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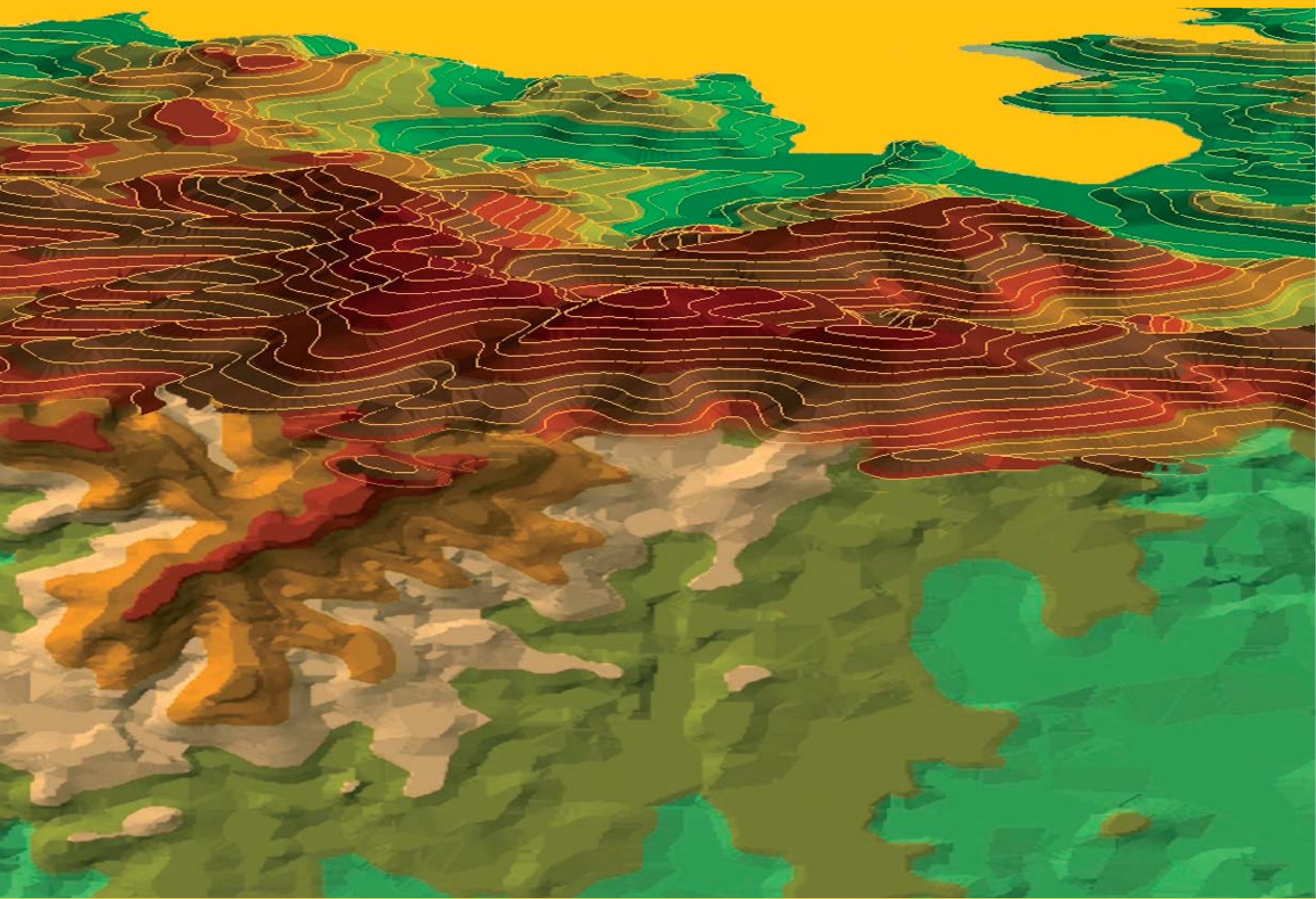

Fig. 8: Hellisheiði, the third-largest geothermal power plant in the world (the southwest Iceland) (Photo: B. Frantál)

Fig. 9: One of the two experimental wind turbines constructed in the Haf area, Highlands of Iceland (Photo: B. Frantál)

Illustrations related to the paper by B. Frantál et al.

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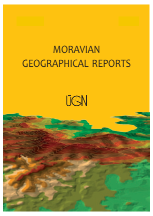

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Sustainable biofuel: A question of scale and aims

Margherita CIERVO [a], Serge SCHMITZ [b] *

Abstract

Bio-energy (like other renewable energy sources) is proposed as a solution for climate change and other energy-related and economic issues. The predominant production model, however, which is based on first-generation biofuels developed on a global scale, creates ecological impacts throughout the production chain, resulting in a sustainability paradox, as well as social unrest and territorial conflict. Therefore, attention here is focussed on agro-energy and second-generation biofuels, investigating the structural differences, the advantages, the potential problems and the possible solutions of some local biofuel initiatives in North Western Europe. Finally, we propose a regional agrarian model to avoid the impacts and contradictions of the global industrial model, to produce a better ecological balance at both the local and the global levels, and to improve the democratic character of energy governance. In addition, we suggest a paradigmatic reading to better understand the cultural, political and socio-economic implications of the two models.

Keywords: *biofuel; global industrial model; regional agrarian model; local scale; short chain; North Western Europe*

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1. Introduction

Renewable energy (RE) is proposed by world agencies and governments as a solution to global climate change: on a global scale (to cut CO_2 emissions and mitigate climate change); on a national scale (to reduce energy supply costs, diversify fuel resources, diminish dependence on fossil fuel imports, enhance the security of the energy supply and address fossil fuel scarcity); and on a regional scale (to improve rural economies). Referring especially to the "southern" countries, RE is promoted as a way to generate employment and income, the opportunities for foreign investment, development in depressed areas, new taxes and foreign exchange revenues (Sawyer, 2008). At other scales, RE, especially agroenergy and biofuel, can produce socio-economic and environmental problems (deforestation and destruction of biodiversity, dependence on imports, food insecurity and rural poverty), which can lead to social unrest and social conflict. Several researchers have already noted the shortcomings of the large-scale production and export of first-generation biofuels (ethanol and biodiesel) (e.g. Altieri, 2009; Ponti and Guitierrez, 2009; Rathmann et al., 2010; Van der Horst and Vermeylen, 2011). The public debate has focused on the overall carbon footprint and rarely includes spatial analysis of environmental and social impacts (Secchi et al., 2011). This model is promoted by international organisations (the United Nations, G8 bio-energy partnership, World Trade Organization, etc.), the European Union (EU), the United States of America (USA) and other governments, resulting in considerable investments in export-oriented biomass and biofuel (Faaij, 2011), reinforced by interconnected market/economic factors, such as differences in production costs across nations (Lamers et al., 2011). Economic and political elites believe that global biofuel production and consumption will mitigate climate change and enhance energy security (Mol, 2007).

In the last decade, biofuel production and global trade have grown exponentially. Production has increased from less than 30 petajoule (PJ) in 2000 (0.8 Mtonnes) to 572 PJ (15.2 Mtonnes) in 2009 for biodiesel, from 340 PJ in 2000 to over 1,540 PJ in 2009 for fuel ethanol (Lamers et al., 2011), and currently biofuels (biodiesel and ethanol) represent the vast majority of the renewable share of global energy demand for transport, providing around 4% of world road transport fuel (REN21, 2017). The prevailing trend is for biofuel streams to move from south to north on a global scale. Ethanol is produced primarily in Brazil, whereas the largest biodiesel producers are Argentina, Malaysia and Indonesia, and both fuels are exported mainly to the EU and the USA (Lamers et al., 2011; Mol, 2010).

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In Europe, the EU supports biofuel primarily for the purposes of CO_2 emissions reduction, energy security, diversification and increasing farmers' incomes. In 2015, 79.4% of biofuel consumption for transport came from biodiesel, 19.5% from bioethanol and the rest (1.1%) from biogas (EurObservER, 2016). Germany, followed by France and Spain, are the largest European producers and among the top 16 countries for biofuel global production (REN21, 2017). The main consumers of biodiesel in the EU are France, Germany and Italy (49% of the total) (EurObservER, 2016). In recent years, we have also observed an increase in vegetable oil imports from other EU countries and from the global market, and some countries have become increasingly dependent on imports (Junginger et al., 2008; Kalt and Kranzl, 2012).

This paper analyses local initiatives to produce biofuel in North Western Europe and discusses their efficiency. Do local initiatives better fit the aims of sustainable development? We focus on second-generation biofuels and investigate the following research questions:

1. Is it possible to define a production-distribution-consumption model to avoid the contradictions and problems produced by the global model?;
2. What are the location criteria that must be met by a site to reduce or offset negative local impacts?; and
3. Is it possible to define an optimal spatial scale for bioenergy development, i.e. the most pertinent spatial scale at which the contradictions and problems produced by the global model can be overcome and allow for the democratisation of energy governance?

Geographers have a long tradition in local impact assessment, highlighting scale effects and looking for the best locations. As human geographers, we insist that bioenergy assessment analyses the whole production process from a holistic point of view, including the different locations and social and environmental implications at various scales.

This paper is structured as follows: after background on the impact of the global industrial model (section 2.1), the territorial dimension and the spatial scale (section 2.2), section 3 presents local initiatives in North Western Europe. These last are analysed (section 4) and their efficiency is questioned (section 5). In particular, we examine local biofuel production (section 4.1), the location and social acceptance issue (4.2), the entrepreneurial and territorial models (4.3), and local scale and governance (4.4). We propose a comparison between the global and the regional scale models in section 5.1 and, finally, we present a regional agrarian model (section 5.2).

2. Theoretical background

The assessment of biofuel as a sustainable energy source depends on the entire process (Cockerill and Martin, 2008). Nevertheless, we lack information about the complete cycle and its impact at different scales (German et al., 2010), and these assessments raise ethical concerns regarding equity, biodiversity and the future of mankind (Gamborg et al., 2012).

2.1 The impact of the global industrial model

The global model of large-scale production and long-distance transport concerns both the supply of raw materials and the countries where biofuel is consumed. This model creates ecological impacts and contradictions relating to environmental, socio-economic and geopolitical aims (Ponti and Gutierrez, 2009; Russi, 2008). Various studies, referring particularly to first-generation biofuels but also to biogas produced according to a profit logic and without connections to local communities (Carrosio, 2013), show the impacts on environmental and socio-economic organisation (Altieri, 2009; de Carvalho and Marin, 2011; Naylor, 2007; Sawyer, 2008). Several studies underline changes in agriculture, the alteration of land use dynamics, food insecurity and an increase in food prices (Azar and Larson, 2000; Rathmann et al. 2010). Other research outlines several interrelated problems: the spatial relations between deforestation and biofuel production (Gao et al., 2011); the high energy and water costs of crop irrigation and production (Dalla Marta et al., 2011; Pérez et al., 2011; Williams et al., 2012); threats to biodiversity (Rowe et al., 2009; Sullivan et al., 2011); the loss of local control over territories and ecosystems and the land grab phenomenon (Cotula, 2012; Dauvergne and Neville, 2010; Duvail et al., 2012; Vermeulen and Cotula 2010); territorial disputes (Amigun et al. 2011; Fernandes et al. 2010); involvement and tensions with indigenous communities (Colbran, 2011; Hazlewood, 2012; Montefrio and Sonnenfeld, 2013); connections to the climate dimension (Jensen and Andersen, 2013; Tsao et al., 2012); and direct questioning of the sustainability of these REs (Levidow and Paul, 2010; Zeller and Grass, 2008).

