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WATERMILL AND SMALL-SCALE HYDROELECTRIC POWER PLANT LANDSCAPES ASSESSED ACCORDING TO ECOLOGICAL ASPECTS

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Abstract. Research of watermill and small-scale hydroelectric power plant (HPP) landscapes in Latvia according to ecological aspects is a part of a more complex research. The aim of this research is to examine the existing situation of watermill and small-scale HPP landscapes in Latvia by applying the ecological assessment criteria, and then try to formulate a definition of common tendencies of the landscape character. This paper provides a landscape inventory matrix for research in the field studies of landscape identification at the local planning level. The duration of the research was from 2010 to 2012. The research includes 42 territories starting with the three most densely developed areas in Latvia: in Latgale, Kurzeme and Vidzeme uplands distribution ranges. The research results reflect tendencies of the landscape features assessed according to the previously developed criteria of ecological aspects.

Keywords: local planning level, identifying features, landscape, Latvia.

Introduction

Until the present moment, the quality of previously cultural and industrial landscapes related to territories of watermills and small-scale hydroelectric power plants (HPPs) in Latvia as evaluated by various aspects has not been very clear. Analyses were carried out by several authors in different scientific fields: historical review by Teivens (1985), Raitis and Virsnieks (1944) and Siļķe (2008); hydrological and environmental review by *Valsts SIA Vides projekti* (2004); and research of historically literary review by Zemdega (2004).

In research of any landscape quality, there is a need to look at different aspects (*e. g.,* aesthetics, technology, public use and, as in this particular study, ecology) for better understanding of landscape structure, functionality, resources, aesthetical, cultural importance, and to analyse the tendencies in these landscapes so that proper decisions can be made in the future according to development strategies in these territories. This research of watermill and small-scale hydroelectric power plant (HPP) landscapes in Latvia according to ecological aspects is a part of a major, more complex research process within the framework of the scientific discipline of landscape architecture. Several research projects in watermill or small-scale HPP territories in Latvia, alongside the explorations of their landscape architecture, were carried out earlier by the author of this paper (Lazdāne 2011; Lazdāne 2012b). One analysis based on aesthetical aspects is already published (Lazdāne 2012a). In relation to ecological aspects within the scientific discipline of landscape architecture, several recent research works could be mentioned; for example, Tērauds, Nikodemus, Rasa and Bells (2008); Zigmunde (2010a, 2010b); Dreija (2011); Lakovskis (2011); and Bells and Nikodemus (2000).

The need for landscape assessment is critical for future strategic development of landscapes in the aforementioned territories. Thus, the aim of this research is to examine the existing situation of landscapes in watermill and small-scale HPP territories in Latvia while also tracking their ecological aspects for a definition and establishing common tendencies of landscape character.

Ecological Aspects of Landscape

In the framework of this research study, the term 'ecology' means 'studying the relationships between human groups and their physical and social environments' (The American ... 2006). According to this definition of ecology, the term 'landscape' is simply 'an area of land (at any scale) containing an interesting pattern that affects and is affected by an ecological process of interest' (McGarigal 2000). 'Landscape ecology' involves the study of interactions between spatial pattern and ecological process, and interactions among the elements of this pattern, and how these patterns and interactions change over time (Turner *et al.* 2001; McGarigal 2000). Landscape ecology 'is the study of landscapes; specifically, the composition, structure and function of landscapes' (McGarigal 2000). The landscape ecology may focus on spatial extents

that are much larger than those traditionally studied in ecology (Turner *et al.* 2001). The term 'landscape ecology' was introduced by the German bio-geographer Carl Troll (Troll 1939; Turner *et al.* 2001).

The object of landscape ecology is defined in various ways: 1) The spatial relationships among landscape elements and ecosystems; 2) the flows of energy, mineral nutrients and species among the elements, and 3) the ecological dynamics of the landscape mosaic through time (Forman 1983; Turner *et al.* 2001).

