water elements, vegetation structures (shrubs and aquatic plants), farming types and the traditional settlement structures, are gradually being diminished. It is difficult for our visual senses to adapt to the highly artificial lakeshore and those mass-produced structures (tall buildings, marinas, and large installations). This is because one is not only deprived of the experience of a rich landscape, but is visually connected directly to an abstract, over-scaled and repetitive landscape. For example, highly artificial coastal fortifications occupy much of the shoreline of Lake Velence. The receptors will visually experience a uniform and repetitive coastal landscape.

6.2 Recommendations

Based on the findings and issues described above, this section attempts to provide appropriate recommendations and guidelines, mainly with regard to sustainable land use of the lakeshore, lakeshore management, protection of the visual quality of the lakeshore and mitigation of visual impacts.

6.2.1 Sustainable land use and management

For the lakeshore areas in Hungary, the future development of the lakeshore area should be based on a complex plan for the sustainable land resources management and wise use of the lakeshore. Conceptualizing sustainability as achieving a balance between social, economic, and environmental purposes, the role of land use planning and management are of central importance (Briassoulis, 2020). **Sustainable land management** means when actions maximizing economic and social benefits while also maintaining or enhancing the ecological support functions of land resources. The broad aim of sustainable management of land use is to develop land resources in a way that utilizes local potential and suitability, within the carrying capacity of the local environment, avoids negative impacts, and meets current and future social needs (Alexandratos, 1995). Lakeshore management in Balaton and Velence need to integrate aspects of long-term ecological and social objectives and is for the sustainability of the lake and lakeside ecosystem. Modern land uses should be carefully carried out. In particular, the ecological regenerative capacity of the land needs to be maintained and all land-use conversions need to respect nature.

6.2.1.1 Land use planning and governance

Lakeshore mitigation and sustainable management begins with planning. **Land use planning** is a key process and tool to support the implantation of sustainable development goals. The performance of land use planning can have a direct impact on environmental conditions and socio-economics (Lakner et al., 2018). Design and construction errors, aesthetic issues and postconstruction ecological impacts can all be minimized by planning to define problems, set goals and guide development (Macbeth, 1992).

Local governments have an important role in regulating spatial planning. A large lake such as Lake Balaton belongs to several counties, the development and governance activities usually affecting the lake region come from three different counties (Somogy, Zala and Veszprém), so there are differences in the planning and management of this lakeshore zone by each county government. Development plans for the Balaton region have been in place for decades. A fundamental problem has been the lack of coordination over 50 years and the failure to reconcile the interests of counties, municipalities and departments (Buday-Sántha, 2007). Each jurisdiction has a different approach to lakeshore management, with some authorities exercising strict control over development activities and others being relatively lax.

With regard to this issue, it would be useful to establish a dedicated lake management department with planning procedures and protection measures applicable to the specific area, and unified implementation by the county governments of the jurisdictions.

6.2.1.2 Establishing an open set of map resources

Sustainable environmental development required regular assessment and monitoring of spatial land cover distributions and changes. However, the absence of data and map resources for research in Hungary limits academic research on watershed and local-scale landscapes. Consequently, there is an urgent need to improve the inadequacy of spatial and statistical data sources for scholars. Both research and monitoring for local-scale land use/land cover of the Lake regions and catchment areas require a support of free and open map resources. An integrated data system and open map resources would be of great benefits for future research and protection works.

6.2.1.3 Regulations and guidelines

A large proportion of the land use conflicts and environmental issues that currently exist can be addressed through appropriate regulations. On a European scale, the European Water Framework

Directive (WFD, 2000/60/EC)[4] can be regarded as the most significant legislative instrument in the water field on an international basis that had ever been set up in the EU. It is mainly concerned with the integrated assessment of the condition, protection and management of water bodies (including lakes and their shores) in the EU (Farmer, 2001). However, at the local and regional level, the lack of an effective regulatory system and specific environmental regulations for the lakeshore area has resulted in a variety of intensive development activities in the lakeshore area not being stopped in time. Therefore, there should be a systematic set of regulations adapted to the protection and development of the Hungarian Lake shores.

With regard to land use regulations and legal provisions specific to the Lakeshore area, it is suggested that special consideration needs to be given in the following aspects:

- Urban development (settlements, real estate) in lakeshore areas is not recommended. It must be secured by changes to the local plan, building regulations (especially building scale and building height), set safe distances of developments from the shoreline (setbacks for new developments and large structures), restrictions and controls on the location of new artificial surfaces (roads and parking area).
- The lakeshore protection regulations should specify that undeveloped areas and protection measures should be defined within a buffer zone. The width requirements of such natural buffers should be determined by the characteristics of the shoreline, but should not be less than 100 meters.
- In undisturbed shore segments, namely shore zones with less than 10% anthropogenic extent (Figure 6.3), priority should be given to nature conservation (protect rich species and habitats) and access should be limited. It is essential to ensure that undisturbed shore sections and shorelines meet ecological needs.
- Protection of the semi-natural land (wetlands, meadows and marshes).
- Temporal restrictions on recreational activities in the riparian zone and shoreline, and spatial restrictions on the expansion of water sports facilities and water-based tourism facilities.

[4] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

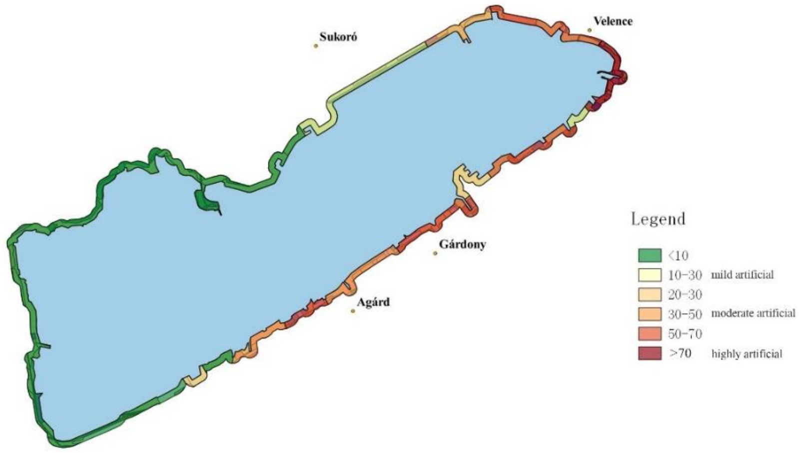


Figure 6.3 Degree of artificiality in the 0-100m lakeshore zone of Velence

6.2.1.4 Establishing reserve and management zone widths

Land-use policy that promotes ecosystem restoration or rehabilitation can rely on tools such as land-use zoning to establish reserves or sensitive areas, and to specify land-use restrictions (Metternicht, 2018). Land use zoning is the output of a spatial and land planning process that divides a given territory into different zones and enforces different rules and regulations for land use, management practices and land cover change. It is necessary to establish a specific conservation zone for lakeshore zones as a basis for lakeshore planning and management to protect against habitat loss and to minimize the cumulative effects of cluster development. The initial classification of lakeshore zoning can be divided into five classes (Figure 6.4), with each class requiring different protection objectives and mitigation aspects (Table 6.1).

- The most sensitive and valuable parts are the littoral areas (land-water transition zones), where there are particular needs to establish environmental and ecological objectives to protect the wildlife and biodiversity, habitats, wetlands, natural shorelines.
- Riparian and lakeshore areas (0-100m shore zone) need special protection as non-developed, low pressure, undisturbed areas. This area is often highly attractive for recreational development and real estate investment, and such development activities need to be strictly controlled and pre-assessed. Together with carefully designed rules to reflect the needs of the particular use.
- The shore area beyond 100m belongs to the Lakeshore Management Area, which is less

sensitive than the littoral and riparian areas. The expansion of large infrastructure and settlements in this area requires attention and monitoring.

Table 6.1 Zoning and guideline of the shore reserves

Classes	Width (m)	Categories of shore	Guidelines
A	-30 to 0	Littoral conservation	Wildlife/biodiversity values; shoreline protection
B	0-30	Riparian reserve	Protect the quality of the visual landscape from visual intrusion. Control the installation of large recreational facilities
C	30-100	Lakeshore reserve	Strict control over the extent and height of new buildings (houses, flat blocks and hotels); careful choice of materials and colors for hard paving
D	100-200	Lakeshore management zone	Advance assessment of the siting of large infrastructure and proper planning of settlements

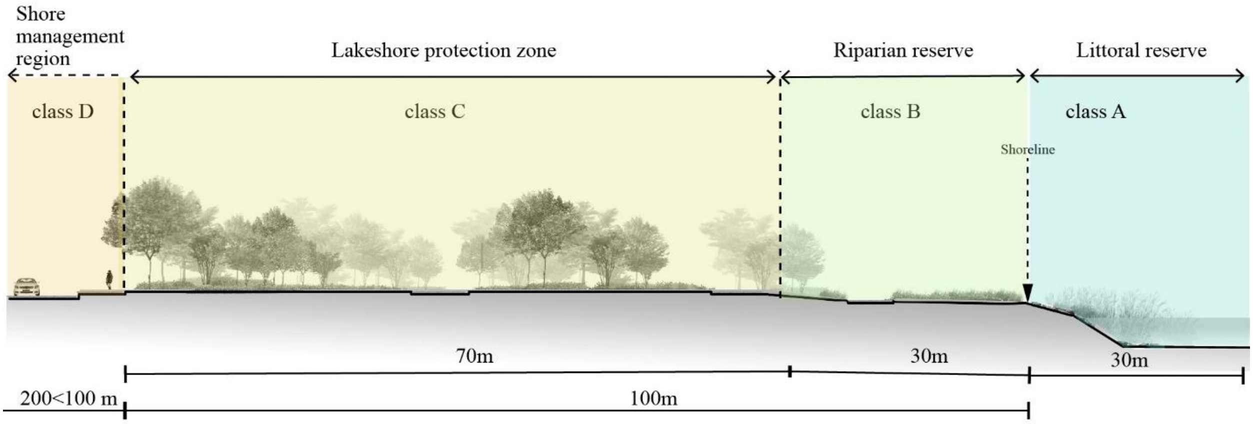


Figure 6.4 Width of lakeshore protection zones

6.2.1.5 Restoration and protection of natural shorelines

Protecting, restoring and enhancing lake shorelines and habitats in littoral areas contribute to improved water quality, enhance overall littoral resilience, support ecotourism through fishing and wildlife viewing activities, and enhance visual landscape quality. More than half of the shoreline of Lake Velence is currently occupied by hardened shoreline and hard surfaces, and the new shoreline renewal work, which began in 2017, is also dominated by hardening techniques. These conditions need to be addressed and more soft technologies (e.g., Marsh toe revetments) and eco-engineering techniques need to be introduced for the future protection and maintenance of the shoreline. Lake Velence could be considered for future improvements by reducing and removing the built retaining walls, protecting the natural vegetation in the littoral zone and placing natural materials (rocks, gravel, wood chips, aquatic plants) in the shallow water areas.

6.2.2 Improvement of visual landscape quality

The sustainable management of lake or lakeshore landscape require **special consideration of visual aspects**. More attention needs to be given to the visual quality of the lakeshore and to the cumulative visual impacts of lakeshore development. Common social goals require the provision of nature-based entertainment facilities, the protection of heritage features, and the promotion of a sense of place (Angradi et al., 2019).

In terms of sustainable aesthetic concept, A fair balance between wild environment and human control is demanded in waterfront landscape (Hu et al., 2019). Nohl (2001) argued that the improvement of landscape aesthetics is strongly linked to the sustainability of the landscape, which emphasizes the need for conservation and management principles to focus on nature and resources. Apart from natural elements, traditional architectural styles and agricultural landscapes (like vineyard landscape) are also important components of the lakeshore landscape in Hungary. The preservation of authenticity and the integration of these values is an important part of the development of a sustainable landscape aesthetic. There is a particular need to identify and protect unique landscape features along the coast (e.g., native plants).

Additionally, sustainable landscape design and landscape planning can help improve visual quality. (Steiner, 2012). The promotion of shore landscapes needs diversified design solutions according to the partition and its characteristics (Hartig & Staats, 2006), specially for the semi-natural lakeshore and the natural/“wild” lakeshore, which are the least popular and most overlooked types of lakeshore. The impacts of the semi-natural lakeshore alteration can be noticed from several aspects: e.g. disappeared spawning sites, altered shoreline and slope morphology, poor buffer capacity, changed visual appearance, more disadvantageous access of water-surface (Boromisza et al., 2014).

6.2.2.1 Protecting the visual quality of the sensitive area

The rich natural and cultural heritage provides the basis for the landscape character and aesthetic value of the lakeshore area. In order to protect the high-quality visual landscape (sensitive areas), the following recommendations are specifically included:

- Visually sensitive areas and scenic viewpoints along the lake shore need to be identified and distinctive landscape features and scarce landscapes in the shoreland need to be preserved.
- In sensitive viewpoints or areas, visual intrusion by large infrastructure and buildings should be avoided by maintaining appropriate safety distances.
- The viewshed of scenic points (near, medium and far views) needs to be assessed and protected.