The negative territorial impacts of the global industrial model observed in the above- mentioned literature have been represented in a matrix (Tab. 1), with respect to: (a) the different phases of the production-distribution-consumption chain; (b) a macro-typology of the impacts (agrarian environmental, landscape, socio-economic and geopolitical); and (c) the main spatial scales at which the impacts appear and can be wholly valuated, as well as the level at which the phenomena are more important and/or more dangerous (also as interpreted in the analysed literature).

Nevertheless, if a global industrial model exists, it should present positive impacts as well. These impacts are related to the enrichment of huge companies, including petrol companies, the weakening of fossil fuel dependency, and the development of new economic activities. Dependence on imports often occurs, however, which conflicts with the objective of energy autonomy, and the people who pay the environmental costs (local inhabitants) are not the same as those who reap the economic benefits (large corporations). This can become a social justice problem, and social tensions can conflict with the aims of sustainable rural development. The global industrial model is characterised by separate places of production and consumption, which are rural areas and urban areas, respectively, and on the global level, southern countries and northern countries, respectively. This separation leads to the delocalisation of resource use (fossil fuels, soil and water for production) and the rescaling of pollution, as in more traditional sectors of global industry (Gupta and Dermibas, 2010). The use of biofuel for transport or heating can improve air quality at the local or regional level (for example, the effect can be important in towns) but worsen the net global level of greenhouse gases emitted in the production and transport phases.

2.2 The territorial dimension and the spatial scale

The international discussion pays little attention to the territorial dimension of biofuel production and, thus, to the relations between biofuel production chains and territorial organisation at different spatial scales (Puttilli, 2009; Puttilli and Tecco, 2012). Bridge et al. (2013) call for

Biofuel production chain	**Spatial scale**			
	Local	Regional	National	Global
Biomass production**	Loss of biodiversity	Deforestation	High energy and water consumption	Degradation of the global ecosystem
	Nutrient leaching and soil erosion	High energy and water consumption	Concentration of lands	GHG emissions associated with direct and indirect land uses
	Soil and water depletion and pollution by pesticides and chemical fertilisers	Landscape changes	Increased price of lands	Dependence on industry and markets for the upstream and downstream phases of production
	Simplification and uniformity of landscape	Alteration of land use and its dynamics	Rural poverty	Dependence of farmers on biofuel corporations
	Changes in agricultural products	Loss of control over territories and ecosystems by local people	Competition among alternative uses of biomass for food, feed, fibre and fuel	Increase of agricultural products (such as wheat, corn, etc.) and food prices (such as pasta, bread, etc.)
	Land use changes	Tensions with indigenous communities	Food insecurity	Competition between food and non-food production over land use
	Scarce or absent relations with the local agricultural chain			Land and water grabbing
	High energy and water costs			
	Competition over scarce resources (water, soil, etc.)			
	Loss of land, livelihoods and traditional ways of life in local communities			
	Disputes with local communities			
Biomass processing	CO_2 emissions and air pollution	Alteration of regional climate	Dependence on imports	Increasing greenhouse effect and climate change
	Landscape changes			
	Public health			
	Fire concerns			
	Few or absent relations with local actors			
Biomass transportation		CO_2 emissions and air pollution	CO_2 emissions and air pollution	Increase in greenhouse effect and climate change
Biofuel manufacturing	CO_2 emissions and air pollution			
	Landscape changes			
Biofuel distribution		CO_2 emissions and air pollution	CO_2 emissions and air pollution	Increase in greenhouse effect and climate change
Biofuel consumption			Dependence on imports	

Tab. 1: Global industrial model: potential territorial impacts of the biofuel production chain at different spatial scales (Notes: *the different spatial scales refer to the main spatial scales at which the impacts appear and can be wholly valuated, as well as the level at which the phenomena are more important and/or more evident and/or more dangerous; ** biomass production refers especially to monoculture for first-generation biofuels in Southern hemisphere countries)*

Sources: authors' conceptualisation based on Altieri (2009); Amigun et al. (2011); Azar and Larson (2000); Carrosio (2013); Colbran (2011); Cotula (2012); Dalla Marta et al. (2011); Dauvergne and Neville (2010); de Carvalho and Marin (2011); Duvail et al. (2012); Fernandes et al. (2010); Gao et al. (2011); Gupta and Dermibas (2010); Hazlewood (2012); Levidow and Paul (2010); Montefrio and Sonnenfeld (2013); Naylor (2007); Jensen and Andersen (2013); Pérez et al. (2011); Ponti and Gutierrez (2009); Rathmann et al. (2010); Rowe et al. (2009); Russi (2008); Sawyer (2008); Sullivan et al. (2011); Tsao et al. (2012); Vermeulen and Cotula (2010); Williams et al. (2012); Zeller and Grass (2008) more attention to be paid to the geographies of the energy transition. In particular, location, landscape, territoriality, spatial differentiation, scaling and spatial embeddedness are identified by these authors as necessary concepts to reflect the spatiality of energy transitions, which is too often analysed as single case studies. The production of bioenergy occurs at different scales (Walker and Cass, 2007). Depending on the scale and the places of production and consumption, the economic, social and environmental implications at the global, regional and local scales vary significantly. This diversity raises spatial equity questions (Pasqualetti, 2000).

The number of studies investigating local biofuel has grown since 2008 and exponentially so in the past few years. In these studies, biofuel is viewed essentially as a business (Tateda et al., 2011; Voytenko and Peck, 2012), and territory, which is at the centre of related research, is perceived as the key to achieving particular goals (with respect to second-generation biofuels as well). For example, territory – at each spatial scale – can be analysed to serve an objective such as the identification or evaluation of agricultural residue, residual biomass and/or other products for bioenergy production (Beccali et al., 2008; Ferreira-Leitao, 2010; Goltsev et al., 2010; Mabee and Mirck, 2011; Tricase and Lombardi, 2009; Yan, 2008). Policies for biofuel development (Borras et al., 2011; Hultman et al., 2012) in rural areas are analysed to verify opportunities, through the development of biomass, to diversify economies and increase farmers' incomes (Mwakaje, 2012; Zolin, 2011). On the other hand, some recent studies question the scale of production (Carrosio, 2013; Cotula, 2012; Monteleone et al., 2009) and pay more attention to the local acceptance of biogas plants (Kortsch et al., 2015; Schumacher and Schultmann, 2017; Soland et al., 2013). Local systems based on ecological principles have been analysed (Altieri, 1999; Huttunen, 2011), as have the driving forces of and attitudes towards biofuel diversification (Frantal and Prousek, 2016). A theoretical agro-territorial energy system with energy production coming from local biomass has also been proposed (Tritz, 2012).

Van der Horst and Vermeylen (2011) established a connection between the spatial scale and the social impacts of biofuel production, showing that domestic production and consumption in so-called developed countries produce a relatively minor social impact in comparison to international chains in so-called developing countries. Social impact is defined as "the consequences to human populations of any public or private actions that alter the way in which people live, work, play, relate to one-another, organise to meet their needs and generally cope as members of society. The term also includes cultural impacts involving change to the norms, values, and beliefs that guide and rationalise their cognition of themselves and their society" (Burdge et al., 2003). To avoid the greatest impacts and contradictions arising from energy-crop monocultures and the global-scale import-export of biomass and biofuel, it is advisable to manage agricultural residue and manure at the local level with a short chain with respect to both spatial (short distance) and organisational aspects (without brokers). A short chain refers to both the production-transformation-consumption levels and the technological, economic, financial, social and political levels.

3. Methodology

The methodology used in this study is essentially inductive, based on qualitative and quantitative analysis and a multi-scale approach. Specifically, it is grounded in the following: (a) indirect observation: the geographic literature, bibliographies, websites, laws and statistical data – on different spatial scales – concerning bioenergy; and (b) direct observation: research in the field with interviews and visits to biogas sites and farms.

First, we studied the situation in Belgium, specifically in the Walloon Region, analysing the initiatives of the Regional Network for Rural Development. This network, which stems from the Leader program, targets endogenous development based on local resources. We looked for local agro-energy models and interviewed the facilitator of

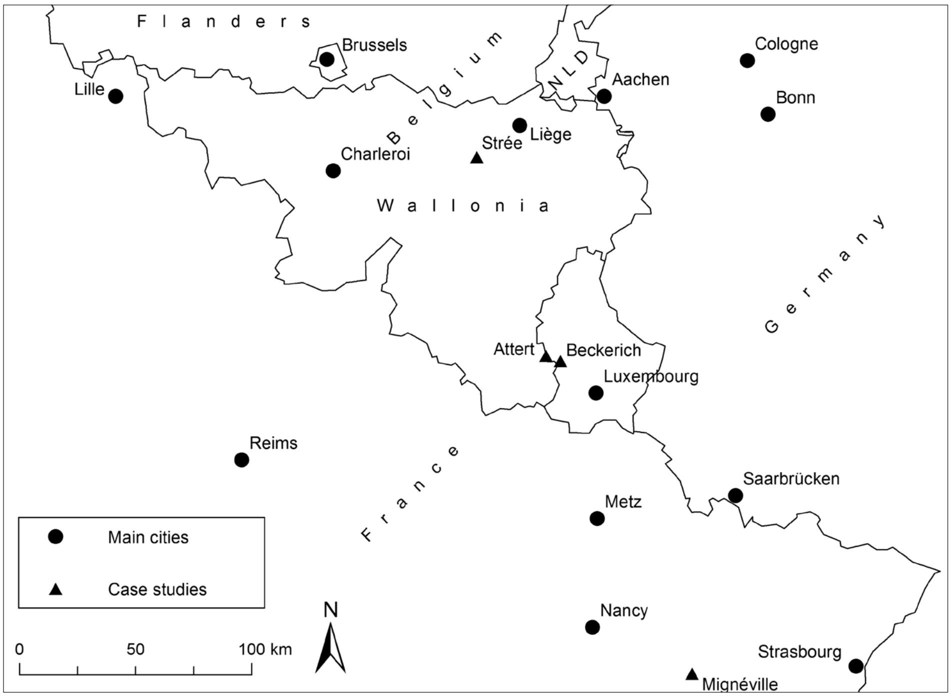

Fig. 1: Locations of the case studies
Source: authors' elaboration

agro-energy development projects in the Walloon Region. The facilitator gave us information and data regarding the eighteen local-scale biogas units in the region. Based on desk research and discussions with the facilitator and Belgian scholars, we decided to focus on the case of a European project aimed at developing biogas production in the Greater Region, a cross-border region in the Rhineland supported by INTERREG programmes that cover 11 million inhabitants. An interesting aspect of the project is that it is conceived on a regional scale (the Greater Region) but developed on a local scale in each country (Belgium, France, Germany and Luxembourg), with very different conditions, processes and, thus, results. We consider this feature very important in observing the weaknesses and strengths of each case. Thus, we study three operative cases that are part of this project.