Until now, a great deal of attention has been paid to landscape pattern and landscape metrics in the field of landscape ecology (Opdam *et al.* 2001; Lakovskis 2011). According to some researchers (*e. g.,* Botequilha, Ahern 2002; Lakovskis 2011), in the process of planning, not sufficient attention is paid to ecological problems, although any landscape planning using the principles of ecological planning in the context of landscape elements, place and region, will undoubtedly promote the quality of landscape ecology (Zigmunde 2010a).

Usually we know by our intuition that a variety of different elements can change the landscape through time and influence ecological dynamics (Turner *et al.* 2001). Not just the natural, but also cultural components of a regional landscape such as forests, grasslands, scrub-lands, wetlands, rivers, fields, residential and industrial areas, roads, traffic lines and power lines and their history contribute to the integral character of the landscape. In addition, the latter 'comprise their various human, ecological, social, economic, psychological, spiritual, aesthetic and functional aspects of experiencing and using the landscapes' (Palang *et al.* 2000). At the same time, it would be too arrogant to suppose today that any single discipline can provide all the solutions for protecting and restoring ecological integrity (France 2008).

Presently, the transformations of landscapes in Latvia are still essential, mainly because of considerable on-going polarisation and marginalisation processes (Nikodemus *et al.* 2005; Peneze 2009; Lakovskis 2011). The transformations of landscape structures (such as the overgrowth of agricultural lands and forest fragmentation) have significantly affected the biological diversity of Latvian landscapes (Bergmanis 1999; Lakovskis 2011).

The landscapes consist of several landscape elements, which could be used as landscape indicators or characteristic elements. The indicator is a parameter that can provide information on the characteristics of the event in its global form (Organization … 2003; Wascher 2002). Many experts agree that a good indicator must meet some fundamental requirements, namely those of representativeness, accessibility, reliability and effectiveness (Bottero 2011).

Materials and Methods

This research took place between 2010 and 2012. In Latvia, the data about the total amount of developed watermill and small-scale HPP territories vary. On the maps produced at the beginning of the 20th century (Ģeodēzijas…) more than 450 watermill territories are shown. According to the research data produced for possible future electricity production at the end of the 20th century by Magelis (1994), more than 540 objects were researched (including both watermills and small-scale HPPs) and marked on the maps accordingly; however, one more map produced in the 21st century (Latvijas mazās … 2008) marks out approximately 150 territories developed with small-scale HPPs working in proper condition for electricity production. Based on the maps analyzed beforehand, three areas in Latvia were selected for the present research: Latgale, Vidzeme, and Kurzeme upland areas. These areas contain the highest density of territories developed with watermills and small-scale HPPs (Fig. 1). The territories were selected randomly, except for one criterion: all three upland areas had to have at least 14 locations in question. These territories were also selected for the existence of architectural environment, diversity of functions (private or public), types of locations (rural, suburb, or urban), landscape construction; that is, only these territories were chosen where the hydro-power production is/was carried out only by water accumulation in reservoirs. As far as the practical development of the research method was concerned, the research was performed by applying the expert approach (using sensory perception and knowledge) according to professional practice and knowledge also based on literature review (Melluma, Leinerte 1992; Unwin 1975; Gaujas... 2005; Zigmunde 2010b; Nodibinājums... 2007; Silva *et al.* 2003; Taylor *et al.* 1987; Nikodemus 2001). Based on previous theoretically prepared identifying features, several random visits to the territories were made, and a matrix with identifying features of each landscape was developed. The same technique for landscape inventory matrix formation had also been used in a previous research project (Lazdāne 2012a). The matrix used in this research contains 19 identifying features (Table 1). These researched features characterise the situations in the territories, tendencies of landscape designs, and help to answer the question: can any ecological aspects be found in the existing situations. Each territory was visited and assessed with the help of the previously prepared landscape inventory matrix, and an expression of its characteristic features was drawn. The table of the landscape inventory matrix was prepared for each territory.