6.2.2.2 Minimize the visual impacts on the lakeshore zone

According to the findings in section 5.4, modifications and construction activities in the lakeshore area can directly result in changes to the shoreline structure, damaging the vegetation cover, and leading to an increase in the artificial levels and hardscapes along the lakeshore. Environmental assessments and related regulations for the lakeshore ought to consider and address the influence of new developments on the visual quality, particularly in the context of expanding built-up areas and major lakeshore renovation projects. In order to maintain the visual landscape quality of the lakefront and to mitigate the visual impact of new development objects and construction processes, the following recommendations are specified:

- **Protection Regulations** should be developed to manage and limit development and construction activities within the lakeshore buffer zone. There is a need to require the reduction and control of large-scale visual intrusion and visual impact caused by new construction projects. Large facilities and revetment structures (riprap, seawalls and piers) in the lakeshore area needs to be strictly controlled. In addition, care should be taken to control the style, height, and duration of construction of building projects.
- The **planning** of the lakeshore area should not only take into account the protection of the landscape resources, but also the possible visual impact of the new objects on the receptors and the scenic beauty. Prior to a development project or building construction being launched, a computer simulation (by GIS tools or 3D models) of the new project should be carried to illustrate the appearance of the development and to evaluate the impact visual zones.

- **Artificial materials and colors** should be carefully selected and used in lakeshore areas, particularly for paving and berms along the lake shoreline. Bioengineering methods are recommended as an alternative to artificial hard revetments to prevent erosion (Appendix 19).
- **Large infrastructure or buildings need to take mitigation measures.** Structural planting can help to integrate a development with the surrounding landscape, and can soften the edges of intrusive buildings and structures (Institute & I.E.M.A, 2013).Trees and healthy canopies in particular can be used to improve the visual quality issues caused in new developments (Sullivan & Lovell, 2006).
- For the subsequent management of the post-development lakeshore, regular maintenance of natural landscape elements (lawns, shrubs, lakeshore reeds) and amenities is required. A standard assessment framework should be established and applied to regularly monitor visual and environmental disturbance. All disturbed areas (construction sites and large exposed areas) should be re-vegetated with native vegetation in exposed areas to reduce visual impacts and erosion after construction is complete. (Walter & Jeffrey L. Bunnell, 1976).
- It is recommended that local communities be encouraged to participate in governance activities and initial discussions on regional planning to enhance awareness of visual impacts and landscape protection.

6.2.2.3 Maintenance of the landscape appearance

According to the findings in Section 5.4, the visual quality of lakeshore landscapes, as generally perceived by receptors, is closely related to maintenance. Well-maintained and organized landscapes contribute to the visual landscape quality. Regular manual maintenance of the lakeshore landscape elements, including cleaning of outdated facilities, keeping the site neat and repairing the natural lakeshore, etc.

In the lakeshore area, plants are exceptionally important to support good environmental quality (mitigating erosion and maintaining good water quality) and scenic beauty (Cowie et al., 1992; E. K. Meyer, 2008; Tan & Peng, 2020). Although vegetation cover is a key factor in measuring the visual quality of lakeshores, wild lakeshore landscapes are not popular with the public as they often represent clutter and lack maintenance. High densities and tall wetland vegetation can sometimes cause a visually negative experience. Thus, long-term care and **regular maintenance of vegetation is required**. In particular, wetland plants (e.g., Phragmites and Typha) and vegetations (weeds, meadows and shrubs) in tourist hotspots require seasonal maintenance and pruning. Ditlhogo (1992) suggested that management by cutting or burning reeds has no significant impact on invertebrate communities and species richness. However, the choice of cutting time is important and the optimal time to cutting reeds is from November to March to ensure their dominance. In addition, The diversity of plant species can have a positive impact on the visual quality of landscape (Ditlhogo et al., 1992; Polat & Akay, 2015). The existing variety of vegetation cover can be enriched by introducing appropriate native woody or aquatic plants.

6.2.3 Summary

In summary, the major recommendations regarding lakeshore land use and visual landscape quality include：

- Sustainable land management and planning considerations；
- Regular monitoring of land cover changes and opening up map and spatial image resources for researchers；
- Establishing specific regulations for the lakefront area and zoning of the lakeshore management and protection areas；
- Special protection measures for natural landscape elements and viewshed of scenic spots in the lakeshore area；
- To minimize visual impact through a combination of measures. Maintaining the appearance of the lakeshore scenery particularly requires regular maintenance of aquatic plants.

7 NEW SCIENTIFIC RESULTS

Finding 1: Developed an effective method for evaluate the relationships between the aesthetic preferences and visual landscape indicators.

To explore the relationship between the public's aesthetic preferences for lakeshores and the characteristics of lakeshore landscapes, I have developed two assessment frameworks, one based on **public participation assessment** and one on **expert assessment.**

1) Firstly, **I identified three groups of the most sensitive receptors** for the landscape preference survey: **waterfront residents, landscape planning practitioners, and outdoor enthusiasts.** And investigated the receptor's perceptions and preferences for **five representative lakeshore landscapes**[5] (with different levels of artificial intervention).

2) **Identified** a set of evaluation indicators（**vegetation coverage area, human activities , density of riparian plants, visual range, naturalness, functionality, accessibility, maintenance**）and corresponding scoring criteria **as the fundamental framework** for **expert assessment**. The identification of landscape indicators was primarily based on consideration of **the physical state and condition of the landscape**. The landscape indicators were scoring **through field survey and spatial monitoring**.

3) After obtained the results of the public preference survey and the metrics-based expert assessment, a Pearson correlation coefficient was conducted to measure the relationship and linear correlation between the public preference judgment consensus and the lakefront visual landscape indicators.

[5] Five types of lakeshore landscape: A highly artificial shore; a semi-artificial shore with partial buildings background; a semi-natural shore without building background; a near-natural shore; a “wild”/ natural shore.

Finding 2: An optimal mixed methods approach was developed to evaluate the visual impact of the modifications on the lakeshore landscape.

Intense construction operations and developing works has continue carried on the lakeshore zone in recent years, which have had a significant visual impact on the natural lake scenery. I have developed **a mixed methods approach** for assessing the **visual landscape quality** of the lakeshore at different phases **(before construction and during construction)**. The assessment approach consists of a subjective Visual Perception Based Assessment (VPBA) method and an objective Landscape Metric Based Assessment (LMBA) method.

a) The **VPBA approach** is based primarily on the evaluation of **ground-level photographs** from two different time periods (T1 = before construction, T2 = during construction) and **involved participants**[6] in judging the visual quality of the lakeshore landscapes through a questionnaire. Negative elements in disturbed lakeshore landscapes are also identified through the public's visual perceptions and responses.

b) The **LMBA approach** has proved more accurate and effective from the previous studies. **A set of relevant indicators**[7] **and objective evaluation criteria were selected to evaluate the visual landscape quality of the disturbed lakeshore.** The landscape metrics are assessed with the help of **GIS tools** and **high-resolution aerial imagery** by measuring, recording, and calculating changes in **landscape features** and **land cover** over different time periods (from 2016 to 2021).

c) Lastly, the results of the two assessment methods were compared and combined to obtain **a combined visual impact rating (FDI)**. **Spearman's rank correlation coefficient** was computed to assess the correlations between results from visual perception-based assessment (VPBA), the results landscape metrics-based assessment (LMBA), and applied landscape indicators.

[6] The participants included waterfront residents, planning and landscape professionals, visitors and outdoor enthusiasts.

[7] Landscape sensitivity, construction duration, and magnitude of the land cover change

Finding 3: Mapped and measured the land use/cover status of Lake Velence at different times, and LU/LC changes over different intervals.

The land use/cover maps produced for different time periods (1989, 2009 and 2019) and the quantification of data (Appendix 9) for each LU/LC type over different times illustrated the following findings:

- At Lake Velence, **Undeveloped land** (semi natural land, water area, forests, and agricultural land) is mainly located to **the west and north of the lakeshore**, while land for **tourism development** (tourism accommodation area, tourism facilities area, and recreational land) and **urban development** (settlements, bare land, transportation land) are mainly located to the **eastern and southern parts of the lakeshore**.
- Over the 30-year period, **semi-natural land** accounted for the **largest proportion** of all land types in the 0-200 m lakeshore zone. semi-natural land accounted for 44.47% of all land use types in 1989, 44.37% in 2009 and declined to 37% in 2019.

The comparative analysis study also identified **major changes in land use/cover types in the lakeshore area over three-time intervals (1898-2009 2009-2019 and 1989-2019):**

- From 1989 to 2009, the changes in this period were mainly reflected in a decrease in **water area (-6.66%) and agricultural land (-2.76%)** and an increase in **forests (4.78%) and urban area (2.69%).**
- From 2009 to 2019, land use changes on the lakeshore were markedly different from the previous period, as **semi-natural land (-7.50%)** decreased significantly in the lakeshore zone, and notable increase in **forest land (2.06%), bare land (2.01%),** and **urban land (1.33%)**.
- Overall, from 1989-2019, the main changes in the shore zone of Lake Velence show a decrease in the **water area, agricultural land and semi-natural land**. Meanwhile, **forest land, urban area and tourism-related areas** have increased significantly.

Finding 4: Identified specific changes in land use/cover in the subdivided Lakeshore zones.

By analysing and visualizing the land use/cover of the three subdivided lakeshore zones (0-30m shore zone, 30-100m shore zone, and 100-200m shore zone) over the period 1989 to 2019.

- The changes in water area and recreational land use are mainly in the 0-30m lakeshore zone and the 30-100m lakeshore zone. Meanwhile, woodlands and urban areas show a significant increase in the 100-200m lakeshore zone.
- All three subdivided Lakeshore zones show significant reductions in semi-natural land between 2009 and 2019, with -7%, -5.6% and -7.7% respectively.

By analyzing the transition process for each land use/cover category over three time periods, the results show that some LU/LC types show **a linear trend of increasing or decreasing**.

a) A significant **linear growth** in the **recreational land, tourism facilities area and bare land** in the **0-30m lakeshore zone** from 1989 to 2019.

b) In the **30-100m** lakeshore zone, there is **no significant change** in the proportion of LU/LC classes, except for a slight increase in tourist accommodation area, urban area and forests.

c) Land use/cover classes in the 100-200m lakeshore zone have changed more dramatically over the last 30 years than in the first two lake zones., with the results show a **clear linear decrease in semi-natural and agricultural land** and a **linear increase** in u**rban land and forest land** from 1989 to 2019.

Finding 5: Identification of land use and land cover changes in the two largest natural lakeshore areas in Hungary.

By mapping and analyzing the land use/land cover of the two largest natural lakeshore areas in Hungary (Lake Balaton and Lake Velence) from 1989-2019, the annual rate of LU/LC change and the area change rate of each LU/LC type in the two lakeshore areas over a 30-year period were determined.

The following similarities in LU/LC change were detected in the two lakeshore areas:

1) Both Lakeshore areas have seen similar changes in the major LU/LC categories[8] over the last 30 years. This is reflected in the **increase** in **tourism development and urban development areas**, and the **decrease** in **undeveloped areas**.

2) The main threat to the shore areas of Lake Velence and Lake Balaton is the increase of **tourism development lands (including recreational lands, tourist accommodation areas and touristic facilities)** and these expansions are mainly **at the expense of semi-natural lands.**

A combined analysis of LU/LC from the two lakeshore areas showed:

a) The area of **all types of land use/land cover** in the lakeshore area are **statistically significantly different in both 1989 and 2019** ($p \leq 0.01$)[9].

b) Of all the land use/cover classes, **forest land** has seen the most prominent growth in the two lakeshore areas. However, **agricultural land** and **semi-natural land** decreased sharply.

---

[8] Undeveloped land, tourism development land, urban development area.
[9] According to the results of the Wilcoxon signed-rank test. Significance level at 0.05.

Finding 6: Identification of growth land use pressures in the near-shore area.

Ports, marinas, and piers were well developed in Lake Balaton and Lake Velence since the 1980s. The last decade has also observed the continued development and expansion of water tourism facilities and water-based tourism (fishing, boating, yachting and sailing) in the two lakes. Based on fine-scale spatial monitoring of the nearshore area (1989 and 2019) and official information released on investments and constructions in the Hungarian Lake region. **The changes and developments in the nearshore areas can be identified as follows:**

1) In Lake Velence, the proportion of natural shoreline has declined from 55% in 1989, to 42% in 2019. The lost natural shoreline has been replaced by concrete shore walls and artificial sandy beaches.

2) The number of marinas on **Lake Valence** has **remained almost the same** and has not changed noticeably in size over the last three decades, but the number of marinas on **Lake Balaton** has increased sharply **from 18 in 1989 to 49 in 2019**.

3) Over all, a total of 59 marinas and 27 boat ports have been built on the shores of Lakes Velence and Baleton by 2019. **Seven of which have a capacity of over 200 berths**. The marinas are evenly distributed over the entire shore zone of Lake Balaton and the southern shore of Lake Velence from Velence to Agárd.

4) Most of the new marinas and **expanded marinas** are concentrated in the **Keszthely region** in the west of Lake Balaton, and the northeast **Balatonfűzfő region.**

5) From 1989 to 2019, a total of **22.88 hectares** of nearshore **water area in Lake Balaton was infilled**, which was mainly **converted to recreational land or marinas**. In Lake Velence, approximately **57.72 hectares** of water area in the nearshore zone was filled in and **31.77 hectares were retreated**. The new filled areas of Lake Velence are basically occupied **by meadows and wildlife habitats**.