These case studies pertain to second-generation biofuels and are characterised by a biogas cogeneration system developed in rural areas. Each case produces electricity and heat and uses by-products such as digestate for compost. The cases are located in Attert (Walloon Region, Belgium), Beckerich (Luxembourg) and Migneville (Vosges, France) (see Fig. 1). We also added a developing project in Strée (Belgium) promoted by the "Pays des Condruses" Local Action Group (LAG), because its institutional objectives included territorial participation, an essential aspect of our research. This last case is the reason we left out the cases and projects in the Walloon Region that were missing social participation.

For each case, we studied indirect sources, identified and interviewed six key actors promoting the initiatives, namely, the Director of the "Pays des Condruses" LAG, the President of the "Au pays de l'Attert" Association, the holder of the Faascht farm (Attert), the Mayor of Beckerich, the President of the "D'millen" Association, the Mayor of Migneville and the owner of an enterprise named "Bio-recycle". The interviews were conducted during the summer of 2013.

The interview questions were developed using an historical-geographic and problematic approach, which focussed attention on processes, spatial and relational aspects, problems and critical points. Thus, we constructed an analytical matrix. In the columns, we have indicated the four main macro-aspects (local development process; institutional, financial, scientific, social and cultural conditions; technical, financial, governmental and territorial problems; and critical points regarding raw materials, energy valorisation and waste) and related questions. Valorisation is used in this report to indicate 'value added' from the process. In the cells, we summarised the responses. Thus, by reading the matrix, we obtain information regarding each case and can immediately compare their main aspects. The interviews were composed of 30 general questions and specific requests referring to each case. The interviews were recorded and analysed separately by two researchers (the authors), and the validity of the information was verified by previously analysed indirect sources and the official data received or collected.

4. Results: Local biofuel initiatives

4.1 Local biofuel production

The peculiar features of each case study are summarised in the following matrix (Tab. 2). The analysis of the technical characteristics and of the interviews allows the identification of relevant differences from the global industrial model. First, the local biofuel initiatives analysed do not use raw materials produced specifically for industry (as is the case of first-generation biofuels) but valorise the residues of primary sectors, such as agriculture (pruned branches, straw, etc.), livestock farming (manure) and forestry. Agro-food industry waste can also be included. Agricultural residues are thought to have substantial potential for the development of bioenergy in numerous countries (in EU-27, the estimate is approximately 250 M dry tonnes/year on average (Scarlat et al., 2010). These residues are characterised by seasonal production and high territorial diffusion and can provide the following benefits:

1. the recovery and valorisation of residues from the agricultural, livestock breeding and agro-food industries (which would otherwise become waste with economic and environmental costs);
2. the "stabilisation" of effluents with harmful health effects (such as pathogenic bacteria) and offensive odours (especially from the spreading of manure onto fields);
3. the diversification of agricultural activity;
4. a reduction in fertilising and heating costs; and
5. increased incomes from selling electricity and heat.

All the cases studied in the field and the 16 cases in Walloon are regionally embedded. On the one hand, raw materials are obtained on a local (manure) or regional scale (agro-food industry waste), and on the other hand, heat and compost add value at the local scale (and in some cases, at the regional scale). Only electricity is valorised on a national scale because producers are obliged by law to sell it to the domestic network. Because manure and agricultural residue do not have high enough energy values to warrant transportation over large distances, the level of supply is critical. For example, in the case of the Faascht farm, we found that one ton of manure produces just 20–25 m^3 of biogas, whereas one ton of chocolate waste can produce 60–80 m^3. Thus, transport would require more energy than is produced by the biomass being moved. Moreover, the transport costs for bioenergy are higher on average than those for fossil energy because of the type of transport, e.g. by road for the former and by railroad, sea, river or pipeline for the latter (Tritz, 2012).

These initiatives can be well developed in rural areas, where there are large farmers and breeders or many small farmers and breeders. They can also create a virtuous circle between breeders who have large amounts of manure to eliminate and farmers who need fertiliser. In this way, it is possible to avoid waste (and the resultant potential contamination) by transforming them into raw materials for biofuel production; further, export-import activities and the consequent air pollution are avoided. Thus, agro-food wastes (that produce higher quantities of energy) coming from a regional scale can add to and optimise energy production from plants. Nevertheless, it is important to evaluate this option for each case in terms of the economic and energy costs of transportation and the subsequent environmental load.

4.2 The location and social acceptance issues

The local initiatives analysed can produce impacts and problems, especially at the local level, resulting in 'not in my back yard' (NIMBY) phenomena. Based on rational choice theory, NIMBY theory states that local inhabitants support energy transition but do not want to be confronted with the real or perceived negative effects

	"Pays des Condruses" LAG (BE)	Faascht farm Attert (BE)	Beckerich (LU)	Bio-recycle farm Migneville (FR)
Biomass resources	Manure, lawn cuttings, wheat, corn, residues of olives and flours from local sources	Manure from farms (6,000 t). Agro-industry wastes coming from the sub-regional level (10,000 t)	Manure, agricultural wastes and corn from local sources	Manure from farms (1,800 t). Agro-industrial wastes from within 100 km (3,700 t)
Biomass valorisation	Heating (for citizens)	Heating (for farm)	Heating (for citizens)	Heating (for farm, six houses and the school) and the drying of forage
	Compost for fertiliser (for farmers)	Electric energy (sold to the national network)	Electric energy (sold to the national network)	Electric energy (national network)
		Fertiliser (for farm, local farmers and sale)	Fertiliser (for farmers)	Fertiliser (for farms)
Promoters	LAG – The LAG aims to create a citizen-based society to valorise the local agricultural wastes and generate heat and fertilisers	Farmer and association – The farm produces milk and cheese. The "Pays de l'Attert" is an association engaged in the cultural and environmental field	Farmers and municipality – Beckerich municipality, composed of eight small villages, has collaborated strictly with the farmers and citizens	Farmer – The Bio-recycle farm produces organic forage and milk
Objectives	Rural development	Farmer: economic, agronomic and environmental aims	Farmers: economic, agronomic and environmental aims	Environmental, economic and agronomic aims
	Environmental aims	Association: environmental aims	Municipality: social, political and environmental aims	Autonomy from market in terms of fertilisers
	EU targets for renewable energy development			Energy transition
Installation	Collective	Private	Collective	Private
Institutional conditions	Regional and local level: favourable	Regional: favourable Local level: indifferent	National and local level: strong political will	National level: favourable
Financial conditions	Government funding (EU, municipality)	Government funding (Walloon region)	Government funding (municipality, state)	Government funding
	Farmers and citizens with money and bank loans	Farmer with a bank loan	Farmers (by bank loan)	Bank loans
			Income from the sale of heat	
Scientific conditions	Favourable	Favourable	Favourable	Absent
Social conditions	Favourable	Indifferent	Collaborative	Indifferent
Cultural conditions	Favourable	Indifferent	Favourable	Indifferent
Citizens attitude	Passive acceptance	Indifferent or mistrustful	Positive and collaborative	Indifferent or mistrustful
Engagement of local community	Stakeholder approach	Communication post-project	Public meetings	Communication post-project
		Farmers bring their manure	Consultative commissions	Farmers bring their manure
Positive local impacts	Reduction of offensive odours	Virtual energy independence	Employment	Employment (2 units)
	Improving water quality	Employment (2.5 units) and satellite activities	Reduction of tariffs	Reduction of offensive odours
			Money remains at the local level	
Negative local impacts	Road traffic	Road traffic	No	Road traffic
Technical problems	Yes	Yes	Yes	Yes
Governance problems	Yes	Yes	No	Yes
Financial problems	Yes	Yes	Yes	No

Tab. 2: Characteristics of the case studies
Source: authors' elaboration

in their neighbourhood (Soland et al., 2013). As the case studies have shown, the main and recurrent impacts are road traffic, landscape impacts, safety concerns and burst pipes. The same cases, however, present possible solutions with reference to the organisation of supply phases and the location of processing plants, as well as information and communication initiatives.

It is important to consider that for the Faascht and Bio-recycle farms, the increase in traffic of concern was two trucks each week. To reduce road traffic, it is essential to organise the biomass and compost supply phases. In reality, as the Beckerich case demonstrates, if the two phases occur at the same time (leaving biomass and taking compost already produced), transport can be decreased by half, reducing road traffic and air pollution and saving money. To avoid the landscape impacts, processing plants could be totally or partially covered with earth. In this way, the plant cannot be seen from the street, as in the case of the Bio-recycle farm in Migneville. If such an arrangement is not possible (for example, in the presence of groundwater), it is important to reduce the visual impact of biofuel units by planting trees and native vegetation. Furthermore, the stock area should be covered or surrounded by vegetation. To alleviate concerns about safety, burst pipes and tanks, it is important to localise the processing plant away from urban areas and away from houses. As the Faascht farm and the Becherich case have shown, a distance of one km from the nearest house and 1.5 km from the nearest town is considered sufficient. Another important aspect is communicating with inhabitants and organising public conferences with experts to make clear the real risks associated with the processing plant. In fact, in the case examined in the Walloon Region, where the plant is in town (Surice farm), there was social and political opposition to both the offensive odour and the potential for burst pipes.

Electricity must be sold via the official distribution network operator in most European countries (which may lead to difficulties such as under-capacity of transport, competition among producers, high costs, and poor perception by locals of local energy production). In these four case studies, however, heat appears to be more profitable, especially because of stronger support from public authorities in the three studied countries. Because of the difficulty of transporting heat, it may be advisable to locate plants close to large consumers of heat.

As Wolsink (2007) and Schmitz et al. (2012) have noted, the process of the project is often more important than the plant. Who is leading? Who invests? How is the project discussed with citizens? Who seems to win and who seems to lose? The literature emphasises the importance of factors such as the perception of justice, especially the balance of perceived costs and benefits, and trust in the plant operator, as very influential factors to explain local acceptance (Grannec et al., 2016; Schumacher and Schultmann, 2017; Soland et al., 2013).

Contrary to other studies on the acceptance of biogas plants (Kortsch et al., 2015; Schumacher and Schultmann, 2017; Soland et al., 2013), we heard very little mention of smell. This may be explained both by the evolution of the technology, and by the use, in the four studied farms, of a mix of cow manure and agro-industrial or agricultural wastes. Indeed, the biomethanisation of cattle manure substitutes for the spreading of manure on the fields and so reduces the odours (Mignon, 2009). Grannec et al. (2016) pointed out that, in Brittany, the fear of accidents related to road traffic or the presence of gas has more influence than the odours or the noise.