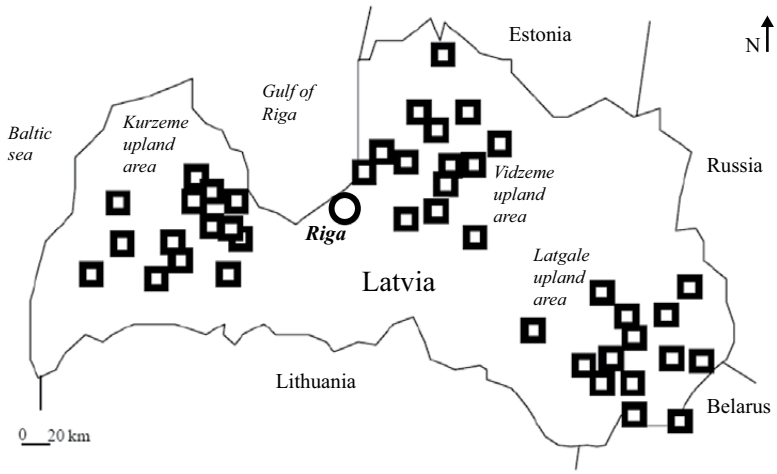

Fig. 1. Locations of researched territories on a schematic map of Latvia. *Source:* Designed by Lazdāne

Table 1. Landscape inventory matrix according to ecological aspects. *Source:* Compiled by Lazdāne (according to literature review based on Melluma, Leinerte 1992; Unwin 1975; Gaujas... 2005; Zigmunde 2010b; Nodibinājums... 2007; Silva *et al.* 2003; Taylor *et al.* 1987; Nikodemus 2001)

Identifying features	Expressions			
Wind (approximately 0–7 m/s)	Shelter	Breezy	In some places draughty	In the main part, windswept
D.0	D.0.1	D.0.2	D.0.3	D.0.4
Value, %	50	14	26	10
Indication of sudden erosion	Not observed	Along the riverbank next to weir	Along the waterside	In relief of surrounded territory
D.1	D.1.1	D.1.2	D.1.3	D.1.4
Value, %	71	10	14	5
Waterside coverage with trees	Not observed in all territory, or in several parts	Not observed in one part of the waterside	Sparse coverage in the most part of the waterside	Dense vegetation coverage
D.2	D.2.1	D.2.2	D.2.3	D.2.4
Value, %	38	17	21	24
Groups of self-sowing trees	Some trees	Fragmentarily, mainly along the waterside	Fragmentarily, in almost all territory	Evenly covered almost all territory
D.3	D.3.1	D.3.2	D.3.3	D.3.4
Value, %	14	26	24	36
Water surface overgrowth with water-plants on the upper part of the sluice	Almost none observed	Overgrowth with water-plants on the narrow zone along the waterside and /or fragmentarily in the middle	Overgrowth with water-plants on the wide zone along the waterside	Overgrowth with water-plants in almost all territory of the water surface
D.4	D.4.1	D.4.2	D.4.3	D.4.4
Value, %	9	43	38	10
Water surface overgrowth with water-plants on the lower part the sluice	Almost none observed	Overgrowth with water-plants on the narrow zone along the waterside and /or fragmentarily in the middle	Overgrowth with water-plants on the wide zone along the waterside	Overgrowth with water-plants in almost all territory of the water surface
D.5	D.5.1	D.5.2	D.5.3	D.5.4
Value, %	14	24	24	38
Water surface filled in with fallen trees and branches	Not observed	Several fallen trees or branches are observed	A lot of fallen trees or branches are observed	Part of the territory is impossible to observe because of plenty of fallen trees and branches