Finding 7: Public preference for different types of lakeshore landscapes and lakeshore embankments

According to the extent of human influences and different intervention levels, **five representative types of Lakeshore landscape**[10] (from a highly artificial lakeshore landscape transition into a "wild" lakeshore) were selected for evaluation**.** Additionally, there are **nine types** of **lakeshore embankment**[11] that were selected for the preference assessment. Based on the results of the evaluation from the receptors[12], I draw the following conclusions:

a) The **most popular lakeshore landscape** scenes are the **semi-artificial lakeshore** (41%), followed by the **artificial lakeshore** (26%) and the **near-natural lakeshore** (25%). Both **highly artificial and semi-natural lakeshore landscapes** are **unpopular** and received the most negative aesthetic ratings, with 37% chose the "wild" lakeshore, 37% chose the semi-natural lakeshore and 20% chose the artificial lakeshore as the least preferred.

b) The most popular **lakeshore revetment types** are: The **natural beach** with curved wooden groyne (P3), and the **rip/rap bank slope** with open grassland (P5), and the **rock slope revetment** with unobstructed pavement (P7).

c) By comparing the results and responses to the aesthetic ratings of the four lakeshore landscape groups it can be concluded that **experts and the waterfront residents differ in their concerns and preferences for the lakeshore**. However, there is **no statistically significant difference** in the aesthetic evaluation of the lakeshore by the public and experts in this study ($p > 0.05$)[13].

---

[10] Five types of lakeshore landscape included: an artificial shore; a semi-artificial shore; a semi-natural shore with fences; a near-natural shore with the unobstructed pavement; a natural shore.

[11] Embankment types: P1 a concrete revetment with partly sand slope, P2 a shore with timber piles, P3 a natural beach with wooden groyne; P4 a shore entire edge provided metal railings, P5 a rip/rap bank slope with openly grassland, P6 a shore restricted by aquatic plants and wooden fences on both sides of the pavement; P7 a rock slope revetment with unobstructed pavement, P8 a rock slope revetment with obstructed pavement, P9 a concrete revetment without sloping breakwater.

[12] N=62 valid perceived responses.

[13] Fisher's exact test was used to determine if there was a significant association between experts and residents (significance level≤0.05)

Finding 8: Identification of correlations between lakeshore landscape preferences and visual indicators.

In order to discover the influence of visual indicators [14]on the public's judgement of aesthetic preferences, a correlation test between the perceived scores of the study sites and visual landscape indicators was analyzed by means of Pearson correlation coefficients.

Based on the results, I have identified:

a) **The aesthetic judgements** are significant **positive correlated** with **accessibility** ($r=0.82$, $p<0.01$), **visual range** ($r=0.81$, $p<0.01$), and **maintenance state** ($r=0.79$, $p<0.01$).

b) However, the aesthetic values by cognitive judgements are **negatively correlated** with **naturalness** ($r=-0.46$, $p<0.01$), **aquatic plants** ($r=-0.79$, $p<0.01$) and **vegetation coverage** ($r=-0.4$, $p<0.01$).

In this study, **naturalness, aquatic plant cover** and **vegetation cover** had a significant negative effect on the aesthetic preference of the studied lakeshore landscape. **This finding is inconsistent with the outcomes of most previous related articles.** The main reason why the lakeshore vegetation cover is not conducive to visual aesthetics is that the density and height of the aquatic plants cause a partial closure of the visual zone and obstruct the visual axis.

Finding 9: Outcomes of a lakeshore visual impact assessment based on a mixed methods approach

Six pilot sites[15] along the lake were selected as samples for visual impact assessment.

1) According to the **LMBA method**, during the construction phase, the greatest visual impact on the lakeshore landscape was at **the stockpile site** (S5), followed by **Site 2** (tailings pond) and **Site 6** (promenade construction site).

---

[14] Visual factors included vegetation coverage area, human activities, density of riparian plants, visual range, naturalness, functionality, accessibility, and maintenance.

[15] Six lakeshores that underwent different modifications: S1=a pavement renewal site, S2=a new tailing pond field, S3= a site under reconstruction for embankment and walkway, S4=demolition site, S5=stockpile field, S6=new promenade construction site.

2) Results for the **VPBA approach** showed that perceived aesthetic scores and median scores were **significantly lower**[16] at all survey sites **during construction (T2)** than perceived aesthetic scores in the **previous landscape (T1).** The site that received the highest visual impact rating was **the material stockpile site** (S5), followed by the **reconstruction of the embankment** (S3) and **the new tailings storage site** (S2).

3) Combining the results of the two assessment methods, the **final composite degree of visual impact (FDI)** shows that **Sites 2 and 5** received a visual impact level rating of **D**, meaning **significant negative visual impact**, and **Sites 3 and 6** were rated **C (moderate negative visual impact)**.

Visual impact factors on the lakeshore during the construction phase were identified through assessment and responses from receptors. The visual stimulation of the lakeshore construction and renovation on the receptors is mainly reflected in the **incongruous object intrusion scenes** (piles of construction materials and heavy equipment) and **textural contrasts** (e.g., granular foundation paving, turf scars from crushing operations), and **cluttered scenes.** All of which reduce the aesthetic and visual amenity of the lakefront landscape and disrupted the connection between the receptors and the lakefront landscape. A summary of public reactions and votes on negative landscape elements shows that:

1) The three most **prominent factors** contributing to the **negative visual impact** of construction were **damaged vegetation** at around 22%, followed by **stockpile of construction materials (soil, grave, rocks, sand)** at 18.4% and **unpaved or bare ground** at around 17.4%.

2) In general, nearly 39.4% of the negative visual impacts on the lakeshore landscape were associated with **land cover change (LC)** and 34.5% were **visually volumetric intrusion elements (IE)**. High contrast material elements (EM) and other peripheral elements (SE) account-ed for 15.5% and 11.9% of the total impact categories respectively.

[16] A Wilcoxon signed rank test showed statistically significant differences in visual quality before and during construction ($Z=-12.277$, p-value < 0.01)

Finding 10: Identified the strengths of using mixed methods for visual impact assessment.

The case of the Velence Lakeshore study shows that the results of the two evaluation methods (LMBA method and VPBA method) **do not conflict, but rather complement and cross-reference each other.** This mixed methods template may be helpful in monitoring and assessing the visual quality and visual impact of other lakes with similar development contexts.

After testing different assessment methods, the following conclusions were drawn.:

- The **LMBA method** can be used as a **simple** and **cost-effective systematic assessment tool** for **preliminary estimates** of the impact of development or modification on the lakeshore landscape. Such **remote sensing and geoprocessing methods** allow for **accurate physical measurements** and regular monitoring of changes in land cover and landscape patterns through GIS software and temporal-spatial datasets. **In practical terms,** it is more **reliable and efficient**.
- The application of a **visual perception assessment survey** can collect and r**eflect receptors' intuitive sense responses and judgements** on landscape change and visual stimuli. It also helps researcher to **identify the main visual stimulus** to the receptors of construction activities and sites.
- Planners cannot solely rely on **aerial images or spatial landscape information** to evaluate the visual impact of construction and modifications. **Site surveys and ground-level photographs** are still indispensable tools for assessing visual disturbance.
- A mixed methods approach helps to **obtain information from multiple perspectives** and provides **different criteria** for assessing the visual impact of interventions and modifications on the lakeshore landscape. The results of the two assessment methods are combined to obtain a comprehensive evaluation of the final impact value (FDI), which can provide a reference basis for subsequent governance and mitigation measures.

8 SUMMARY

This dissertation focuses on the land use and aesthetic quality of the landscape in the lakeshore area. By studying and assessing the lakeshore of Lake Velence, changes in lakeshore land use/cover from 1989 to 2009 are presented, and the visual quality of the lakeshore in different states is also assessed through multiple methods. The dissertation consists of seven main research components. Firstly, the literature review summarized the theoretical background and methods used in previous studies and identified the limitations of the relevant research. This provided the basis for setting out the research questions and objectives. The next chapter details the delineation of the study area and the geographical location, landscape characteristics and development context of the study area. The chapters on methodology and results are both structured and presented around the two main branches of research.

The results of the study show that changes in land use/cover type are notable in the lakefront areas of both Lake Velence and Lake Balaton over the last three decades. This is mainly reflected in increased built-up land and afforestation, and a decrease in semi-natural land. Most new lakeshore construction projects have been achieved through the expense and conversion of semi-natural land. It can be argued that the elimination of semi-natural land on the lakeshore and its replacement by man-made structures is a hazardous change. The results of the lakeshore landscape preference survey and visual impact assessment show that most people consider some level of development to be acceptable, mainly in relation to the maintenance, appearance, and function of the landscape. However, lakeshore development activities and changes in land cover have had a significant impact on the visual quality of the lakeshore landscape.

In response to the issues and negative impacts identified in the studies, Chapter 6 provides recommendations and mitigation measures. Chapter 7summarised and listed all the findings and briefly elaborates the conclusions of each study subsection. All the findings have been analysed and validated.

ACKNOWLEDGMENTS

This dissertation would not have existed without the generosity and guidance of the faculty and coordinators of the Doctoral School of Landscape Ecology. I am especially grateful to my supervisor, Dr. Zsombor Boromisza, for accepting me as his PhD student and guiding me through each step of the four-year PhD study processes, and I sincerely thank him for his support, kindness and enthusiasm.

I am deeply thankful to Mr. Gergely Attila who generously shared map resources with me and told me about his interesting experiences, which was very enlightening. Besides, thanks to all my colleagues in the Department of Landscape Protection and Restoration for given me many unforgettable moments and cares. It was great to have the opportunity to meet and work with them during my PhD journey.

I would like to thank Dr. Sandor Jombach, Dr. Ágnes Sallay, Dr. László Kollányi and Dr. Marta Ladanyi for teaching me how to use research tools and methods, that immensely helped me to carry out my research smoothly. Furthermore, I would like to thank all schoolmates I have met throughout my academic journey for their valuable helps and insights.

My sincere thanks also go to the doctoral school committee, for their encouragement, insightful feedbacks and assistances. Also, enormous thanks to the patient reviewers who read this dissertation and gave their comments.

And finally, I would like to express my gratitude to my family for always understanding me and supporting me to pursue my dreams. So many people helped me with this dissertation, and accompanied me through my PhD journey. I will never be able to thank them all sufficiently.

REFERENCES

1. Acar, C., Kurdoglu, B. C., Kurdoglu, O., & Acar, H. (2006). Public preferences for visual quality and management in the Kackar Mountains National Park (Turkey). *International Journal of Sustainable Development & World Ecology*, *13*(6), 499–512.
2. Agarwal, C. (2002). *A review and assessment of land-use change models: Dynamics of space, time, and human choice*.
3. Alexander, R. R. (1974). *Silviculture of subalpine forests in the central and southern Rocky Mountains: The status of our knowledge* (Vol. 121). Rocky Mountain Forest and Range Experiment Station, Forest Service, US ….
4. Alexandratos, N. (1995). *World agriculture: Towards 2010: An FAO study*.
5. András, C., Anett, E., & András, I. (2022). *Targeted Analysis of Lake Balaton-Towards an integrated development*. ESPON 2020 Cooperation Programme.
6. Angradi, T. R., Williams, K. C., Hoffman, J. C., & Bolgrien, D. W. (2019). Goals, beneficiaries, and indicators of waterfront revitalization in Great Lakes Areas of Concern and coastal communities. *Journal of Great Lakes Research*, *45*(5), 851–863. https://doi.org/10.1016/j.jglr.2019.07.001
7. Aoki, Y. (1999). Review article: Trends in the study of the psychological evaluation of landscape. *Landscape Research - LANDSC RES*, *24*, 85–94. https://doi.org/10.1080/01426399908706552
8. Aoki Y. (2013). A historical review of landscape appreciation studies published in english journals until 2013. *Journal of Environmental Science.*, *43(5)*, 115-124.
9. Arriaza, M., Cañas-Ortega, J. F., Cañas-Madueño, J. A., & Ruiz-Aviles, P. (2004). Assessing the visual quality of rural landscapes. *Landscape and Urban Planning*, *69*(1), 115–125. https://doi.org/10.1016/j.landurbplan.2003.10.029
10. Arsanjani, J. J. (2013). *Dynamic land use/cover change modelling: Geosimulation and multiagent-based modelling* (2012th edition). Springer.
11. Bakker, M. M., & van Doorn, A. M. (2009). Farmer-specific relationships between land use change and landscape factors: Introducing agents in empirical land use modelling. *Land Use Policy*, *26*(3), 809–817.
12. Batar, A., Watanabe, T., & Kumar, A. (2017). Assessment of Land-Use/Land-Cover Change and Forest Fragmentation in the Garhwal Himalayan Region of India. *Environments*, *4*(2), 34. https://doi.org/10.3390/environments4020034
13. Bernát, G., Boross, N., Somogyi, B., Vörös, L., G-Tóth, L., & Boros, G. (2020). Oligotrophication of Lake Balaton over a 20-year period and its implications for the relationship between phytoplankton and zooplankton biomass. *Hydrobiologia*, *847*(19), 3999–4013.
14. Bicudo da Silva, R. F., Millington, J. D. A., Moran, E. F., Batistella, M., & Liu, J. (2020). Three decades of land-use and land-cover change in mountain regions of the Brazilian Atlantic Forest. *Landscape and Urban Planning*, *204*, 103948. https://doi.org/10.1016/j.landurbplan.2020.103948
15. Bishop, I. D. (2003). Assessment of Visual Qualities, Impacts, and Behaviours, in the Landscape, by Using Measures of Visibility. *Environment and Planning B: Planning and Design*, *30*(5), 677–688. https://doi.org/10.1068/b12956
16. Bishop, I. D., & Bruce Hull, R. (1991). Integrating technologies for visual resource management. *Journal of Environmental Management*, *32*(4), 295–312. https://doi.org/10.1016/S0301-4797(05)80068-4