4.3 Entrepreneurial and territorial models

The case studies can be divided into two types depending on the main actors, their interests, their aims, and the direct benefits and advantages, which can be private or collective. Hence, we can define two production/consumption models: the entrepreneurial model and the territorial model (Tab. 3).

The entrepreneurial model includes an enterprise and its economic and agronomic aims. The economic objectives are both "active", meaning an increase of incomes (for example, through energy production and sale) and "passive", that save money (for example, reducing fertiliser and heating costs). The agronomic objectives are to obtain high-quality compost and nourishing forage rich in protein. The territorial model includes the collective and its socio-economic, political and environmental objectives, such as reducing tariffs, achieving energy autonomy (namely the ability to produce energy to satisfy the local energy demand without energy import), realising agricultural diversification, decreasing the use of nitrates, and protecting groundwater and soil. In theory, the territorial model could achieve the ideal zero environmental impact and a closed-loop system if raw materials came only from the farmer collective and compost, heat and electricity are valorised only by this collective.

The entrepreneurial model can be "associative" if it is led by a group of entrepreneurs and experts (as is the case with the Faascht farm) or "familial" if it is run mainly by a family (for example, the Bio-recycle farm). The territorial model can be "participated" if there are different actors who participate (as is the case with the "Pays des Condruses" LAG), whereas the model is "participative" when there are institutional mechanisms enabling and supporting engagement and participation by the whole community (as in the Beckerich case). The presence of raw materials alone, however, is not sufficient to form a territorial district. To this end, local social relations are fundamental. These relations can refer to public subjects, private subjects, formal networks or informal networks, which can act as collective actors to identify common objectives and implement a project to develop the potential of a territory.

	Production / consumption models			
Model	Entrepreneurial		Territorial	
Typology	associative	familial	participated	participative
Objectives	economic, agronomic		socio-economic, political environmental	

Tab. 3: Entrepreneurial and territorial models of biofuel production/consumption
Source: authors' conceptualisation

Within the entrepreneurial model – as in the cases of the Faascht and Bio-recycle farms – it is difficult to achieve independence of supply at the level of a single enterprise because of a processing plant's technical capacities:

> "For example, the farm is not self-sufficient in biomass supply. But the farm is independent in practice by using the waste of cows, by drying the fodder thanks to the heat produced by biomethanisation (food self-sufficiency for the cows); by fertilising the land with the compost produced from the digestate (fertiliser autonomy); by heating the buildings thanks to the heat produced by the biomethanisation. It is also independent, from a virtual point of view, because the electricity produced and sold to the national grid is more than the needs of the farm" (Mr. Claudepierre, Bio-recycle farm, Migneville).

In reality, at the farm level and with the aim of making biofuel production economically convenient, the processing plant may require more raw materials than those supplied by the farm's activity. Thus, if a farm wanted to reach autonomy with respect to fertiliser, heating and energy, it would have to sacrifice autonomy in terms of provisioning and would be obliged to use agroindustry wastes sourced at the regional level. The limit of the territorial model is the distance between farmers because manure and agricultural residue do not have large energy capacities. According to the interviews, if manure is transported more than 15 km, more energy is consumed by transport than is produced by the manure.

Another important issue for both models is the use of compost. Compost should be used locally; however, in some cases, depending on the legal issues, it can be sold for economic revenue. A limit to the development of agrarian local initiatives is the need for huge investments. Considering that farmers do not have large amounts of capital and taking into account a general lack of bank credit (generally, banks do not lend money because of the long time required for a return on the investment), to collect capital for building plants, farmers must "open" the enterprise to external investors, changing the legal form and thus the aims of their original project. The case studies show four possible ways to avoid this risk: beginning with a small processing plant that requires modest investment (Bio-recycle farm), beginning only if the farm has sufficient capital or a high credit capacity (Faascht farm), engaging in a public collection ("Pays des Condruses" LAG), and receiving substantial public support (Becherich). Another requirement for autonomy is the technological skill of the local producers.

4.4 The local scale and governance

The local (meaning the face-to-face level) and the regional scales also seem to be the optimal spatial scales for creating more effective democratisation of energy governance, as the case studies have shown. In fact, at these scales, it is possible to develop an effective short chain (in terms of investment and funding from local farmers, consumers and citizens). In particular, the local scale can make it possible for both control and economic benefits to remain at the local level, while the regional may offer resources (for example, industrial wastes) that could be lacking at the local level, without producing the negative impacts or contradictions intrinsic to the other spatial scales (first and foremost the global level).

In these cases, there is a true re-appropriation of RE sources by certain people (as in the Faascht and Bio-recycle farms), by a group of citizens (as in the "Pays des Condruses" LAG) or by the entire community (as in the case of Beckerich).

Referring specifically to local participation, the case studies have shown very diverse social and cultural conditions given similar institutional and financial conditions. In this regard, we observed that where people are indifferent (e.g. the Faascht farm in Attert and the Bio-recycle farm in Migneville), the installations are private and there is no involvement by citizens (the inhabitants were informed via communications post-project and after the farms had opened their doors to visitors):

> "Open days give the opportunity to visit the biomethanisation unit, the farm, we host a barbecue ... guiding tour. But, these activities happened after the project. There was no commitment of the population before the construction. Before, we used the local paper to inform about the project" (Marcel Nickers, Association 'Au Pays de l'Attert' a.s.b.l.[1] Attert).

In contrast, where public opinions are favourable (e.g. the "Pays des Condruses" LAG and Beckerich), the projects are collectives and there is direct participation (by part or all of the community). For the two collective cases, we observed a substantial difference in citizens' general attitudes, namely, passive acceptance in the case of the "Pays des Condruses" LAG and a positive and collaborative approach concerning Beckerich. The first case involved a top-down project initiated by a local institution (LAG) and realised by stakeholder consultation; the second case involved a bottom-up approach generated by public meetings and a consultative commission with strong political end engagement:

> "First, we inform through meetings open to all residents, followed by field visits to enable people to realise ... We use also a local newspaper for the ongoing information (in several languages). Direct participation is achieved by the voluntary participation in the consultative committees of citizens; by taking part to the creation of a cooperative to manage a collective installation; by using public space for collective energy production" (Ms. Isabelle Bernard, President of the Association D'millen a.s.b.l., Beckerich).

The local scale should strengthen the acquaintance and the truth between stakeholders. Nevertheless, the literature underlines the fact that proper information and the possibility to participate actively in the project will boost acceptance (Schweizer-Ries, 2008; Van Rompaey et al., 2011).

5. Discussion

5.1 The global versus regional scale model

Because it avoids most of the problems and contradictions concerning environmental, agrarian, socio-economic and geopolitical aspects produced by the global industrial model, a regional scale model – referring to the maximum level of raw materials supply and products valorisation – seems to be the optimal spatial scale for developing bioenergy (Tab. 4).

The regional scale makes it possible to reduce CO_2 emissions and other polluting substances resulting from the production and transport of biomass and biofuel over long

[1] The ´association sans but lucratif´ (a.s.b.l.) (´association without lucrative purpose´in English) is the legal term for a 'not-for-profit association' in Belgium and some other French speaking countries.

distances, reduce energy dependence on biomass or biofuel imports, prevent the loss of control over territories and ecosystems by local people due to water and land grabbing by biomass producers, reduce territorial disputes regarding alternative uses of land, and address conflicts related to defending territory from the interests of large corporations. If we interpret these models from a paradigmatic viewpoint, we can better understand their cultural, political, economic and spatial implications.

The global industrial model is based on the same paradigm of growth and the neoliberal logic of a global market and competition that characterise the exploitative policies of fossil energy sources. For most of the cases, this approach involves control over and intensification of the production cycle, the incrementalisation of productive factors, the abatement of production costs (especially with respect to labour costs) and an increasing distance among places of production, transformation and distribution. The long chain entails a further ecological burden from the energy consumed because of increased transport distances. Thus, the environmental and social costs are externalised and territorial organisations are affected. Referring to first-generation biofuels, this model is characterised by a very tight link between agriculture and industry and strictly market-oriented production. In this way, agriculture becomes a supplier of raw material for energy and is thus the weak link in the chain. Farmers are dispossessed of their original social role, becoming executors of commands dictated by the logic and interests of industry and crushed by market mechanisms. In contrast, we advocate a regional agrarian model.

5.2 The regional agrarian model

The regional agrarian model is based on a territorial logic arising from the perception-value-interest system of the people who inhabit the place. This model could produce a territorial distribution of small- to medium-sized plants and, consequently, energy independence from global markets (of fertilisers and energy) and, possibly, international politics.

Thus, the inhabitants of Beckerich have no economic or political concerns with respect to heating their houses. They have no concerns about biomass prices on the global market or about international geopolitical decisions, and the money that citizens pay for heat remains in the region:

> "The price people paid is lower, but more importantly, it is a question of independence and autonomy with regard to the international market and politics. We say: 'Do you want to be dependent on Iraq and Saudi Arabia energy source or on nine councilors and farmers that you know?'. Then, people understand the issue of energy sovereignty. Become self-sufficient and not dependent, economically and politically, on who controls the resources and the energy market" (Mayor Camille Gira, Beckerich).