Continued Table 1

Identifying features	Expressions			
D.6	D.6.1	D.6.2	D.6.3	D.6.4
Value, %	67	17	14	2
Old trees with wide foliage or are hollow	Not observed	One old tree with wide foliage or hollow	Several old trees with wide foliage or hollow	
D.7	D.7.1	D.7.2	D.7.3	
Value, %	10	0	90	
Location of trees in appropriate place for characteristic dimensions of the species	In appropriate places, according to characteristic dimensions of the species	A few trees are growing in inappropriate places (too close to the buildings, *etc.*)	Territory is overgrown with trees in inappropriate places (too close to the buildings, *etc.*)	
D.8	D.8.1	D.8.2	D.8.3	
Value, %	67	24	9	
Use of modern, new shapes and species of decorative plants or trees	Not observed	Several plants	Several groups of plants and /or trees	Territory is mainly shaped by decorative plants and /or trees
D.9	D.9.1	D.9.2	D.9.3	D.9.4
Value, %	69	10	21	0
Use of trimmed bushes or trees for decorative aim	The crowns of trees and bushes are not shaped	The crowns of trees and bushes are shaped, natural look is retained	Several bushes and /or trees are with crowns trimmed and shaped for decorative purposes	
D.10	D.10.1	D.10.2	D.10.3	
Value, %	55	40	5	
Feeding places for wildlife (birds, animals, *etc.*)	Not observed	There are bird-tables located	There are bird-tables and other animals feeding places	
D.11	D.11.1	D.11.2	D.11.3	
Value, %	86	12	2	
Fish pass over the dams in rivers	A dam exists, but fish pass is not observed	A dam exist with a fish pass observed	Dam does not exist any more, natural water flow	
D.12	D.12.1	D.12.2	D.12.3	
Value, %	81	0	19	
The building materials, used for facade decoration	Mainly wood, stone, clay products, plastering materials	Mix of wood, stone, clay products, plastering building materials and plastic, concrete, silicate bricks, metal materials	Mainly, plastic, concrete, silicate bricks, metal materials	
D.13	D.13.1	D.13.2	D.13.3	
Value, %	55	38	7	
Garbage pollution in the territory	Not observed	Several small pieces are observed	One or more concentrated spots of garbage	Extensive garbage pollution
D.14	D.14.1	D.14.2	D.14.3	D.14.4
Value, %	81	7	12	0
The possibilities for proper garbage sorting and throwing in garbage cans	Garbage cans are not located	Garbage cans are located, but without possibility to sort	Garbage cans are located, with possibility to sort	
D.15	D.15.1	D.15.2	D.15.3	
Value, %	62	38	0	
Publicly located information regarding fisheries regulations in a particular territory	Not located	Only written information is located	Written information and explaining symbols, images, and information is located	
D.16	D.16.1	D.16.2	D.16.3	
Value, %	79	21	0	
Publicly located information regarding nature protection status of rare trees, species, or nature reserve	Not located or observed	Located, but not explained	Located and explained	
D.17	D.17.1	D.17.2	D.17.3	
Value, %	96	2	2	
Mechanical noise in territory	None detected	Noises are low and /or rare	Most part of the territory is noisy	
D.18	D.18.1	D.18.2	D.18.3	
Value, %	36	55	9	

In this research, after the inventory matrix was completely filled out for each territory, the general data were calculated and shown in percentages. The percentage value was chosen for clarity in proportions (since data in absolute numbers might be confusing) for each identifying feature expression.