17. Bishop, I. D., & Hulse, D. W. (1994). Prediction of scenic beauty using mapped data and geographic information systems. *Landscape and Urban Planning*, *30*(1), 59–70. https://doi.org/10.1016/0169-2046(94)90067-1
18. Blankson, E. J., & Green, B. H. (1991). Use of landscape classification as an essential prerequisite to landscape evaluation. *Landscape and Urban Planning*, *21*(3), 149–162. https://doi.org/10.1016/0169-2046(91)90014-D
19. Boavida-Portugal, I., Rocha, J., & Ferreira, C. C. (2016). Exploring the impacts of future tourism development on land use/cover changes. *Applied Geography*, *77*, 82–91. https://doi.org/10.1016/j.apgeog.2016.10.009
20. Boromisza, Z. (2012). Complex shore zone evaluation of lake Velence, Hungary. *Applied Ecology and Environmental Research*, *10*, 31–46. https://doi.org/10.15666/aeer/1001_031046
21. Boromisza, Z., Török, É. P., & Ács, T. (2014). LAKESHORE-RESTORATION - LANDSCAPE ECOLOGY - LAND USE: ASSESSMENT OF SHORE-SECTIONS, BEING SUITABLE FOR RESTORATION, BY THE EXAMPLE OF LAKE VELENCE (HUNGARY). *Journal of Earth and Environmental Sciences*, 179–188.
22. Brabyn, L., & Mark, D. M. (2011). Using viewsheds, GIS, and a landscape classification to tag landscape photographs. *Applied Geography*, *31*(3), 1115–1122. https://doi.org/10.1016/j.apgeog.2011.03.003
23. Brauns, M., Gücker, B., Wagner, C., Garcia, X.-F., Walz, N., & Pusch, M. T. (2011). Human lakeshore development alters the structure and trophic basis of littoral food webs. *Journal of Applied Ecology*, *48*(4), 916–925.
24. Briassoulis, H. (2020). Analysis of Land Use Change: Theoretical and Modeling Approaches. *Web Book of Regional Science*. https://researchrepository.wvu.edu/rri-web-book/3
25. Bruttomesso, R. (2001). Complexity on the urban waterfront. In *Waterfronts in Post-Industrial Cities*. Taylor & Francis.
26. Buday-Sántha, A. (2007). Development Issues of the Balaton Region. *Discussion Papers*, *61*, Article 61.
27. Canter, L. W. (1996). *Environmental impact assessment* (2nd ed.). McGraw-Hill.
28. Carpenter, S. R., Benson, B. J., Biggs, R., Chipman, J. W., Foley, J. A., Golding, S. A., Hammer, R. B., Hanson, P. C., Johnson, P. T. J., Kamarainen, A. M., Kratz, T. K., Lathrop, R. C., McMahon, K. D., Provencher, B., Rusak, J. A., Solomon, C. T., Stanley, E. H., Turner, M. G., Vander Zanden, M. J., … Yuan, H. (2007). Understanding Regional Change: A Comparison of Two Lake Districts. *BioScience*, *57*(4), 323–335. https://doi.org/10.1641/B570407
29. Carys Swanwick, Department of Landscape, & University of Sheffield. (2002). *Landscape Character Assessment—Guidance for England and Scotland*.
30. Chen, G. Y., Guo, D. Z., Wojtaszek, M. V., & Márkus, B. (2012). Land use and land cover change based on remote sensing and GIS in Changping, Beijing, China and Lake Velence Watershed, Hungary. *Advanced Materials Research*, *403*, 1543–1547.
31. Chen, X., Li, B.-L., & Allen, M. F. (2010). Characterizing urbanization, and agricultural and conservation land-use change in Riverside County, California, USA. *Annals of the New York Academy of Sciences*, *1195*(s1), E164–E176. https://doi.org/10.1111/j.1749-6632.2009.05403.x
32. Cheung, D. M., & Tang, B. (2015). Social order, leisure, or tourist attraction? The changing planning missions for waterfront space in Hong Kong. *Habitat International*, *47*, 231–240. https://doi.org/10.1016/j.habitatint.2015.01.006
33. Cooke, G. D., Welch, E. B., Peterson, S.A., & Nichols, S. (2005). Restoration and management of lakes and reservoirs. *Third Edition. Taylor and Francis Group*, 131–140.
34. Cowie, N. R., Sutherland, W. J., Ditlhogo, M. K., & James, R. (1992). The effects of conservation management of reed beds. II. The flora and litter disappearance. *Journal of Applied Ecology*, 277–284.

35. Cui, L., Li, G., Chen, Y., & Li, L. (2021). Response of Landscape Evolution to Human Disturbances in the Coastal Wetlands in Northern Jiangsu Province, China. *Remote Sensing*, *13*(11), Article 11. https://doi.org/10.3390/rs13112030
36. Dąbrowska, J., Kaczmarek, H., Markowska, J., Tyszkowski, S., Kempa, O., Gałęza, M., Kucharczak-Moryl, E., & Moryl, A. (2016). Shore zone in protection of water quality in agricultural landscape—The Mściwojów Reservoir, southwestern Poland. *Environmental Monitoring and Assessment*, *188*. https://doi.org/10.1007/s10661-016-5470-5
37. Daniel, T. C. (2001). Whither scenic beauty? Visual landscape quality assessment in the 21st century. *Landscape and Urban Planning*, *54*(1–4), 267–281. https://doi.org/10.1016/S0169-2046(01)00141-4
38. Daniel, T. C., & Boster, R. S. (1976). Measuring landscape esthetics: The scenic beauty estimation method. *Res. Pap. RM-RP-167. U.S. Department of Agriculture, Forest Service, Rocky Mountain Range and Experiment Station. 66 p.*, *167*. http://www.fs.usda.gov/treesearch/pubs/20911
39. de la Fuente de Val, G., Atauri, J. A., & de Lucio, J. V. (2006a). Relationship between landscape visual attributes and spatial pattern indices: A test study in Mediterranean-climate landscapes. *Landscape and Urban Planning*, *77*(4), 393–407. https://doi.org/10.1016/j.landurbplan.2005.05.003
40. de la Fuente de Val, G., Atauri, J., & de Lucio, J. (2006b). Relationship between landscape visual attributes and spatial pattern indices: A test study in Mediterranean-climate landscapes. *Landscape and Urban Planning*, *77*, 393–407. https://doi.org/10.1016/j.landurbplan.2005.05.003
41. Deng, Z., Zhang, X., Li, D., & Pan, G. (2015). Simulation of land use/land cover change and its effects on the hydrological characteristics of the upper reaches of the Hanjiang Basin. *Environmental Earth Sciences*, *73*(3), 1119–1132. https://doi.org/10.1007/s12665-014-3465-5
42. Dessel, W., Van Rompaey, A., Poelmans, L., & Szilassi, P. (2008). Predicting land cover changes and their impact on the sediment influx in the Lake Balaton catchment. *Landscape Ecology*, *23*, 645–656. https://doi.org/10.1007/s10980-008-9227-6
43. Dezso, Z., Bartholy, J., Pongracz, R., & Barcza, Z. (2005). Analysis of land-use/land-cover change in the Carpathian region based on remote sensing techniques. *Physics and Chemistry of the Earth, Parts A/B/C*, *30*(1), 109–115. https://doi.org/10.1016/j.pce.2004.08.017
44. Ditlhogo, M. K. M., James, R., Laurence, B. R., & Sutherland, W. J. (1992). The Effects of Conservation Management of Reed Beds. I. The Invertebrates. *Journal of Applied Ecology*, *29*(2), 265–276. https://doi.org/10.2307/2404495
45. Dokulil, M. T. (2014). Environmental Impacts of Tourism on Lakes. In A. A. Ansari & S. S. Gill (Eds.), *Eutrophication: Causes, Consequences and Control* (pp. 81–88). Springer Netherlands. https://doi.org/10.1007/978-94-007-7814-6_7
46. Doucet, B., Van Kempen, R., & Van Weesep, J. (2011). Resident Perceptions of Flagship Waterfront Regeneration: The Case of the Kop Van Zuid in Rotterdam. *Tijdschrift Voor Economische En Sociale Geografie*, *102*(2), 125–145. https://doi.org/10.1111/j.1467-9663.2010.00611.x
47. Dupont, L., Ooms, K., Antrop, M., & Van Etvelde, V. (2017). Testing the validity of a saliency-based method for visual assessment of constructions in the landscape. *Landscape and Urban Planning*, *167*, 325–338. https://doi.org/10.1016/j.landurbplan.2017.07.005
48. Etter, A., McAlpine, C., Wilson, K., Phinn, S., & Possingham, H. (2006). Regional patterns of agricultural land use and deforestation in Colombia. *Agriculture, Ecosystems & Environment*, *114*(2–4), 369–386.
49. Ewald, K. C. (2001). The neglect of aesthetics in landscape planning in Switzerland. *Landscape and Urban Planning*, *54*(1), 255–266. https://doi.org/10.1016/S0169-2046(01)00140-2

50. Farmer, A. M. (2001). The EC water framework Directive: An introduction. *Water Law*, *12*(1), 40–46.
51. FPC, B. (1995). Riparian Management Area Guidebook. *Forest Practices Code of British Columbia, Victoria, BC*.
52. Frank, S., Fürst, C., Koschke, L., Witt, A., & Makeschin, F. (2013). Assessment of landscape aesthetics—Validation of a landscape metrics-based assessment by visual estimation of the scenic beauty. *Ecological Indicators*, *32*, 222–231. https://doi.org/10.1016/j.ecolind.2013.03.026
53. Furgała-Selezniow, G., Jankun-Woźnicka, M., & Mika, M. (2020). Lake regions under human pressure in the context of socio-economic transition in Central-Eastern Europe: The case study of Olsztyn Lakeland, Poland. *Land Use Policy*, *90*, 104350. https://doi.org/10.1016/j.landusepol.2019.104350
54. Furgala-Selezniow, G., Skrzypczak, A., Kajko, A., Wiszniewska, K., & Mamcarz, A. (2012). Touristic and Recreational Use of the Shore Zone of Ukiel Lake (Olsztyn,Poland). *Polish Journal of Natural Science*, *27*, 41–52.
55. Furgala-Selezniow, G., Turkowski, K., Nowak, A., Skrzypczak, A., & Mamcarz, A. (2006). 8. The Ostroda–Elblag Canal in Poland: The Past and Future for Water Tourism. In *8. The Ostroda–Elblag Canal in Poland: The Past and Future for Water Tourism* (pp. 131–148). Channel View Publications. https://doi.org/10.21832/9781845410421-011
56. Gábor, W. (2016). Historical review of the tourism development of Lake Velence. *Turizam*, *20*(4), 192–211. https://doi.org/10.5937/Turizam1604192G
57. Gabrielsen, P., & Bosch, P. (2003). Environmental indicators: Typology and use in reporting. *EEA, Copenhagen*.
58. Gong, J., Li, J., Yang, J., Li, S., & Tang, W. (2017). Land Use and Land Cover Change in the Qinghai Lake Region of the Tibetan Plateau and Its Impact on Ecosystem Services. *International Journal of Environmental Research and Public Health*, *14*(7), Article 7. https://doi.org/10.3390/ijerph14070818
59. Hahn, T., Heinrup, M., & Lindborg, R. (2018). Landscape heterogeneity correlates with recreational values: A case study from Swedish agricultural landscapes and implications for policy. *Landscape Research*, *43*(5), 696–707. https://doi.org/10.1080/01426397.2017.1335862
60. Hall, C. M., & Härkönen, T. (Eds.). (2006). *Lake Tourism: An integrated approach to lacustrine tourism systems*. Channel View Publications.
61. Hartig, T., & Staats, H. (2006). The need for psychological restoration as a determinant of environmental preferences. *Journal of Environmental Psychology*, *26*(3), 215–226. https://doi.org/10.1016/j.jenvp.2006.07.007
62. Hatvani, I. G., de Barros, V. D., Tanos, P., Kovács, J., Székely Kovács, I., & Clement, A. (2020). Spatiotemporal changes and drivers of trophic status over three decades in the largest shallow lake in Central Europe, Lake Balaton. *Ecological Engineering*, *151*, 105861. https://doi.org/10.1016/j.ecoleng.2020.105861
63. He, J., Huang, J., & Li, C. (2017). The evaluation for the impact of land use change on habitat quality: A joint contribution of cellular automata scenario simulation and habitat quality assessment model. *Ecological Modelling*, *366*, 58–67. https://doi.org/10.1016/j.ecolmodel.2017.10.001
64. Hernández, J., García, L., & Ayuga, F. (2004a). Assessment of the visual impact made on the landscape by new buildings: A methodology for site selection. *Landscape and Urban Planning*, *68*(1), 15–28. https://doi.org/10.1016/S0169-2046(03)00116-6
65. Hernández, J., García, L., & Ayuga, F. (2004b). Integration Methodologies for Visual Impact Assessment of Rural Buildings by Geographic Information Systems. *Biosystems Engineering*, *88*(2), 255–263. https://doi.org/10.1016/j.biosystemseng.2004.02.008