	Global model	Regional model
Objectives of producers	Business: profit, expanding into innovative sectors, penetrating or developing a new market, public incentives	Economic aims: both "active" (increased income through energy production and sale) and "passive" (saving fertilising, heating and/or fuel costs); autonomy from the market
		Agronomic aims: high-quality compost; better quality of soil and products
		Environmental aims: reduction of nitrates; safety of groundwater
Objectives of public authorities	Local scale: e.g. Public administration → royalties	Political aims: energy autonomy, energy transition and paradigm change, public transport, rural development, diversification of agricultural activity
	Regional scale: e.g. Region → economic development	Social aims: reduction of tariffs and accessible price for the poorest; increase in farmers' incomes
	National scale: e.g. State → strategic and geopolitical interests	Environmental aims: reduction of CO_2; protection of biodiversity
	Continental scale: e.g. European Union → reduction of climatic change	
Producers	Mainly exogenous in the form of large corporations (which can be directly linked with the oil corporations)	Basically endogenous (private, public or collective actors) and informal and formal networks: cooperatives, consortiums, associations, municipalities, LAGs
Spatial perception	Space as a neutral and functional object/box	Space as a place and a house
Scale of production	Global scale	Local, sub-regional and regional scale
Biofuel chain	Long chain	Short chain
Biomass origin	Global scale	Local, sub-regional and regional scale
Main biomass resource	Monoculture, agroindustry wastes	Manures, agricultural residue, agroindustry residue
Main biomass provisioning	By brokers and traders	By farmers

Tab. 4: Main elements of the global model and the regional model for biofuel production
Source: authors' elaboration

	Global model	Regional model
Main biomass valorisation	Electric energy	Warmth for heating buildings and drying forage
	Biofuel for transport	Electric energy
	Warmth for heating	Compost for fertilising
Plant size	Large size	Small to medium size
Ecological impact	Potentially strong	Potentially light
Relation with the local agricultural chain	Scarce or absent	A key point and a characteristic component of this model
Relation with local actors	Little direct involvement (the only exception may be for the biomass production)	Local actors are the main subjects of the production-transformation-consumption chain
Main relations	Vertical relations among production, transformation and consumption areas	Horizontal relations among local actors
Market	Organised on a global scale	Non-existent or organised on local, sub-regional and/or regional scales
Main positive local impacts	Jobs	Energy independence
		Reduction of tariffs
		Jobs and satellite activities
		Money remains at the local level
		Elimination of pathogenic bacteria and offensive odours from effluents
		Improved water quality
Main negative local impacts	Road traffic and air pollution	Road traffic
	Soil and water pollution by pesticides and chemicals fertilisers	
	High energy and water use	
	Changing land use	
	Deforestation	
	Loss of biodiversity	
	Competition over scarce resources	
	Loss of control over territories from local people	
	Social tensions	
	Simplification of landscapes	

Tab. 4: continuing

Moreover, the regional agrarian model valorises agricultural and livestock breeding residue and by-products and realises public and private objectives. Public objectives are many and include: reducing greenhouse emissions throughout the chain of production; preventing emissions of CH_4 (methane) from effluent manure warehousing; valorising agricultural, breeding and agroindustry wastes (which would otherwise be decomposed, incurring economic and environmental costs); saving energy (and reducing pollution) used to produce chemical fertilisers; being independent from mineral resources, such as potassium and phosphate, located outside of Europe; having energy autonomy; being energy independent from fossil fuel; and increasing social accessibility to energy (Cameron, 2014). As for the private benefits for farmers, the following are important: reducing the costs of the management of agricultural and breeding residues; realising a structural solution for manure management; saving heating and fertiliser costs; independence from chemical fertilisers and energy markets; improving the agronomic value of soils through mineralised nitrogen (which is better assimilated by plants); reducing the risks of nitrogen leaching and underground water contamination; reducing pathogens and offensive odours; increasing incomes from sales of heat and electricity; and the independence of agricultural activity through the use of its residues and by-products.

We should note that, at the local level and according to the political conditions in the cases analysed, energy independence is a "virtual independence". In fact, farmers are obliged by law to sell the energy produced to the national network, and people continue buying electricity from large corporations. Thus, there is an economic advantage for farms and a general environmental benefit, but there are no direct economic and political benefits for the local community.

From the case studies, we learned that these local initiatives have to interact with the regional level that waste and manure may need to be imported to economically use equipment, to achieve economic and/or financial equilibrium and to produce sufficient electricity and heat for the community. This requirement weakens the CO_2 balance of production. Moreover, some uncertainty exists with respect to the market value of the waste involved in biomethanisation, which makes budgeting more complex. In addition, due to the general lack of bank credit in this sector, political support seems necessary for investment and development purposes. It could be argued that because of the multiple advantages for the local (and global) society, communities should support agrarian regional biogas producers or at least pay for their services.

Nonetheless, the local nuisances of biofuel plants should be mitigated. The main localisation criterion to reduce or eliminate negative local impacts is to choose a place for processing plants near areas of biomass production and heating consumption. In this regard, to reduce transport costs and increase net energy production, some studies suggest a distance of 10 km (to a maximum of 60 km) between the collection/storage points and the energy conversion plants (Paiano et al., 2011). In France, heating is used in a local distribution network smaller than 10 km to avoid energy losses (Tritz, 2012). It is clear that the best organisational option is to utilise a short chain. Theoretically, processing plants could be located near production or consumption areas, at a point among production areas or at a point among production and consumption areas. If the choice is made only to minimise transport costs, we could use a spatial model for industrial location, beginning with Weber's model. If we also consider territorial impact and social acceptability (that is to say, that the plant's implementation has not to be opposed to the values, ideas and interests of the inhabitants as a whole), however, it is better to look for a rural area where biomass is produced, with measures to avoid landscape impacts. In fact, only in this case it is possible to alleviate public concerns regarding burst pipes and safety.

We also infer that if the initial cultural and social conditions are essential to determining the nature and typology of the initiative, the approach used for developing the project is not neutral with respect to the participation of local residents. As we see it, in the top-down process, engagement is at the level of stakeholders, whereas in the case of a bottom-up process, it is the community that participates. Thus, it is clear that real and strong political will is very important for creating the conditions necessary for the effective democratisation of energy governance. The main energy suppliers are facing four challenges (the four Ds): decreased consumption, decarbonisation, spatial deconcentration and digitalisation. Biofuel is foreseen as a necessary transitional energy within a global and national framework (Van Troye, 2016). Despite the well-known impacts, it should be an intermediate state before an international green electricity network. Changing the scale of the analysis suggests that another model of production and consumption may exist with a positive balance both at the global and local levels.

6. Conclusions

Starting from the limitations and paradoxes of the global industrial model of biofuel production, this study has analysed how other models could achieve a more balanced production from environmental, social and economic points of view. We define such a model as regional, referring to the maximum spatial scale for the origin of raw materials and the location of biomass valorisation to achieve economic equilibrium without losing environmental benefits. It is clear that to achieve the greatest advantage, agricultural residues and manure must be transformed and used in the place where they are produced. We define this model as agrarian based on its tight links with other agricultural activities, livestock breeding and the valorisation of their residues. The beneficial aspect is the transformation of waste into raw material for biofuels used primarily by farms and local communities, avoiding pollution and saving fertiliser, heating and power costs. To mitigate the negative impacts of this model, location in rural areas (away from houses) and in sites totally or partially covered with earth is crucial, as is the combined organisation of biomass and compost supply phases.

There is an urgent need to broaden our view of RE and to analyse the whole process and its impacts on different places. Beside technical and economic issues, social and environmental costs should be included to assess the performance of bioenergy. Location, landscape and spatial differentiation issues have gained the attention of researchers. Regional and local control need to be analysed as well. Through attention to the spatial embeddedness of bioenergy, we have attempted to contribute to the creation and implementation of models for energy production and consumption that are more suitable for current conditions.

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References:

ALTIERI, M. (1999): Applying agroecology to enhance the productivity of peasant farming systems in Latin America. Environment, Development and Sustainability, 1(3–4): 197–217.

ALTIERI, M. A. (2009): The Ecological Impacts of Large-Scale Agrofuel Monoculture Production Systems in the Americas. Bulletin of Science Technology & Society, 29(3): 236–244.

AMIGUN, B., MUSANGO, J. K., BRENT, A. C. (2011): Community perspectives on the introduction of biodiesel production in the Eastern Cape Province of South Africa. Energy, 36: 2502–2058.

AZAR, C., LARSON, E. D. (2000): Bioenergy and land-use competition in Northeast Brazil. Energy for Sustainable Development, 4(1): 64–71.

BECCALI, M., COLUMBA, P., D'ALBERTI, V., FRANZITTA, V. (2009): Assessment of bioenergy potential in Sicily: a GIS-based support methodology. Biomass and Bioenergy, 33(1): 79–87.

BORRAS, J. R., FIG, D., SUAREZ, S. M. (2011): The politics of agrofuels and mega-land and water deals: insights from the ProCana case, Mozambique. Review of African Political Economy, 38(128): 215–234.

BRIDGE, G., BOUZAROVSKI, S., BRADSHAW, M., EYRE, N. (2013): Geographies of energy transition: Space, place and the low-carbon economy. Energy Policy, 53: 331–340.

BURDGE, R. J., CHAMLEY, S., DOWNS, M., FINSTERBUSCH, K., FREUDENBURG, B., FRICKE, P., THOMPSON, J. G. (2003): Principles and guidelines for social impact assessment in the USA. Impact Assessment and Project Appraisal, 21(3): 231–250.

CAMERON, J. (2014): Politics of Hope: Rethinking Geographic Scale, "Impact" Scale, and Markets. Antipode, 46(1): 53–71.

CARROSIO, G. (2013): Energy production from biogas in the Italian countryside: policies and organizational models. Energy Policy, 63: 3–9.

COCKERILL, S., MARTIN, C. (2008): Are biofuels sustainable? The EU perspective. Biotechnology for Biofuels, 1(9): 1–6.

COLBRAN, N. (2011): Indigenous peoples in Indonesia: At risk of disappearing as distinct peoples in the rush for biofuel? International Journal on Minority and Group Rights, 18(1): 63–92.

COTULA, L. (2012): The international political economy of the global land rush: a critical appraisal of trends, scale, geography and drivers. The Journal of Peasant Studies, 39(3–4): 649–680.

DALLA MARTA, A., NATALI, F., MANCINI, M., FERRISE, R., BINDI, M., ORLANDINI, S. (2011): Energy and Water Use Related to the Cultivation of Energy Crops: a Case Study in the Tuscany Region. Ecology and Society, 16(2): 2.

DAUVERGNE, P., NEVILLE, K. J. (2010): Forests, food, and fuel in the tropics: The uneven social and ecological consequences of the emerging political economy of biofuels. Journal of Peasant Studies, 37(4): 631–660.

DE CARVALHO, S. P., MARIN, J. O. B. (2011): Agricultura familiar e agroindústria canavieira: impasses sociais. Revista de Economia e Sociologia Rural, 49(3): 681–708.

DUVAIL, S., MÉDARD, C., HAMERLYNCK, O., NYINGI, D. W. (2012): Land and water grabbing in an East African coastal wetland: The case of the Tana delta. Water Alternatives, 5(2): 322–343.

EUROBSERVER (2016): Biofuels barometer 2016 [online]. Available at: www.eurobserv-er.org/biofuels-barometer-2016/

FAAIJ, A. (2011): Developments in international bio-energy markets and trade. Biomass and Bioenergy, 32(8): 657–659.

FERNANDES, B. M., WELCH, C. A., GONÇALVES, E. C. (2010): Agrofuel policies in Brazil: Paradigmatic and territorial disputes. Journal of Peasant Studies, 37(4): 793–819.

FERREIRA-LEITAO, V., FORTES GOTTSCHALK, L. M., FERRARA, M. A., LIMA NEPOMUCENO, A., CORREA MOLINARI, H. B., BON, E. P. S. (2010): Biomass Residues in Brazil: Availability and Potential Uses. Waste Biomass Valor, 1(1): 65–76.

FRANTÁL, B., PROUSEK, A. (2016): It's not right, but we do it. Exploring why and how Czech farmers become renewable energy producers. Biomass and Bioenergy, 87: 26–34.

GAMBORG, C., MILLAR, K., SHORTALL, O., SANDØE, P. (2012): Bioenergy and Land Use: Framing the Ethical Debate. Journal of Agricultural & Environmental Ethics, 25: 909–925.