Results and Discussion

All 42 landscapes of watermills and small-scale HPPs were visited and researched. The results show that landscapes assessable by ecological aspect are mainly located in a place surrounded by trees (D.2.2 – 17%, D.2.3 – 21%, D.2.4 – 24%) (Fig. 2), and only 38 percent of the territories contain several open views in the landscapes surrounded by trees (Fig. 3). If a dense arrangement of trees and bushes and other flora gives sufficient space to link various habitat types, then their percentage is high in the researched territories. Diverse ecological systems require connections to keep them alive and functioning (Landscape … 1997). In these territories, there is also a comfortable micro-climate because of wind shelter (D.0.1 – 50%, D.0.2. – 14%), and silent neighbourhood (D.18.1 – 36%, D.18.2 – 55%). Silent neighbourhood and wind shelter percentages show that there are potentials to develop low intensity recreational features and/or residential housing. As far as noise impacts are concerned, as researched previously by several other authors (*e. g.,* Babish *et al.* 2005; Stansfeld *et al.* 2005; Bluhm *et al.* 2007; Gidlof-Gunnarsson and Ohrstrom 2007), traffic noise may cause non-auditory stress effects such as changes in the physiological systems, various cognitive deficits, and sleep disturbances, modifications of social behaviour, psychosocial stress-related symptoms, and emotional/motivational effects. Noise can be characterised by its frequency content, perceived loudness of complex sounds, different noise types, *etc.* (Berglund *et al.* 1999). The existing condition of low noise intensity has to be carefully maintained in future developments. For example, noise may be caused on these sites by different forms of entertainment (*e. g.,* sports and music events) (Berglund *et al.* 1999). However, there is also a need to understand that different people will respond quite differently to the same noise stimulus (Job 1988).

Fig. 2. Enclosure of trees (forest) on a small-scale HPP water reservoir. *Source:* Lazdāne's private archive, 2012

Fig. 3. Open views to surrounding landscape from a watermill. *Source:* Lazdāne's private archive, 2012

Sudden erosion of relief was not detected in most of the territories (D.1.1 – 71%). Most of the territories fall within the type of human maintenance, where the fragile part of vegetation (such as dangerous, broken trees, and branches) is managed (D.6), and are clean (D.14.1 – 81%). However, at the same time, in most of the visible landscapes, old trees are with wide foliage or hollow (D.7.3 – 90%). Trees are often called the silent protectors of our and plants' health, they reduce soil erosion, act as sink for atmospheric carbon dioxide, provide a shelter to countless species of wildlife, mitigate solar glare (especially in urban areas), *etc.,* and their foliage, flowers, bark add beauty to their habitat (Kohli *et al.* 2003). The plans for maximum care for old or wide foliage trees have to be developed, but at the same time, the safety issues for inhabitants also have to be prudently considered. In the researched territories, 24 per cent of (D.8.2) trees are growing in inappropriate places (too close to buildings, *etc.*), and nine per cent (D.8.3) in most of the territories have overgrown in inappropriate places (Fig. 5), which could indicate that such territories were abandoned quite a long time ago since uncontrolled vegetation of trees is growing there. Any disturbance at ecological level extends beyond the season, year or decade, and the disturbance in any part will be reflected in the dynamics of the entire life of landscape ecosystem (Forman 1987; Bormann 1987; Naveh, Lieberman 1984; Silva Ecosystem … 1992).

The researched territories mainly look natural or wild, because modern, new shapes and species of decorative plants or trees are not widely used (D.9.1 – 69%, D.10.1 – 55%, D.10.2 – 40%). In describing the existing situations, it can be said that natural appearance is still

maintained. The tendencies to use new, modern bush, flower and tree species in these territories have not been recognised yet, but in the future, with the start of intense development of the territories the situation may change quickly. This part of expression is especially important, because, when cultural or historical territories are developed as authentic environments, the diversity and modernity of species has to be supervised closely.