66. Hiltunen, M. J. (2007). Environmental Impacts of Rural Second Home Tourism – Case Lake District in Finland. *Scandinavian Journal of Hospitality and Tourism*, *7*(3), 243–265. https://doi.org/10.1080/15022250701312335
67. Hourdequin, M., & Havlick, D. G. (Eds.). (2016). *Restoring layered landscapes: History, ecology, and culture*. Oxford University Press.
68. HRDUP. (1980). *Urban planning and city building concept of Lake Velence region: Gárdony, Pákozd, Velence, Kápolnásnyék, Sukoró, Nadap, Pázmánd, Vereb, Lovasberény, Pátka.*
69. Hu, S., Yue, H., & Zhou, Z. (2019). Preferences for urban stream landscapes: Opportunities to promote unmanaged riparian vegetation. *Urban Forestry & Urban Greening*, *38*, 114–123. https://doi.org/10.1016/j.ufug.2018.12.001
70. Institute, L., & I.E.M.A. (2013). *Guidelines for Landscape and Visual Impact Assessment* (3 edition). Routledge.
71. Jiang, L., Kang, J., & Schroth, O. (2015). Prediction of the visual impact of motorways using GIS. *Environmental Impact Assessment Review*, *55*, 59–73. https://doi.org/10.1016/j.eiar.2015.07.001
72. Jordan, G., Van Rompaey, A., Szilassi, P., Csillag, G., Mannaerts, C., & Woldai, T. (2005). Historical land use changes and their impact on sediment fluxes in the Balaton basin (Hungary). *Agriculture, Ecosystems & Environment*, *108*(2), 119–133.
73. Jorgensen, A. (2011). Beyond the view: Future directions in landscape aesthetics research. *Landscape and Urban Planning*, *100*(4), 353–355. https://doi.org/10.1016/j.landurbplan.2011.02.023
74. Keleş, E., Atik, D., & Bayrak, G. (2018). Visual Landscape Quality Assessment in Historical Cultural Landscape Areas. *European Journal of Sustainable Development*, *7*(3), 287–300.
75. Kertész, Á., Nagy, L. A., & Balázs, B. (2019). Effect of land use change on ecosystem services in Lake Balaton Catchment. *Land Use Policy*, *80*, 430–438. https://doi.org/10.1016/j.landusepol.2018.04.005
76. Koomen, E., & Stillwell, J. (2007). Modelling land-use change. In *Modelling land-use change* (pp. 1–22). Springer.
77. Kostopoulou, S. (2013). On the Revitalized Waterfront: Creative Milieu for Creative Tourism. *Sustainability*, *5*(11), Article 11. https://doi.org/10.3390/su5114578
78. Krause, C. L. (2001). Our visual landscape Managing the landscape under special consideration of visual aspects. *Landscape and Urban Planning*, 16.
79. Lakner, Z., Kiss, A., Merlet, I., Oláh, J., Máté, D., Grabara, J., & Popp, J. (2018). Building Coalitions for a Diversified and Sustainable Tourism: Two Case Studies from Hungary. *Sustainability*, *10*(4), Article 4. https://doi.org/10.3390/su10041090
80. Latinopoulos, D., Ntislidou, C., & Kagalou, I. (2018). A multi-approach Lake Habitat Survey method for impact assessment in two heavily modified lakes: A case of two Northern Greek lakes. *Environmental Monitoring and Assessment*, *190*(11), 658. https://doi.org/10.1007/s10661-018-7045-0
81. Li, X., Li, L., Wang, X., Lin, Q., Wu, D., Dong, Y., & Han, S. (2021). Visual quality evaluation model of an urban river landscape based on random forest. *Ecological Indicators*, *133*, 108381. https://doi.org/10.1016/j.ecolind.2021.108381
82. Lin, L., Homma, R., & Iki, K. (2018). Preferences for a lake landscape: Effects of building height and lake width. *Environmental Impact Assessment Review*, *70*, 22–33. https://doi.org/10.1016/j.eiar.2018.03.001
83. Lindsay, A. R., Gillum, S. S., & Meyer, M. W. (2002). Influence of lakeshore development on breeding bird communities in a mixed northern forest. *Biological Conservation*, *107*(1), 1–11. https://doi.org/10.1016/S0006-3207(01)00260-9

84. Liu, G., Liu, Z., Hu, H., Wu, G., & Dai, L. (2008). The impact of tourism on agriculture in Lugu Lake region. *International Journal of Sustainable Development & World Ecology*, *15*(1), 3–9. https://doi.org/10.1080/13504500809469762
85. Lőrincz, K., Grósz, A. S., & Csapó, J. (2021). Evaluation of Quality of Life and Living Space in the Balaton Destination (Hungary) Based on the Perceptions of the Local Residents and the Owners of Second Homes. *European Countryside*, *13*(1), 108–129. https://doi.org/10.2478/euco-2021-0007
86. Macbeth, J. (1992). Ocean cruising: A sailing subculture. *The Sociological Review*, *40*(2), 319–343.
87. Maikov, K. (2013). *Landscape characteristics in Tartu City Parks: User influences through design*. 353–364. https://doi.org/10.2495/SC130301
88. Marton, G., & Jónás-Berki, M. G. (2013). Aktív turizmus pozíciója a Balaton térségében. *Modern Geográfia*, *8*(1), 13–22.
89. Mendoza, M. E., Granados, E. L., Geneletti, D., Pérez-Salicrup, D. R., & Salinas, V. (2011). Analysing land cover and land use change processes at watershed level: A multitemporal study in the Lake Cuitzeo Watershed, Mexico (1975–2003). *Applied Geography*, *31*(1), 237–250. https://doi.org/10.1016/j.apgeog.2010.05.010
90. Metternicht, G. (2018). *Land use and spatial planning: Enabling sustainable management of land resources*. Springer.
91. Meyer, E. K. (2008). Sustaining beauty. The performance of appearance: A manifesto in three parts. *Journal of Landscape Architecture*, *3*(1), 6–23.
92. Meyer, W. B., & II, B. L. T. (Eds.). (1994). *Changes in Land Use and Land Cover: A Global Perspective* (1st Edition). Cambridge University Press.
93. Misthos, L.-M., Pavlidis, A., Karabassakis, E., Menegaki, M., Krassanakis, V., & Nakos, B. (2020). Exploring the visual impact from open pit mines applying eye movement analyses on mining landscape photographs. *International Journal of Mining, Reclamation and Environment*, *34*(9), 609–624. https://doi.org/10.1080/17480930.2019.1576582
94. Mitsova, D., & Esnard, A.-M. (2012). Holding Back the Sea: An Overview of Shore Zone Planning and Management. *Journal of Planning Literature*, *27*(4), 446–459. https://doi.org/10.1177/0885412212456880
95. Moran, S., Perreault, M., & Smardon, R. (2016). Finding our way: A case study of urban waterway restoration and participatory process. *Landscape and Urban Planning*. https://doi.org/10.1016/j.landurbplan.2016.08.004
96. Németh, G., Lóczy, D., & Gyenizse, P. (2021). Long-Term Land Use and Landscape Pattern Changes in a Marshland of Hungary. *Sustainability*, *13*(22), Article 22. https://doi.org/10.3390/su132212664
97. Nohl, W. (2001). Sustainable landscape use and aesthetic perception–preliminary reflections on future landscape aesthetics. *Landscape and Urban Planning*, *54*(1), 223–237. https://doi.org/10.1016/S0169-2046(01)00138-4
98. Oliva, S. (2006). The effects of waterfront development on housing prices: The case of eastern Baltimore [M.C.P., University of Maryland, College Park]. In *ProQuest Dissertations and Theses*. https://www.proquest.com/docview/305310681/abstract/41568A7718EB4680PQ/1
99. Ostendorp, W., Schmieder, K., & Joehnk, K. (2004). Assessment of human pressures and their hydromorphological impacts on lakeshores in Europe. *Ecohydrology and Hydrobiology*, *4*, 379–395.
100. Pálfi, A., Nemes, V., & Horváth, Z. (2015). Tourism destination management offices in the tourism region of Balaton. *Transylvanian Journal of Tourism and Territorial Development*, *1*(1), 70–77.
101. Palmer, J. F. (1983a). *Visual quality and visual impact assessment*. Unpublished. https://doi.org/10.13140/2.1.4276.6723

102. Palmer, J. F. (1983b). Visual quality and visual impact assessment. *Social Impact Assessment Methods. London: Sage Publications*, 268–283.

103. Papageorgiou, M. (2016). Coastal and marine tourism: A challenging factor in Marine Spatial Planning. *Ocean & Coastal Management*, *129*, 44–48. https://doi.org/10.1016/j.ocecoaman.2016.05.006

104. Papatheochari, T., & Coccossis, H. (2019). Development of a waterfront regeneration tool to support local decision making in the context of integrated coastal zone management. *Ocean & Coastal Management*, *169*, 284–295. https://doi.org/10.1016/j.ocecoaman.2018.12.013

105. Papp, F. (1995). Re-examination of the shore fortification works at Lake Velence (In Hungarian). Víz-Inter Mérnökiroda Kft., Székesfehérvár, 75 p. *Víz-Inter Mérnökiroda Kft., Székesfehérvár*, *75*.

106. Pilkey, O. H., & Young, R. S. (2005). Will Hurricane Katrina impact shoreline management? Here's why it should. *Journal of Coastal Research*, *21*(6), iii–x.

107. Polat, A. T., & Akay, A. (2015). Relationships between the visual preferences of urban recreation area users and various landscape design elements. *Urban Forestry & Urban Greening*, *14*(3), 573–582. https://doi.org/10.1016/j.ufug.2015.05.009

108. Pomucz, A. B., & Csete, M. (2015). Sustainability Assessment of Hungarian Lakeside Tourism Development. *Periodica Polytechnica Social and Management Sciences*, *23*(2), Article 2. https://doi.org/10.3311/PPso.7506

109. Puczkó, L., & Rátz, T. (2000). Tourist and Resident Perceptions of the Physical Impacts of Tourism at Lake Balaton, Hungary: Issues for Sustainable Tourism Management. *Journal of Sustainable Tourism*, *8*(6), 458–478. https://doi.org/10.1080/09669580008667380

110. Purcell, A. H., Friedrich, C., & Resh, V. H. (2002). An Assessment of a Small Urban Stream Restoration Project in Northern California. *Restoration Ecology*, *10*(4), 685–694. https://doi.org/10.1046/j.1526-100X.2002.01049.x

111. Qi, T., Wang, Y., & Wang, W. (2013). Review of international visual landscape research. *Advances in Geography, 2013, 32(6):*, 975–983.

112. Radomski, P., & Goeman, T. J. (2001). Consequences of Human Lakeshore Development on Emergent and Floating-Leaf Vegetation Abundance. *North American Journal of Fisheries Management*, *21*(1), 46–61. https://doi.org/10.1577/1548-8675(2001)021<0046:COHLDO>2.0.CO;2

113. Ramos, B. M., & Pastor, I. O. (2012). Mapping the visual landscape quality in Europe using physical attributes. *Journal of Maps*, *8*(1), 56–61. https://doi.org/10.1080/17445647.2012.668763

114. Rátz, T. (2002). Residents' perceptions of the socio-cultural impacts of tourism at Lake Balaton, Hungary. In *Tourism and sustainable community development* (pp. 54–65). Routledge.

115. Remenyik, B., & Csilla, M. (2018). The trends of the lake tourism and results of Balaton research. *Studia Mundi - Economica*, *5*, 113–127. https://doi.org/10.18531/Studia.Mundi.2018.05.03.113-127

116. Remenyik, B., Geza, T., Dávid, L., Szücs, C., Vasa, L., & Uakhitova, G. (2013). *Lakes under pressure: Data on the development of lake tourism in Hungary*. *28*, 119–130.

117. Robertson, W., Whitman, D., Zhang, K., & Leatherman, S. P. (2004). Mapping shoreline position using airborne laser altimetry. *Journal of Coastal Research*, *20*(3), 884–892.

118. Rovira Soto, M. T., & Anton Clavé, S. (2017). Second homes and urban landscape patterns in Mediterranean coastal tourism destinations. *Land Use Policy*, *68*, 117–132. https://doi.org/10.1016/j.landusepol.2017.07.018

119. Sargentis, G. F., Hadjibiros, K., & Christofides, A. (2005). Plastiras Lake: The impact of water level on the aesthetic value of the landscape. *Proceedings of the International Conference on Environmental Science and Technology*, *2*, 817–824.