GAO, Y., SKUTSCH M., DRIGO R., PACHECO, P., MASERA, O. (2011): Assessing deforestation from biofuels: Methodological challenges. Applied Geography, 31(2): 508–518.

GERMAN, L., SCHONEVELD, G., SKUTCH, M., ANDRIANI, R., OBIDZINSKI, K., PACHECO, P. (2010): The local social and environmental impacts of biofuel feedstock expansion. A synthesis of case studies from Asia, Africa and Latin America. CIFOR infobrief, 34.

GOLTSEV, V., ILAVSKÝ, J., GERASIMOV, Y., KARJALAINEN, T. (2010): Potential for biofuel development in Tihvin and Boksitogorsk districts of the Leningrad region - The analysis of energy wood supply systems and costs. Forest Policy and Economics, 12(4): 308–316.

GRANNEC, M. L., LOUSSOUARN, A., LEVASSEUR, P. (2016): Perception sociale locale de projets de méthanisation agricole: vision croisée de différents acteurs du territoire. Journées Recherches Porcine, 48: 189–190.

GUPTA, R. B., DEMIRBAS, A. (2010): Gasoline, diesel, and ethanol biofuels from grasses and plants. Cambridge, Cambridge University Press.

JUNGINGER, M., BOLKESJØ, T., BRADLEY, D., DOLZAN, D., FAAIJ, A., HEINIMO, J., HEKTOR, B., LEISTAD, O., LING, E., PERRY, M., PIACENTE, E., ROSILLO-CALLE, F., RYCKMANS, Y., SCHOUWENBERG, P., SOLBERG, B., TRØMBORG, E., DA SILVA WALTER, A., DE WIT, M. (2008): Developments in international bioenergy trade. Biomass and bioenergy, 32: 717–729.

JENSEN, M., ANDERSEN, A. H. (2013): Biofuels: A contested response to climate change. Sustainability: Science, Practice, and Policy, 9(1): 42–56.

HAZLEWOOD, J. A. (2012): CO_2lonialism and the "Unintended Consequences" of Commoditizing Climate Change: Geographies of Hope Amid a Sea of Oil Palms in the Northwest Ecuadorian Pacific Region. Journal of Sustainable Forestry, 31(1–2): 120–153.

HULTMAN, N. E., SULLE, E. B., RAMIG, C. W., SYKORA-BODIE, S. (2012): Biofuels Investments in Tanzania: Policy Options for Sustainable Business Models. Journal of Environment and Development, 21(3): 339–361.

HUTTUNEN, S. (2011): Embeddedness in local farm-scale bioenergy production. Ager (11): 107–127.

KALT, G., KRANZL, L. (2012): An assessment of international trade related to bioenergy use in Austria—Methodological aspects, recent developments and the relevance of indirect trade. Energy Policy, 46: 537–549.

KORTSCH, T., HILDEBRAND, J., SCHWEIZER-RIES, P. (2015): Acceptance of biomass plants–Results of a longitudinal study in the bioenergy-region Altmark. Renewable energy, 83. 690–697.

LAMERS, P., HAMELINCK, C., JUNGINGER, M., FAAIJ, A. (2011): International bioenergy trade – A review of past developments in the liquid biofuel market. Renewable and Sustainable Energy Reviews, 15(6): 2655–2676.

LEVIDOW, L., PAUL, H. (2010): Global agrofuel crops as contested sustainability, part I: Sustaining what development? Capitalism, Nature, Socialism, 21(2): 64–86.

MABEE, W. E., MIRCK, J. (2011): A regional evaluation of potential bioenergy production pathways in Eastern Ontario Canada. Annals of the Association of American Geographers, 101(4): 897–906.

MIGNON C. (2009): Biométhanisation: utilisation du digestat comme fertilisant en agriculture. Gembloux, CRA ValBiom.

MOL, A. P. J. (2010): Environmental authorities and biofuel controversies. Environmental Politics, 19(1): 61–79.

MONTEFRIO, M. J. F., SONNENFELD, D. A. (2013): Global-Local Tensions in Contract Farming of Biofuel Crops Involving Indigenous Communities in the Philippines. Society and Natural Resources, 26(3): 239–253.

MONTELEONE, M., COSENTINO, S. L., DE MASTRO, G., MAZZONCINI, M. (2009): Modelli produttivi agri-energetici: l'integrazione di filiera dalla scala aziendale a quella territoriale. Italian Journal of Agronomy/Rivista di Agronomia, 4(1): 125–140.

MWAKAJE, A. G. (2012): Can Tanzania realise rural development through biofuel plantations? Insights from the study in Rufiji District. Energy for Sustainable Development, 16(3): 320–327.

NAYLOR, R. A. (2007): Ripple effects of crop-based biofuels on global food security and the environment. Environment, 49(9): 30–43.

PAIANO, A., CAMAGGIO, G., LAGIOIA, G. (2011). Territorial level for biofuel production – Case study of an Italian region. Renewable and Sustainable Energy Reviews, 15(5): 2222–2231.

PASQUALETTI, M. (2000): Morality, space, and the power of wind-energy landscape landscapes. The Geographical Review, 90(3): 381–394.

PÉREZ, M. A., PEŃA, M. R., ALVAREZ, P. (2011): Agro-industria cańera y uso del agua: Análisis crítico en el contexto de la política de agrocombustibles en Colombia. Ambiente e Sociedade, 14 (2): 153–178.

PONTI, L., GUITIERREZ, A. P. (2009): Overview on biofuel form in a European perspective. Bulletin of Science, Technology & Society, 29(6): 493–503.

PUTTILLI, M. (2009): Per un approccio geografico alla transizione energetica. Le vocazioni energetiche territoriali. Bollettino della Società Geografica Italiana, 2(3): 601–616.

PUTTILLI, M.,TECCO, N. (2012): Tra industria e territorio. La filiera del biodiesel in una prospettiva geografica, Bollettino della Società Geografica Italiana, 5(2): 353–367.

RATHMANN, R., SZKLO, A., SCHAEFFER, R. (2010): Land use competition for production of food and liquid biofuels: An analysis of the arguments in the current debate. Renewable Energy, 35(1): 14–22.

REN21 (2017): Renewables 2017 Global Status Report, Paris: REN21 Secretariat.

ROWE, R. L., STREET, N. R., TAYLOR, G. (2009): Identifying potential environmental impacts of large-scale deployment of dedicated bioenergy crops in the UK. Renewable & Sustainable Energy Reviews, 13(1): 271–290.

RUSSI, D. (2008): An integrated assessment of a large scale biodiesel production in Italy: Killing several birds with one stone? Energy Policy, 36(3): 1169–1180.

SAWYER, D. (2008): Climate change, biofuels and eco-social impacts in the Brazilian Amazon and Cerrado. Philosophical Transactions of the Royal Society, 363(1498): 1747–1752.

SCARLAT, N., MARTINOV, M., DALLEMAND, J.-F. (2010): Assessment of the availability of agricultural crop residues in the European Union: Potential and limitations for bioenergy use. Waste Management, 30: 1889–1897.

SCHMITZ, S., VANDERHEYDEN, V., VANDEN BROUCKE, S., LOOPMANS, M. (2012): The Shaping of Social attitudes toward Energy-Parks in the Belgian Countryside. Horizons in Geography, 81(1): 83–93.

SCHUMACHER, K., SCHULTMANN, F. (2017): Local Acceptance of Biogas Plants: A Comparative Study in the Trinational Upper Rhine Region. Waste and Biomass Valorization, 8: 2393–2412.

SCHWEIZER-RIES, P. (2008): Energy sustainable communities: Environmental psychological investigations. Energy Policy, 36(11): 4126–4135.

SECCHI, S., KURKAKOVA, L., GASSMAN, P. W., HART, C. (2011): Land use change in a biofuel hotspot: The case of Iowa, USA. Biomass and Bioenergy, 35(6): 2391–2400.

SOLAND, M., STEIMER, N., WALTER, G. (2013): Local acceptance of existing biogas plants in Switzerland. Energy Policy, 61: 802–810.

SULLIVAN, T. P., SULLIVAN, D. S., LINDGREN P. M. F., RANSOME D. B., BULL, J. G., RISTEA, C. (2011): Bioenergy or biodiversity? Woody debris structures and maintenance of red-backed voles on clear cuts. Biomass and Bioenergy, 35(10): 4390–4398.

TATEDA, M., YAMASHITA, C., KIM, Y., ATHAPATTU, B. C. L. (2011): Preparation for Establishing Environmentally and Socially Friendly Business in the Biomass Town of Imizu City, Toyama, Japan: A Case Study of the Waste Vegetable Oil–Recycling Business. Environmental Practice, 13(2): 143–154.

TRICASE, C., LOMBARDI, M. (2009): State of the art and prospects of Italian biogas production from animal sewage: technical-economic considerations. Renewable Energy, 34(3): 477–485.

TRITZ, Y. (2012): Le Système énergétique agri-territorial: les bioénergies comme outil de développement local. Géographie, économie, société, 14(1): 31–52.

TSAO, C. C., CAMPBELL, J. E., MENA-CARRASCO M., SPAK S. N., CARMICHAEL, G. R., CHEN, Y. (2012): Increased estimates of air-pollution emissions from Brazilian sugar-cane ethanol. Nature Climate Change, 2(1): 53–57.

VAN DER HORST, D., VERMEYLEN, S. (2011): Spatial scale and social impacts of biofuel production. Biomass and bioenergy, 35(6): 2435–2443.

VAN ROMPAEY, A., SCHMITZ, S., KESTELOOT, C., PEETERS, K., MOENS, B., VAN HEMELRIJCK, H., VANDERHEYDEN, V., LOOPMANS M., VANDEN BROUCKE, S. (2011): Landscape Capacity and Social Attitudes towards Wind Energy Projects in Belgium. Brussels, Belgium Federal Science Policy.

VAN TROYE, P. (2016): ENGIE in light of the energy revolution, 22 Sept 2016, University of Liege.

VERMEULEN, S., COTULA, L. (2010): Over the heads of local people: consultation, consent, and recompense in large-scale land deals for biofuels projects in Africa. The Journal of Peasant Studies, 37(4): 899–916.

VOYTENKO, Y., PECK, P. (2012): Organisational frameworks for straw-based energy systems in Sweden and Denmark. Biomass and Bioenergy, 38(1): 34–48.

WALKER, G., CASS, N. (2007). Carbon reduction, 'the public' and renewable energy: engaging with socio-technical configurations. Area, 39(4): 458–469.

WILLIAMS, T. O., GYAMPOH, B., KIZITO, F., NAMARA, R. (2012): Water implications of large-scale land acquisitions in Ghana. Water Alternatives, 5(2): 243–265.

WOLSINK, M. (2007): Wind power implementation: the nature of public attitudes: Equity and fairness instead of ‘backyard´ motives. Renewable and sustainable energy reviews, 11(6): 1188–1207.