As far as the waters are concerned, the most researched territories have dams, but do not have fish passes (D.12.1 – 81%), and in 19 per cent (D.12.3) of the territories, the dams and sluices are destroyed (Fig. 4). This may be due to the fact that fish passes are very expensive to build and maintain (Armstrong *et al.* 2010). The design type of the passes (e. g., Pool and Traverse; Denil, *etc.*) depends upon a number of factors, such as type and form of the structure, where it is to be located, local topography, river characteristics, etc. (Armstrong *et al.* 2010). As the research results show, in order to develop the fish passes on the rivers, it is important to consider several interests such as flora and fauna, landscape and sites of historic or archaeological interest; activities such as boating and canoeing and access to waterways, maintenance of water levels in navigable rivers and canals, *etc.* (Armstrong *et al.* 2010). The results on the overgrowth of water plants on the upper part of the sluice (Fig. 6) and lower part of the sluice (Figs 7 and 8) are different (D.4, D.5). If we look at the results about the information regarding fishing regulations in

Fig. 6. Water surface overgrowth with water-plants on the upper part of the sluice: Overgrowth with water-plants on the narrow zone along the waterside and/or fragmentarily in the middle.
Source: Lazdāne's private archive, 2012

Fig. 4. Ruined sluices of a dam on a watermill reservoir.
Source: Lazdāne's private archive, 2012

Fig. 7. Water surface overgrowth with water-plants on the lower part of a sluice: Almost none observed.
Source: Lazdāne's private archive, 2012

Fig. 5. Trees inside the ruins of an old watermill building.
Source: Lazdāne's private archive, 2012

Fig. 8. Water surface overgrowth with water-plants on the lower part of the sluice: overgrowth with water-plants in almost all territory of the water surface.
Source: Lazdāne's private archive, 2012

these territories, it is not found in 79 per cent (D.16.1) of the territories. Also the information regarding nature protection status is not found in many territories (D.16.1 – 79%), but this feature may be non-existent in most of the territories, because they do not have any natural features, which need special protection.

Based on the research results, it is important to understand that the future development of infrastructure will cause changes on natural environment and that it is easy to destroy or degrade natural environment or ecological systems (Flink 2002). In each specific territory, landscape architecture may be further explored in connection to ecological approaches in the future.

Conclusions

Landscapes assessed according to ecological aspects show the main tendencies on the landscape character. The landscapes are mostly naturally shaped with the existing water reservoir and different pattern of trees and plantations. Several landscapes have become more natural after being in an abandoned state for a long time, but the same environment does not exist as it once did in the previous qualities. It seems buildings and infrastructure that existed before have not been demolished properly; thus, they exist in ruined or abandoned conditions, together with new natural environment. These circumstances will bring new challenges, but questions as how to naturalize the unused territories with less damage to the environment, less impact on the natural system, and without danger to the fauna, or who may use these territories, still remain open.

For the landscape management planning in the future, it would be critical to use the data from this research. The results show that choices for any future support for development, possibly having different purpose, need to be clearly explained and weighed out before making any decisions.

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VANDENS MALŪNŲ IR MAŽŲJŲ HIDROELEKTRINIŲ KRAŠTOVAIZDŽIO VERTINIMAS EKOLOGINIAIS ASPEKTAIS

L. Lazdane

Santrauka

Latvijos vandens malūnų ir mažųjų hidroelektrinių kraštovaizdžio vertinimo ekologiniais aspektais tyrimas yra kompleksinio tyrimo dalis. Tyrimo tikslas yra įvertinti esamą vandens malūnų ir mažųjų hidroelektrinių kraštovaizdžio situaciją ekologiniais aspektais ir išryškinti bendrąsias kraštovaizdžio charakterio tendencijas. Straipsnyje atspindėta kraštovaizdžio inventorizavimo matrica kraštovaizdžiui identifikuoti planavimo lygmeniu. Tyrimas atliktas 2010–2012 metais. Tyrimas apima 42 teritorijas, išsidėsčiusias trijose tankiausiai apgyvendintose Latvijos dalyse: Latgaloje, Kuržemėje ir Vidžemėje. Remiantis anksčiau suformuluotais kriterijais kraštovaizdžiui tirti ekologiškumo aspektais, tyrimo rezultatai atskleidžia tam tikras tendencijas.

Reikšminiai žodžiai: kraštovaizdžio planavimo lygmuo, identifikavimo požymiai, kraštovaizdis, Latvija.