120. Schirpke, U., Scolozzi, R., & Tappeiner, U. (2021). “A Gem among the Rocks”—Identifying and Measuring Visual Preferences for Mountain Lakes. *Water*, *13*(9), Article 9. https://doi.org/10.3390/w13091151
121. Schmid, W. A. (2001). The emerging role of visual resource assessment and visualisation in landscape planning in Switzerland. *Landscape and Urban Planning*, *54*(1–4), 213–221. https://doi.org/10.1016/S0169-2046(01)00137-2
122. Schmieder, K. (2004). European lake shores in danger—Concepts for a sustainable development. *Limnologica*, *34*(1), 3–14. https://doi.org/10.1016/S0075-9511(04)80016-1
123. Schnaiberg, J., Riera, J., Turner, M. G., & Voss, P. R. (2002). Explaining human settlement patterns in a recreational lake district: Vilas County, Wisconsin, USA. *Environmental Management*, *30*(1), 24–34.
124. Sevenant, M., & Antrop, M. (2009). Cognitive attributes and aesthetic preferences in assessment and differentiation of landscapes. *Journal of Environmental Management*, *90*(9), 2889–2899. https://doi.org/10.1016/j.jenvman.2007.10.016
125. Smardon, R. C. (1988). Visual Impact Assessment for Island and Coastal Environments. *Impact Assessment*, *6*(1), 5–24. https://doi.org/10.1080/07349165.1988.9725619
126. Smith, M., & Puczko, L. (2008). *Health and Wellness Tourism*. Routledge. https://doi.org/10.4324/9780080942032
127. Spielhofer, R., Hunziker, M., Kienast, F., Wissen Hayek, U., & Grêt-Regamey, A. (2021). Does rated visual landscape quality match visual features? An analysis for renewable energy landscapes. *Landscape and Urban Planning*, *209*, 104000. https://doi.org/10.1016/j.landurbplan.2020.104000
128. Stedman, R. C., & Hammer, R. B. (2006). Environmental perception in a rapidly growing, amenity-rich region: The effects of lakeshore development on perceived water quality in Vilas County, Wisconsin. *Society and Natural Resources*, *19*(2), 137–151.
129. Steiner, F. R. (2012). *The living landscape: An ecological approach to landscape planning*. Island Press.
130. Strayer, D. L., & Findlay, S. E. G. (2010). Ecology of freshwater shore zones. *Aquatic Sciences*, *72*(2), 127–163. https://doi.org/10.1007/s00027-010-0128-9
131. Sullivan, W. C., & Lovell, S. T. (2006). Improving the visual quality of commercial development at the rural–urban fringe. *Landscape and Urban Planning*, *77*(1), 152–166. https://doi.org/10.1016/j.landurbplan.2005.01.008
132. Svobodova, K., Sklenicka, P., Molnarova, K., & Vojar, J. (2014). Does the composition of landscape photographs affect visual preferences? The rule of the Golden Section and the position of the horizon. *Journal of Environmental Psychology*, *38*, 143–152. https://doi.org/10.1016/j.jenvp.2014.01.005
133. Swetnam, R. D., Harrison-Curran, S. K., & Smith, G. R. (2017). Quantifying visual landscape quality in rural Wales: A GIS-enabled method for extensive monitoring of a valued cultural ecosystem service. *Ecosystem Services*, *26*, 451–464. https://doi.org/10.1016/j.ecoser.2016.11.004
134. Szilágyi F., Szabó Sz. & Mándoki M. (1989). Restoration of Lake Velence. In. Saláni, J.,Heródek, S. (eds.): Conservation and Management of lakes. *Symposia Biologica Hungarica, 38, Akadémiai Kiadó, Budapest,* 529-545.
135. Tadese, M., Kumar, L., Koech, R., & Kogo, B. K. (2020). Mapping of land-use/land-cover changes and its dynamics in Awash River Basin using remote sensing and GIS. *Remote Sensing Applications: Society and Environment*, *19*, 100352. https://doi.org/10.1016/j.rsase.2020.100352
136. Tamáska, M. (2006). Inheritance sociological examination of traditional and modern dwelling houses. *Szociológiai Szemle*, *4*, 36–62.

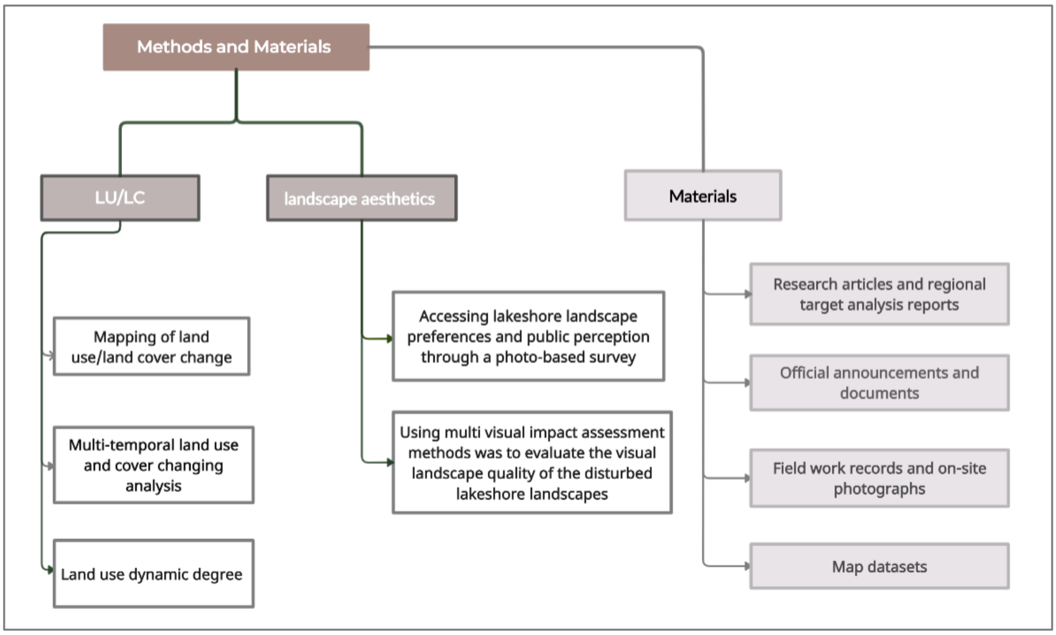
137. Tan, X., & Peng, Y. (2020). Scenic beauty evaluation of plant landscape in Yunlong Lake wetland park of Xuzhou City, China. *Arabian Journal of Geosciences*, *13*(15), 701. https://doi.org/10.1007/s12517-020-05626-x
138. Trial, P. F., Gelwick, F. P., & Webb, M. A. (2001). Effects of shoreline urbanization on littoral fish assemblages. *Lake and Reservoir Management*, *17*(2), 127–138.
139. Tveit, M., Ode, Å., & Fry, G. (2006). Key concepts in a framework for analysing visual landscape character. *Landscape Research*, *31*(3), 229–255. https://doi.org/10.1080/01426390600783269
140. Tyson, M. M. (1998). *The Healing Landscape: Therapeutic Outdoor Environments*. McGraw-Hill.
141. Ulrich, R. S. (1977). Visual landscape preference: A model and application. *Man-Environment Systems*, *7*(5), 279–293.
142. Valbuena, D., Verburg, P. H., & Bregt, A. K. (2008). A method to define a typology for agent-based analysis in regional land-use research. *Agriculture, Ecosystems & Environment*, *128*(1–2), 27–36.
143. Vouligny, É., Domon, G., & Ruiz, J. (2009). An assessment of ordinary landscapes by an expert and by its residents: Landscape values in areas of intensive agricultural use. *Land Use Policy*, *26*(4), 890–900. https://doi.org/10.1016/j.landusepol.2008.10.016
144. Walter, F. A., & Jeffrey L. Bunnell. (1976). Environmental Protection Guidelines for Construction Projects. *Journal (American Water Works Association)*, *68*. https://doi.org/10.2307/41268536
145. Wang, R., Zhao, J., & Liu, Z. (2016). Consensus in visual preferences: The effects of aesthetic quality and landscape types. *Urban Forestry & Urban Greening*, *20*, 210–217. https://doi.org/10.1016/j.ufug.2016.09.005
146. Wehrly, K. E., Breck, J. E., Wang, L., & Szabo-Kraft, L. (2012). Assessing local and landscape patterns of residential shoreline development in Michigan lakes. *Lake and Reservoir Management*, *28*(2), 158–169. https://doi.org/10.1080/07438141.2012.690824
147. Werner, A., & Zander, P. (2001). Models Assessing the Impact of Land-Use Change in Rural Areas on Development of Environmental Threats and Their Use for Agricultural Politics. In *Landscape Ecology in Agroecosystems Management*. CRC Press.
148. Wettstein, D. (2013). Historical analysis of regional planning of Balaton. *Pollack Periodica*, *8*(1), 141–152. https://doi.org/10.1556/Pollack.8.2013.1.13
149. White, M., Smith, A., Humphryes, K., Pahl, S., Snelling, D., & Depledge, M. (2010). Blue space: The importance of water for preference, affect, and restorativeness ratings of natural and built scenes. *Journal of Environmental Psychology*, *30*(4), 482–493. https://doi.org/10.1016/j.jenvp.2010.04.004
150. Wilcoxon, F. (1945). Individual Comparisons by Ranking Methods. *Biometrics Bulletin*, *1*(6), 80–83. https://doi.org/10.2307/3001968
151. Wróżyński, R., Sojka, M., & Pyszny, K. (2016). The application of GIS and 3D graphic software to visual impact assessment of wind turbines. *Renewable Energy*, *96*, 625–635. https://doi.org/10.1016/j.renene.2016.05.016
152. Wu, Y., Bishop, I., Hossain, H., & Sposito, V. (2006). Using GIS in Landscape Visual Quality Assessment. *Applied GIS*, *2*(3), 18.1-18.20. https://doi.org/10.2104/ag060018
153. Yang, P. P.-J., Putra, S. Y., & Li, W. (2007). Viewsphere: A GIS-based 3D visibility analysis for urban design evaluation. *Environment and Planning B: Planning and Design*, *34*(6), 971–992.
154. Yazici, K. (2018). EVALUATION OF VISUAL LANDSCAPE QUALITY IN THE WETLANDS NORTH OF SIVAS (TURKEY). *Applied Ecology and Environmental Research*, *16*(4), 4183–4197. https://doi.org/10.15666/aeer/1604_41834197

155. Ziółek, M., Zgłobicki, W., Ziolek, G., & Baran-Zglobicka, B. (2004). Landscape aesthetics versus ecological aesthetics(on the example of polish national parks). *Серія Географічна*, *С.*, 292–301.

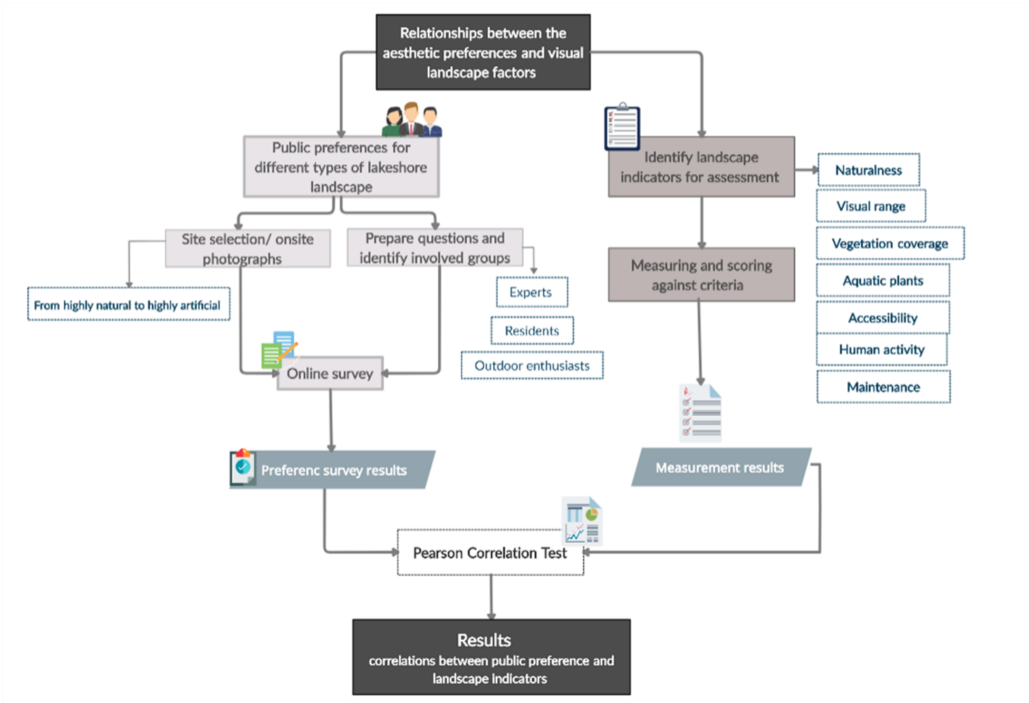
LIST OF TABLES

LIST OF FIGURES

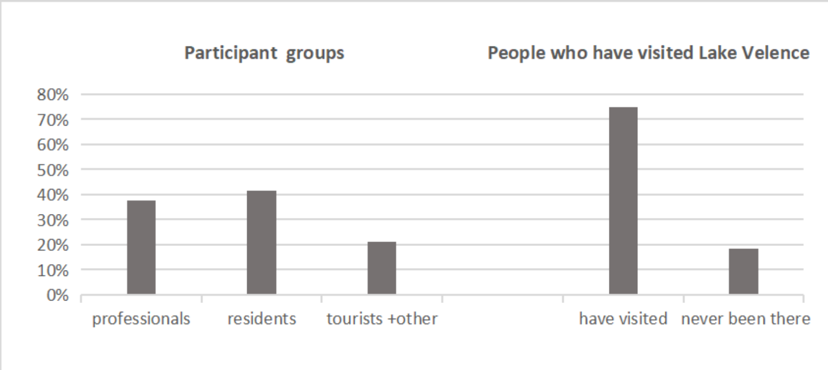
APPENDIX



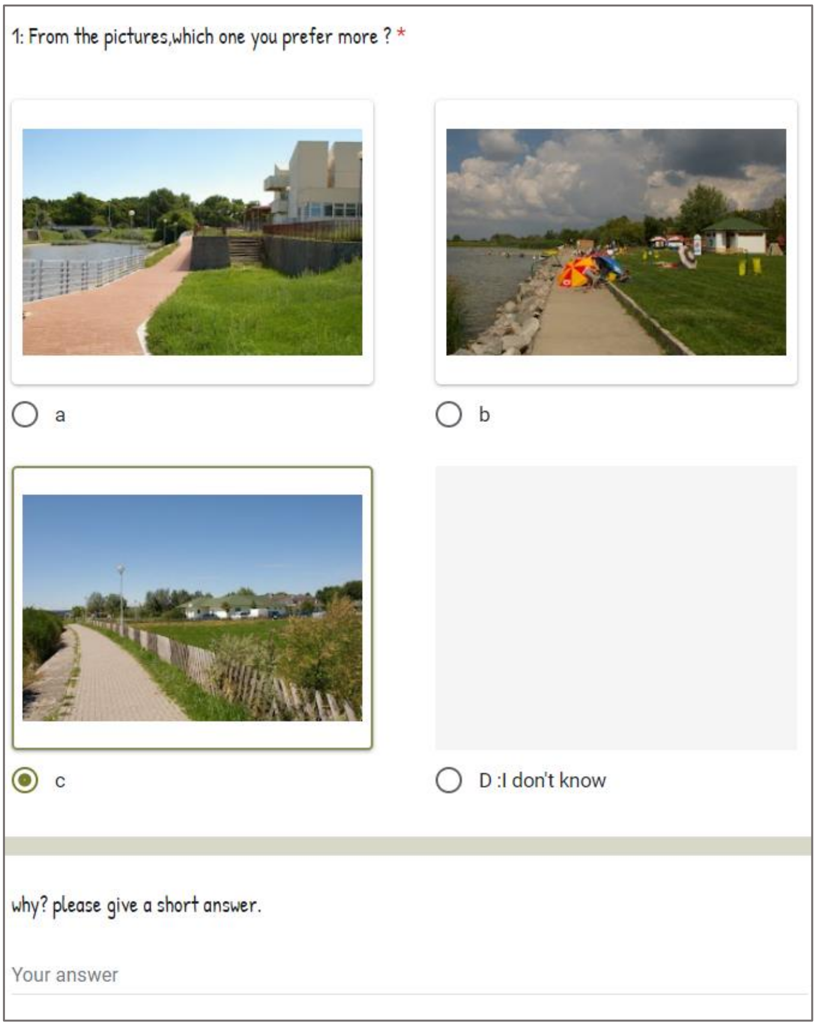
Appendix 1 Methods and materials



Appendix 2 Diagram of the steps of the public engaged landscape preference survey and expert assessment survey