YAN, L. Z. (2008): Potential yield of bioethanol from energy crops and their regional distribution in China. Transactions of the Chinese Society of Agricultural Engineering, 24 (5): 213–216.

ZELLER, M., GRASS, M. (2008): Agrofuel boom or doom? Opportunities and constraints for agrofuels in developing countries. Quarterly Journal of International Agriculture, 47(4): 285–305.

ZOLIN, M. B. (2011): Diversification of Household Income in Rural Areas: Opportunities and Risks of Biomass Energy. The Open Geography Journal, 4(1): 16–28.

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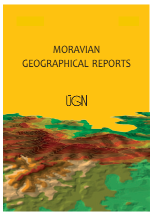

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DE GRUYTER OPEN

The importance of on-site evaluation for placing renewable energy in the landscape: A case study of the Búrfell wind farm (Iceland)

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Abstract

Using a case study of the Búrfell wind farm project, a large wind farm proposed in the Central Highlands of Iceland, the authors attempt to provide new insights into the factors shaping subjective landscape perceptions and attitudes to renewable energy developments, and into alternative methods that may be used for their assessment. The research was based on an on-site visit and actual experience of the place, investigated using a combination of mental mapping, the technique of the semantic differential and a questionnaire survey. The results show that participants visiting a landscape and using all sensory organs in combination with mental mapping, can reveal more important information than using only 'laboratory' methods with static photographs. The results suggest that the perception of landscape is highly subjective. Those perceiving the landscape as more open, homogenous, industrial, unfamiliar and resilient also consider it more compatible with wind turbines. The perception of the landscape's compatibility with wind turbines proved to be a dominant factor shaping attitudes towards the project. The acceptance of wind turbines is not, however, inconsistent with the perception of landscape as beautiful, wild and unique. Participants from more densely populated countries and countries with a developed wind energy industry were more tolerant of wind turbines in the Icelandic landscape.

Keywords: *landscape perception; wind energy; on-site evaluation; mental mapping; semantic differential; Central Highlands of Iceland*

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1. Introduction

The natural resources of Iceland include an abundance of geothermal, hydropower and wind energy, of which only a part is currently being utilised. The cost of converting these resources to electricity is relatively low, making them attractive and highly marketable for industrial development (Gunnarsson and Gunnarsson, 2002; Ragnarsson et al., 2015).

Most of the high-temperature geothermal areas, powerful river systems and unusually high wind potential sites are located in the Central Highlands – a vast and unpopulated area that has become very popular among tourists due to its wild and barren landscape, with spectacular volcanoes and glaciers (Ólafsdóttir and Runnström, 2011). Plans for the further exploitation of the natural resources have been recently introduced, and include projects for large wind farms. These would be an entirely new element in the Icelandic landscape, potentially raising conflicts among different stakeholders, and creating new challenges for planners, policy makers and researchers (Sæþórsdóttir, 2011; 2012).

It has been suggested that the visual impact of wind turbines on the landscape is the most significant factor influencing local opposition (e.g. Wolsink, 2007; van Veelen and Haggett, 2016). Previous studies have attempted to quantify landscape impacts by assessing the landscape's physical characteristics, or by surveying visual preferences using static photographs, visualisations and similar

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simulations (e.g. Sibille et al., 2009; Běťáková et al., 2015; Molnárová et al., 2012; Maehr et al., 2015). There is, however, also a growing body of evidence showing that the actual *ex-post* perception of landscapes with wind turbines might not be as negative as one might conclude from research employing surrogates (e.g. photographs) of landscape. A survey amongst tourists in the Czech Republic (Frantál and Kunc, 2011) shows only one quarter of visitors reporting a negative effect of wind turbines on the landscape. Similarly, de Sousa and Kastenholz (2015) did not find any particular influence of wind farms on rural tourism in Portugal. While tourists' perceptions of energy landscapes might differ from that of local residents, it might also suggest that the imagery of wind turbines itself is not the key negative impact, but more of a proxy through which dissatisfaction with the distribution of benefits and damages of a wind project is expressed (Baxter et al., 2013).

Furthermore, the studies also show a gap between 'laboratory' methods using surrogates of landscapes (photographs, visualisations) and those employing actual landscape experiences (places *in situ*). It has been shown that perceptions of the landscape are the result of the interaction of all senses (Jallouli and Moreau, 2009; Pedersen and Larsman, 2008), as well as a product of cognitive processes, where the physical setting is assessed through individuals' cultural and personal backgrounds (Bidwell, 2013). The visual impact of wind turbines on acceptance is thus not linked just to the context of the physical landscape, but also to psychometric and socio-economic parameters which shape the way in which landscape is perceived and experienced (Kontogianni, 2014).

The landscape is therefore a subjective experience, and there is a certain difficulty in evaluating the appreciation of landscape, and in finding its main characteristics (Tress and Tress, 2001). Different methods are used for evaluating scenic value, the primary dichotomy being between expert-led and participatory methods (Cetkovský and Nováková, 2009). Another difference is that between methods using various rating scales or rankings of visual stimuli for the assessment of landscape perceptions and preferences, and methods using verbal descriptions or image expressions.

The aim of this paper is to provide new insights into the factors shaping landscape perceptions and attitudes towards renewable energy developments, and the research methods that may be used in this respect. Using the case study of the Búrfell wind farm project, the first large wind farm proposal in Iceland, the authors apply a combination of 'old-school' research methods and techniques which have been used only sparsely in the field of renewable energy planning. These methods include mental mapping and the semantic differential scales. We suggest that these methods (although more time-consuming to implement and evaluate) are not only an alternative to the more common use of photo-visualizations and rating scales, but provide an option for how to better capture and understand the subjective perceptions and preferences of people, and are thus helpful in the planning and decision-making processes for selecting the most appropriate locations for future renewable energy developments.

The paper has theoretical-cognitive, methodological and applied objectives. The cognitive objectives are identical to the more general problems described above and to the specific research questions formulated in section 4.2. The methodological objective is to enrich landscape research methodology in the context of renewable energy planning with techniques that have so far been sparsely used. The empirical findings can also offer useful insights for the future planning and design of wind farms beyond Iceland.

2. Theoretical departures

Nowadays, the energy transition towards renewable sources is conceived as a social issue with technical aspects, instead of the other way around (Pasqualetti, 2011). The social acceptance of renewables is high in general, but significant opposition often rises when implementing concrete projects. Such a behavioural gap was at first explained by (selfish) NIMBYism (Bell et al., 2005), but after extensive critique of such an oversimplification it is now often looked at through the lens of place attachment, landscape character and identity (Devine-Wright and Howes, 2010; van Veelen and Haggett, 2016). This perspective considers the physical character of the landscape and the emotional responses to this, to be a key component of place attachment. Thus, as 'place', the landscape is not a static, pre-given entity, but rather its meanings are contingent, and at times controversial, produced through practices of social and economic relations (Harvey, 1994; Massey, 2004).

Any adverse change of landscape will impinge on existing place identities and place attachments (Vorkinn and Riese, 2001; Devine-Wright and Howes, 2010). In this way, the change itself is the most controversial aspect and not necessarily the resulting landscapes. History provides many examples of at first purely technical landscapes being adopted, through time, by citizens and now seen as quality places and/or tourist attractions, not rarely put under protection (Edwards and Llurdés, 1996). Similarly, new renewable energy developments can be used for place branding and energy tourism development (Frantál and Urbánková, 2014), and they may contribute towards the construction of new and positive place identities (Walker, 2011).

It has been widely acknowledged that the physical parameters of renewable energy projects (such as the distance, number and height of wind turbines) alone are insufficient to explain opinions on a particular development. Rather, the place-based perspective advanced by Devine-Wright and others (van der Horst 2007; Devine-Wright and Howes, 2010; Devine-Wright, 2011; van Veelen and Haggett, 2016) has shown the importance of considering the socially constructed, symbolic dimensions of place, and how new developments are deemed to fit with these. The continued expansion of renewable energy into rural landscapes therefore requires a re-evaluation of the use and form of these landscapes, as well as the meanings and attachments embedded in them (Bridge et al., 2013).

It is also important to point out that perception is a selective process in which people have a tendency not to notice or more quickly forget stimuli that cause visual or emotional discomfort or contradict their prior beliefs (Bell, 2012). In this sense, Sæþórsdóttir (2011) found that in the minds of tourists, the Icelandic highlands represent wilderness and even though human influence there has been considerable (including several geothermal and hydro power plants, transmission lines and other infrastructures), most of the visitors still experience the area as 'unspoilt wilderness'. This indicates that people see what they want to see and they create and maintain in their minds an image of landscape that may emphasise or dismiss particular landscape features. This example of the 'social construction of the wilderness' in Iceland illustrates how wilderness or wild landscape is more a subjective idea than an empirical reality (cf.

Sæþórsdóttir, 2011; Sæþórsdóttir and Saarinen, 2016). In a related study, however, Stefánsson et al. (2017) found that transmission lines and wind turbines have a negative effect on the perception of landscape, diminishing the feeling of wilderness, according to surveyed tourists.

The emergence of different place-related concepts and approaches to understand the perceived 'fit' of proposed or existing technologies in a particular place, has been accompanied by a proliferation of research methods. The most common way of conducting a visual impact assessment employs static photographs, often with a montage of proposed projects (Palmer et al., 2017). While photographs are generally accepted as a credible representation of landscape (Daniel and Meitner, 2001), there are still some unsettled fundamental questions, concerning both technical details (e.g. which focal length to use, how to set the landscape horizon, which format to use) and semantics (Svobodová et al., 2014; Palmer et al., 2017; Bevk et al., 2017). Ribe et al. (2018) report that the quality of simulation of landscape is an important factor in such studies and can have an effect on resulting preferences. They also report that research concerning the acceptability of wind energy development is lacking in rigorous experimental approaches.

Studies surveying visual preferences of landscape photographs with and without wind turbines mostly reveal a low acceptance of wind turbines in landscapes of high scenic quality and higher acceptance in unattractive landscapes (Lothian, 2008; Molnárová et al., 2012; Běťáková et al., 2015), and that wind turbines receive higher acceptance if their number is limited and they are located far away from observation points. They do not, however, reveal which specific landscape characteristics contribute to the perceived scenic value and the compatibility of wind turbines with landscape, or what contextual factors affect the perceptions and preferences.

Moreover, as photographs are simulations of real landscapes which only offer specific visual stimuli, the landscape experience evoked is inherently limited. Conversely, drawing from *in situ* experiences of landscape (i.e. actually being in the landscape) might produce richer information, as showed by some previous studies (Scott et al., 2008; Jallouli and Moreau, 2009). The study reported here uses a combination of personal visits to the site for a proposed wind farm and a subsequent survey of participants. The post-visit survey included techniques of mental mapping and using the semantic differential to discover what are the visual elements of the site and characteristics of landscape that are recalled and considered to be important in forming the participants' attitudes to a proposed wind energy development in the area.