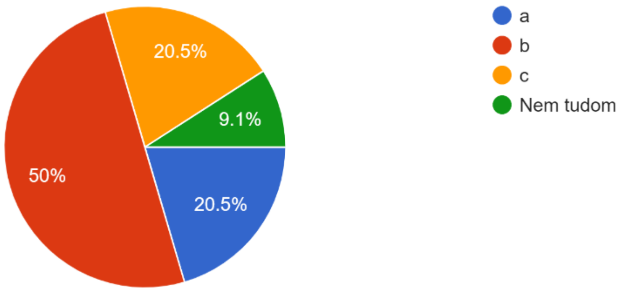
Appendix 3 Proportion of different groups involved in the landscape preference survey



Appendix 4 Questionnaire on the public's preference for different types of lakeshore revetments (Take comparison group 2 as an example)

Which of the pictures would you prefer?

44 responses



Why? Please give a short answer.

33 responses

Because there is no fence.

Although the first picture is prettier, there are very few places for sunbathers and beachgoers to pack their bags, and a few people can lie down in a row.

As far as I can see, this is the free beach in Gárdony. Neat stones and pavement, well-kept grass for sunbathing.

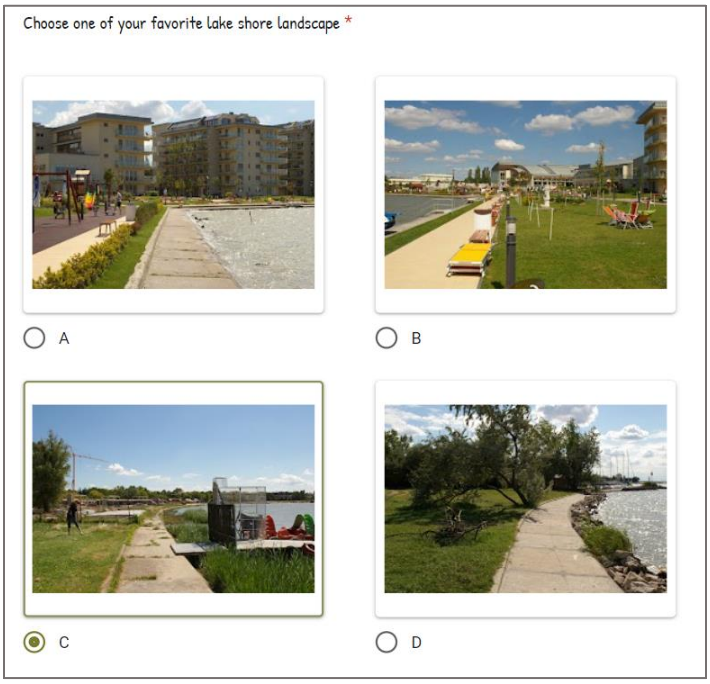
Renovated, stone colored.

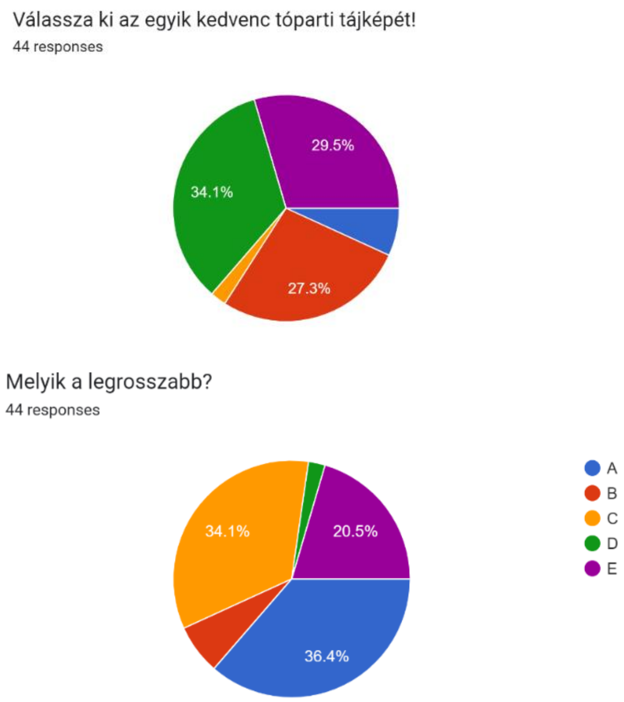
organized

Mostly single

B. only because all the others lock people behind a fence. But B. is not the natural coast either. That would be the best, and not stones and concrete on the beach. Lake Venice in its natural state is not a concrete turtle!!!!!!

Appendix 5 Responses from participants to the second set of lakeshore views





Appendix 6 Questionnaire and responses of local residents' preferences for different levels of artificial lakeshore

Why? Please give a short answer.

36 responses

It does not fit the Venice lake.

Many buildings are crowded and disgusting. 'D' is best for bathers because of the wooded and grassy part. I would build more fishing piers in this place, because I regularly fish in the place shown in the picture, and more places could be created in the part between Pákozd and Sukoró in addition to the 3.

Crowded

Almost zero "green space".

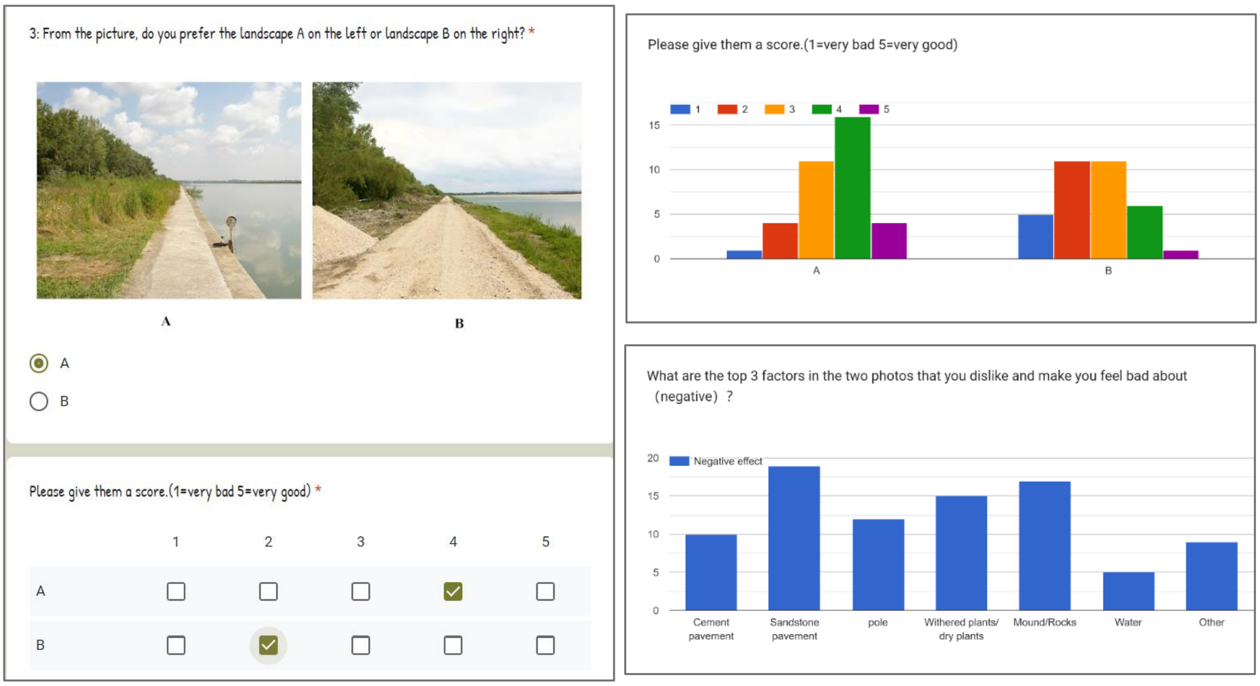
Built in, closed off, overcrowded.

E is natural, c is neglected

Concrete jungle

The last two are the most natural, close to nature. The C also radiates calm and quietness, while a and b are a beach where life is bustling

Appendix 7 Description of reasons given by some participants



Appendix 8 Public ratings of the visual impact of lakeshores through an online questionnaire (take Scene 6 as an example)

LU/LC Class	1989		2009		2019		Change of land use area between 1989-2009	Change of land use area between 2009 and 2019
	Area (ha)	% of the total area	Area (ha)	% of the total area	Area (ha)	% of the total area	%	%
Tourist accommodation area	11.17	1.79%	15.67	2.48%	19.12	3.03%	0.70%	0.55%
Recreational area	59.07	9.46%	60.76	9.63%	63.57	10.07%	0.17%	0.44%
Other tourism facility area	19.38	3.10%	27.87	4.42%	32.03	5.08%	1.31%	0.66%
Transportation land	54.29	8.69%	55.60	8.81%	57.97	9.19%	0.12%	0.37%
Urban area	51.61	8.26%	68.59	10.87%	76.62	12.14%	2.61%	1.27%
Bare land	1.01	0.16%	1.80	0.29%	12.51	1.98%	0.12%	1.70%
Agricultural land	44.51	7.13%	27.38	4.34%	25.86	4.10%	-2.79%	-0.24%
Forest area	54.44	8.72%	84.72	13.43%	96.94	15.36%	4.71%	1.93%
Semi-natural area	277.80	44.47%	280.00	44.37%	236.18	37.43%	-0.10%	-6.95%
Water area	45.85	7.34%	4.66	0.74%	4.45	0.71%	-6.60%	-0.03%

Appendix 9 Area and amount of change in each LULC classes in the 0-200m shore zone.

LU/LC Class	1989		2009		2019		Change of land use area between 1989 and 2009		Change of land use area between 2009 and 2019		Change of land use area between 1989 and 2019		Annual rate of the LULCC (q) 1989-2009	Annual rate of the LULCC (q)1989-2019	Area variation rate of LU/LC (C)1989-2009	Area variation rate of land use (C)1989-2019
	Area (ha)	% of the total area	Area (ha)	% of the total area	Area (ha)	% of the total area	Area (ha)	%	Area (ha)	%	Area (ha)	%	%/year	%/year	%	%
Tourist accommodation area	1.59	1.50	2.63	2.48	2.65	2.50	1.04	0.98	0.02	0.02	1.06	1.00	2.52	1.70	65.41	66.67
Recreational area	16.62	15.69	19.31	18.23	24.79	23.40	2.69	2.53	5.48	5.18	8.17	7.71	0.75	1.33	16.19	49.16
Other tourism facility area	6.09	5.75	10.41	9.83	11.15	10.53	4.32	4.08	0.74	0.70	5.06	4.78	2.68	2.02	70.94	83.09
Transportation land	6.98	6.59	4.45	4.20	4.61	4.35	-2.53	-2.39	0.16	0.15	-2.37	-2.24	-2.25	-1.38	-36.25	-33.95
Urban area	0.65	0.61	1.58	1.49	1.98	1.87	0.93	0.88	0.40	0.38	1.33	1.26	4.44	3.71	143.08	204.62
Agricultural land	0.26	0.25	0.00	0.00	0.00	0.00	-0.26	-0.25	0.00	0.00	-0.26	-0.25	#NUM!	#NUM!	-100.00	-100.00
Forest area	7.76	7.33	6.52	6.15	5.53	5.22	-1.24	-1.17	-0.99	-0.93	-2.23	-2.11	-0.87	-1.13	-15.98	-28.74
Semi-natural area	55.1	52.02	60.26	56.88	50.75	47.91	5.16	4.86	-9.51	-8.97	-4.35	-4.11	0.45	-0.27	9.36	-7.89
Water area	10.83	10.22	0.17	0.16	0.21	0.20	-10.66	-10.06	0.04	0.04	-10.62	-10.03	-20.77	-13.14	-98.43	-98.06
Bare land	0.04	0.04	0.62	0.59	4.26	4.02	0.58	0.55	3.64	3.44	4.22	3.98	13.70	15.56	1450.00	10550.00

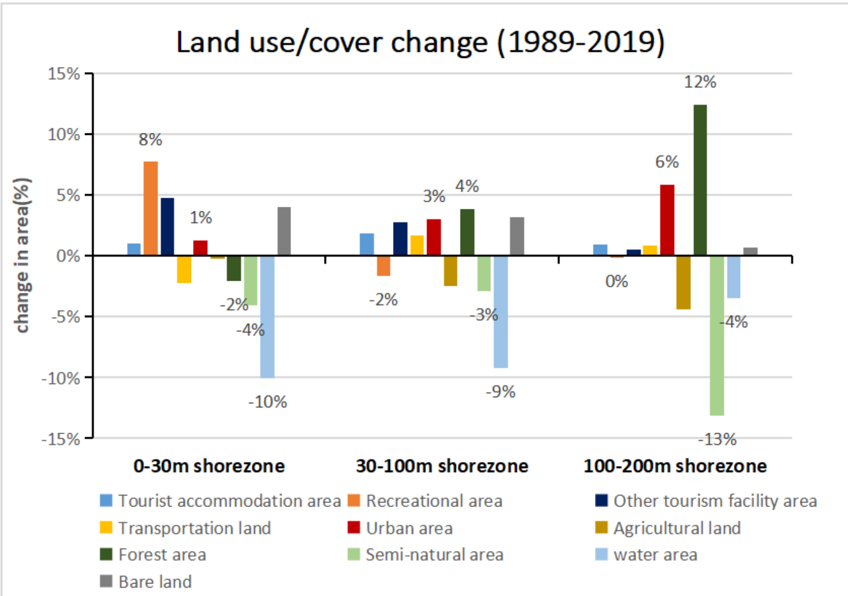
Appendix 10 Area of land use/land cover, annual rate of LU/LC change (q) and area variation rate(C) in the 0-30metershore zone.

LU/LC Class	1989		2009		2019		Change of land use area between 1989 and 2009		Change of land use area between 2009 and 2019		Change of land use area between 1989 and 2019		Annual rate of the change (q) 1989-2009	Annual rate of the change (q)1989-2019	Area variation rate of land use (C)1989-2009	Area variation rate of land use (C)1989-2019
	Area (ha)	% of the total area	Area (ha)	% of the total area	Area (ha)	% of the total area	Area (ha)	%	Area (ha)	%	Area (ha)	%	%/year	%/year	%	%
Tourist accommodation area	6.65	2.99	9.33	4.23	10.89	4.86	2.68	1.24	0.64	0.64	4.24	1.87	1.69	1.64	40.30	63.76
Recreational area	28.77	12.93	28.76	13.03	25.18	11.24	-0.01	0.10	-1.78	-1.78	-3.59	-1.69	0.00	-0.44	-0.03	-12.48
Other tourism facility area	7.76	3.49	10.13	4.59	13.98	6.24	2.37	1.10	1.65	1.65	6.22	2.75	1.33	1.96	30.54	80.15
Transportation land	10.68	4.80	13.46	6.10	14.44	6.45	2.78	1.30	0.35	0.35	3.76	1.65	1.16	1.01	26.03	35.21
Urban area	11.69	5.25	15.56	7.05	18.49	8.26	3.87	1.79	1.21	1.21	6.8	3.00	1.43	1.53	33.11	58.17
Agricultural land	6.82	3.07	1.25	0.57	1.29	0.58	-5.57	-2.50	0.01	0.01	-5.53	-2.49	-8.48	-5.55	-81.67	-81.09
Forest area	20.73	9.32	25.62	11.60	29.43	13.14	4.89	2.29	1.54	1.54	8.7	3.82	1.06	1.17	23.59	41.97
Semi-natural area	108.09	48.58	115.31	52.23	102.36	45.70	7.22	3.65	-6.52	-6.52	-5.73	-2.88	0.32	-0.18	6.68	-5.30
Water area	21.14	9.50	0.65	0.29	0.6	0.27	-20.49	-9.21	-0.03	-0.03	-20.54	-9.23	-17.41	-11.87	-96.93	-97.16
Bare land	0.17	0.08	0.72	0.33	7.31	3.26	0.55	0.25	2.94	2.94	7.14	3.19	7.22	12.54	323.53	4200.00

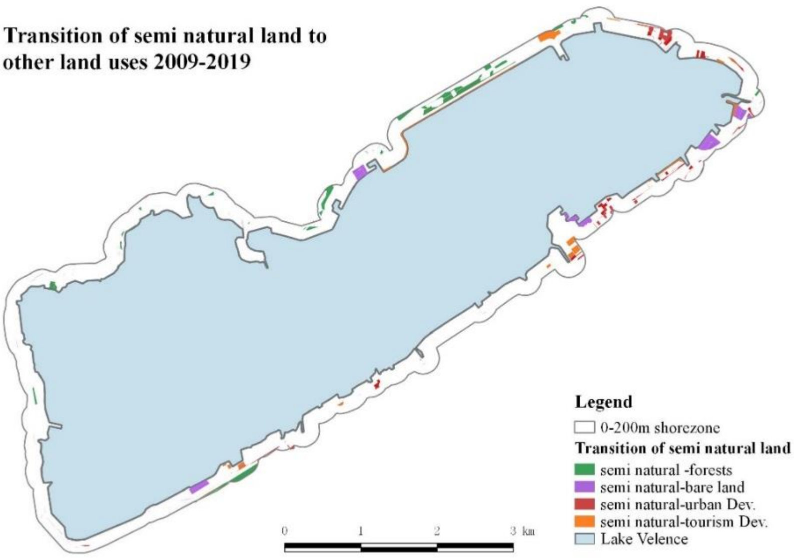
Appendix 11 Area of land use/land cover, annual rate of LU/LC change (q) and area variation rate(C) in the 30-100m shore zone.

LU/LC Class	1989		2009		2019		Change of land use area between 1989 and 2009		Change of land use area between 2009 and 2019		Change of land use area between 1989 and 2019		Annual rate of the change (q)1989-2009	Annual rate of the change (q)1989-2009	Area variation rate of land use (C)1989-2009	Area variation rate of land use (C)1989-2019
	Area (ha)	% of the total area	Area (ha)	% of the total area	Area (ha)	% of the total area	Area (ha)	%	Area (ha)	%	Area (ha)	%	%/year	%/year	%	%
Tourist accommodation area	2.93	1.01	3.34	1.15	5.58	1.92	2.65	0.14	0.77	0.77	2.65	0.91	0.65%	2.15%	13.99	90.44
Recreational area	13.68	4.71	11.32	3.89	13.6	4.68	-0.08	-0.81	0.79	0.79	-0.08	-0.02	-0.95%	-0.02%	-17.25	-0.58
Other tourism facility area	5.53	1.90	6.75	2.32	6.9	2.38	1.37	0.42	0.05	0.05	1.37	0.47	1.00%	0.74%	22.06	24.77
Transportation land	36.63	12.60	37.17	12.79	38.92	13.40	2.29	0.19	0.61	0.61	2.29	0.8	0.07%	0.20%	1.47	6.25
Urban area	39.27	13.51	50.94	17.52	56.15	19.33	16.88	4.02	1.81	1.81	16.88	5.83	1.30%	1.19%	29.72	42.98
Agricultural land	37.43	12.88	26.09	8.98	24.57	8.46	-12.86	-3.9	-0.51	-0.51	-12.86	-4.41	-1.80%	-1.40%	-30.30	-34.36
Forest area	25.95	8.93	51.66	17.77	61.98	21.34	36.03	8.85	3.57	3.57	36.03	12.42	3.44%	2.90%	99.08	138.84
Semi-natural area	114.61	39.42	99.19	34.12	76.39	26.30	-38.22	-5.3	-7.82	-7.82	-38.22	-13.12	-0.72%	-1.35%	-13.45	-33.35
Water	13.88	4.77	3.81	1.31	3.64	1.25	-10.24	-3.46	-0.06	-0.06	-10.24	-3.52	-6.46%	-4.46%	-72.55	-73.78
Bare land	0.80	0.28	0.42	0.14	2.68	0.92	1.88	-0.13	0.78	0.78	1.88	0.65	-3.22%	4.03%	-47.50	235.00

Appendix 12 Area of land use/land cover, annual rate of LU/LC change (q) and area variation rate(C) in the 100-200m shore zone.



Appendix 13 LU/LCC in the three zonal shore areas from 1989-2019

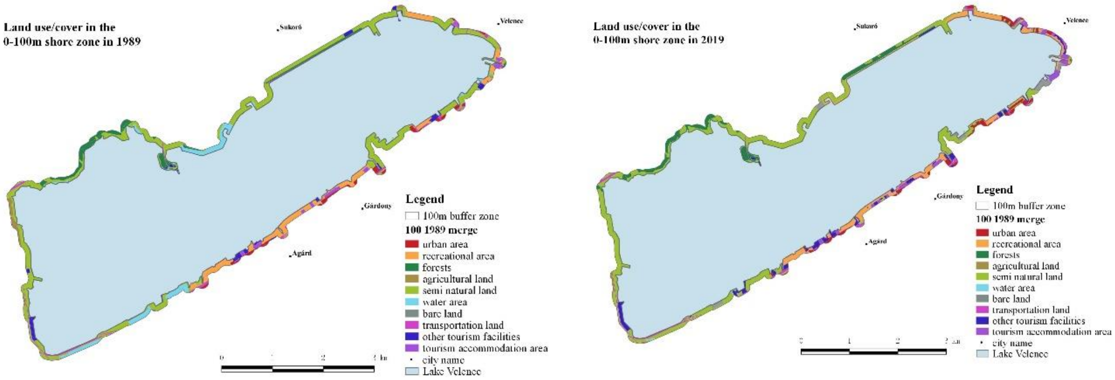


Appendix 14 Transition of semi-natural land on the lakeshore (2009-2019)

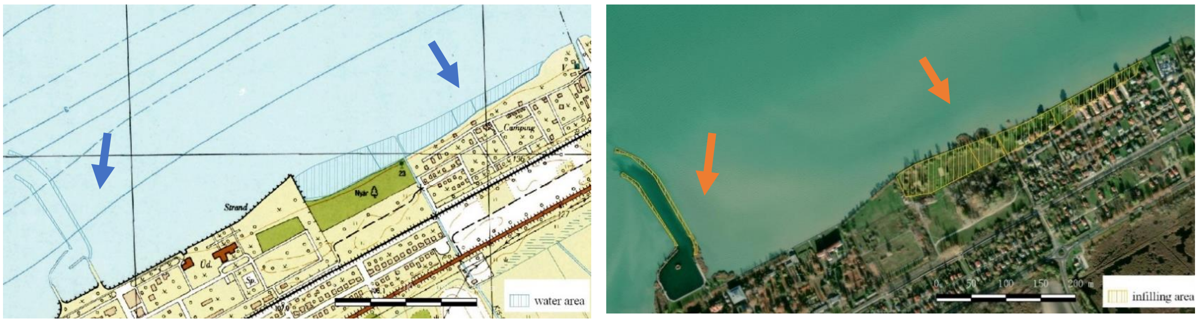
Shoreline type	1989 km	2009 km	2019 km
Natural shoreline	20.27	15.12	15.12
hardened shoreline	16.63	20.66	20.16
Artificial Sand beach	0	0.22	0.72
Total length	36.91	36	36

Appendix 15 Shoreline types and lengths of Lake Velence

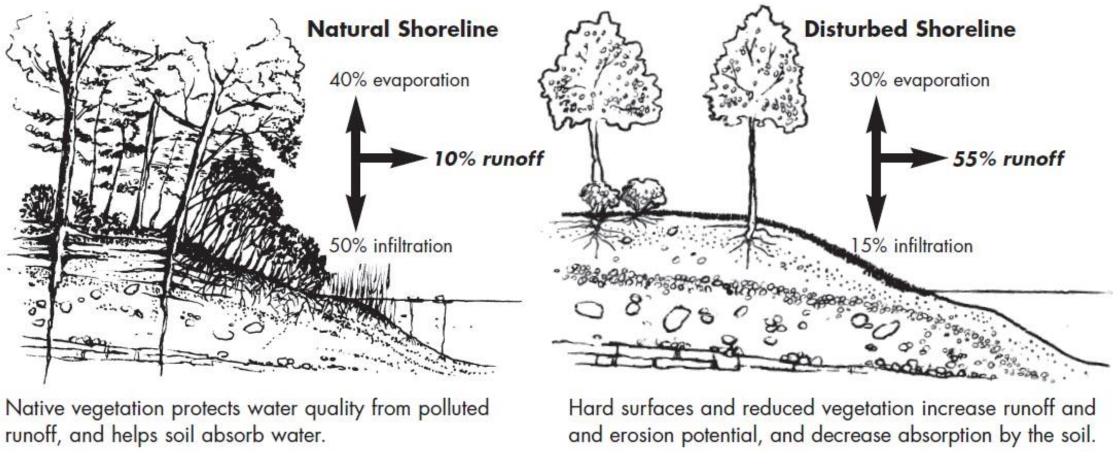
Appendix 16 Shore infilling area and retreat area, and changes in the shoreline of Lake Velence



Appendix 17 Land use/cover of the 0-100m lakeshore area of Lake Velence in 1989 and 2019



Appendix 18 Changes in the near-shore area of Lake Balaton



Appendix 19 Infiltration function of natural and hardened lake shores (original from the Rideau Valley Conversation Authority website)