3. Geographical context of the study

In recent decades the Icelandic economy has diversified from its fishing base to expand services (in particular international tourism) and energy-intensive industries (Gylfason and Wijkman, 2015). Due to its natural conditions, Iceland generates almost 100% of its electricity from renewable sources, about three-fourths from hydropower and one-fourth from geothermal energy (National Energy Authority, 2016). The consumption of electricity is extremely high when measured per head of population – well over 50 MWh/capita in 2014, or more than twice that of Norway, the country that is next on the world list (Orkustofnun, 2017). The reason is that more than 75% of the relatively cheap electricity is sold to large industrial users, mainly three aluminium smelters and one ferrosilicon producer, plus a handful of smaller factories (Orkustofnun, 2016). This has raised concerns about the policy emphasis of successive governments on heavy industry, and its possible detrimental impact on Iceland's nature (Benediktsson, 2007; Karlsdóttir, 2013) and the fast-growing tourism sector (Sæþórsdóttir, 2010; Stefánsson et al., 2017).

International tourism in Iceland has grown rapidly in recent decades, and nature and 'wilderness' are considered the main attractions (Sæþórsdóttir and Saarinen, 2016). Specifically, the Central Highlands are often regarded as one of the last relatively pristine and wild environments left in Europe (Ólafsdóttir and Runnström, 2011). Traffic accessibility to the highlands has gradually increased since early 1970s, mainly following the construction of hydro- and geothermal power plants with related infrastructure, which has subsequently transformed this wilderness into a recreational area (Sæþórsdóttir, 2010). Recently plans for further exploitation of the natural resources have been introduced, which have created new conflicts among different stakeholders and sectors of the national economy (Sæþórsdóttir, 2011; 2012). The highlands have thus become an arena of competition among different ways of seeing, interests, value judgments, myths and discourses regarding the potential use of the landscape, whether for renewable energy exploitation, eco-tourism development or strict wilderness conservation.

In response to this changed arena, a project called the "Master Plan for Nature Protection and Energy Utilisation" has been established by the Icelandic government in order to assess and minimise negative environmental, social and economic impacts of proposed projects (Sæþórsdóttir and Ólafsson, 2010a). The task of the Master Plan is to compare the economic feasibility and environmental impacts of energy projects, which should aid in selecting the most feasible projects to develop. So far the Master Plan has been carried out in three sequential phases, each of which has contributed to the development of methodologies for assessing the energy sites, and for evaluating their qualities and impacts (Sæþórsdóttir and Ólafsson, 2010b). About 100 energy projects have already been evaluated and ranked, including the Búrfell wind farm.

One of the core subjects that experts are requested to evaluate at any proposed site in the context of the Master Plan, is the landscape. The methodologies used for evaluating the aesthetic values of landscape, and decisions on projects so far made, are subject to critical discussions, raising many questions. Waage and Jóhannesdóttir (2017) point out for example: "Who should define the aesthetic values of landscape?" or "When and how should these values be taken into consideration?"

4. Material and methods

4.1 Case study area

The proposal for the Búrfell wind farm was introduced by the National Power Company of Iceland[1] in 2014. It involves the construction of up to 67 wind turbines, each with a

[1] The National Power Company of Iceland (Landsvirkjun) is the country's largest electricity producer and one of the largest producers of renewable energy in Europe.

maximum height of 150 metres to the tip of the blade. Each turbine would have a capacity of 3.0–3.5 MW depending on the final turbine selection (Landsvirkjun, 2017). The construction area spans up to 40 km^2 of lava and sand plain and is located to the east of the Ţjórsá River, in an area where the energy company already operates two wind turbines for research purposes (see Figs. 1 and 2). The site has extraordinary wind potential with a capacity factor of over 38% on average, and the levelised cost of energy is estimated as about 0.088 USD/kWh, which classifies Búrfell among the lowest-cost sites for wind energy in Europe (Ragnarsson et al., 2015).

The proposed project site is located in one of the largest energy production areas in Iceland. Currently, there are six operational hydropower plants located in the larger area, with their related structures such as tailrace canals, reservoirs, quarries, roads and transmission lines. The first power plant was commissioned in 1969. The area can thus be considered as already considerably disturbed by human activities. The site is not defined as a protected area and is beyond the parameters of 'wilderness' as defined in the Nature Conservation Act (Ministry for the Environment and Natural Resources, 1999).

The site can be regarded as on the periphery of the highlands or – from another perspective – as a gateway and a stopping point on the way to the highlands, where 'true' wilderness can be experienced. The site is somewhat demarcated by a mountain range to the east and west, which would reduce the far-reaching visual impact of the wind farm. In an opinion survey (Ólafsdóttir et al., 2015), local residents were asked about the main characteristics of the surrounding landscape. The most common characteristics included sand, wilderness and lava; one fifth of respondents considered it a beautiful landscape, with a mountain view, a vast expanse, with lack of vegetation and much barren land. Approximately 10% emphasised that the volcano Hekla is the main characteristic of the area (see Fig. 3).

Due to the size of the wind farm, the project was subject to an Environmental Impact Assessment (EIA), which was completed in 2016. Complete documentation is accessible at the company's website (Landsvirkjun, 2017). The Icelandic National Planning Agency (NPA) recently gave its negative opinion on the environmental impact assessment of the project, arguing it would have a significant impact on the landscape and wilderness in the area, as well as on tourism and recreation (Skipulagsstofnun, 2016). In the Regional Plan for the Central Highlands of Iceland, dating from 1999, the proposed construction area was defined as lying within a "structure belt", where major mountain roads and structures associated with electricity generation are allowed (Landsvirkjun, 2017). This plan has been superseded by the National Planning Strategy 2015–2026, however, where the preservation of the remaining wilderness in the highlands and their characteristic landscapes are emphasised (Skipulagsstofnun, 2016).

The proposal was one of those considered in the third phase of the Master Plan. Its current status within that planning process is 'on hold' (Rammaáætlun, 2017), which means that the project has not been definitely rejected, but that the company should find a more suitable location or scale down the project if it wants to proceed with it. Both solutions would require a new EIA process.

Fig. 1: Location of the Búrfell wind farm project in the Central Highlands of Iceland
Source: authors´elaboration

Fig. 2: Visualisation of the proposed wind farm. The two experimental wind turbines can be seen in the foreground, as well as the Bjarnalón Reservoir and the tailrace canal from the Sultartangi Hydropower Station
Source: Landsvirkjun (2017)

Fig. 3: The volcano Hekla, partly covered in clouds – one of the landscape dominants in the Búrfell area
Photo: T. Bevk

4.2 Research questions

The specific research questions that have driven this empirical study were defined as follows:

1. How is the Icelandic landscape perceived, in general? And, specifically, how is the Búrfell landscape perceived? Are there significant differences between these perceptions?
2. What visual elements of the Búrfell landscape are considered to be important? How are those visual elements arranged spatially?
3. How compatible with the Búrfell landscape are wind turbines perceived to be?
4. How strongly do landscape perceptions relate to the attitude of accepting or rejecting the wind farm project?
5. What other factors influence public opinions about the project?

The results presented in section 5 have been structured into sub-sections reflecting these research questions.

4.3 Research methods and procedures

This paper is an output of research carried out during the Training School: Questions of Power and Participation: Renewable Energy and Landscape in Policy and Planning, held in May 2017 in Iceland, within the scope of the COST Action RELY (see 'Acknowledgements' for more information). Altogether 30 people from 17 countries participated in the survey. Even though the group consisted of people with varied professional backgrounds (geographers, sociologists, urban planners, landscape architects and engineers), the professional interests of all participants are in some way connected with the issues of renewable energy development and its impacts on the landscape. In this sense, they cannot be considered as 'normal' tourists, but rather as 'expert tourists' within the so-called special interest tourism (Brotherton and Himmetoğlu, 1997; Frantál and Urbánková, 2017). The group was evenly represented by both genders (fifteen males and fifteen females) and different age groups (one third of people under the age of 30, one third between 30 and 40 years, and one third over 40 years old). About two thirds of the participants were first-time visitors to Iceland. The research had an exploratory character and included several phases: a field trip with observations and note-taking; analysis of notes; mental mapping; the construction of relevant semantic differential items; a questionnaire survey; and detailed data analysis and interpretation.

First, the participants were asked to observe the landscape during a one-day field trip that included several locations in Southern Iceland and the Highlands. They were encouraged to write down their feelings and impressions (preferably using adjectives) associated with the Icelandic landscape in general, as well as specific impressions related to the Búrfell site. The visit to the Búrfell site (see Fig. 4) lasted approximately one hour, during which the participants studied an information board presenting basic data about the project and photo visualisation of the wind farm, as well as observing the landscape and the two existing turbines first hand. Also the planned project was discussed with some local experts. The day after the visit, verbal characteristics of landscapes in the form of adjectives as recorded by participants were summarised, sorted and categorised into groups representing different attitude factors, such as evaluation, potency, activity, typicality and complexity (cf. Echelberger, 1979). Afterwards, selected participants (members of a specific working group at the training school, and then the authors of this paper) drew mental maps of the Búrfell site as a means of scoping – to find the most memorable characteristics and the level of agreement between them.

Mental mapping is a valuable tool for understanding how humans perceive and reflect their environment. A mental map using the well-known sketch map technique, reveals an individual's spatial cognition of a landscape that is the reflection of a mental construction of spatial arrangements in memory sketched on paper (Uusitalo, 2010). The conceptual structure of a mental map reflects the manner in which space is represented and apprehended, revealing spatial preferences and attractiveness of specific elements of the landscape. In some cases, mental mapping has been used to engage local residents in the planning process of wind farms, as a tool to express personal preferences about the location of wind farms based on local knowledge (Nováková and Frantál, 2009). Additionally, mental maps include non-spatial components reflecting attributive values, meanings, attitudes and understandings about places which influence individual behaviours

(Uusitalo, 2010). Several typologies were made for studying the content and the structural quality of the sketch maps. The structure of maps, their components, style, content, inclusion or exclusion of elements, accuracy (complexity), interrelation between the types of visual elements and alike, can be analysed in different ways (Appleyard, 1970; Whyte, 1977). Lynch (1960), for example, in his research on the understanding of urban space, defined five key elements in mental maps – nodes, paths, edges, districts and landmarks. While this approach focuses on the content of the maps, others also analyse the composition, view angle and centrality of drawn objects (Ueda et al., 2012).

In our case study, the mental maps were used to determine the scope of perceptions. Based on the on-site visit to the studied landscape, each of the authors drew their own mental map (see Fig. 4). The subsequent analysis of maps exposed how similar the perceptions of this landscape were. The analysis was based on what was drawn, where and how. What is drawn – the content – is more or less self-explanatory: objects appearing repeatedly in the drawings are considered memorable characteristics of the landscape. Where something is drawn – the position of an object on the paper – indicates its importance. Objects drawn centrally or in the foreground of the paper are considered more important than those drawn at the edges or peripherally, but this might also be the consequence of a chosen viewpoint. This is why we also assessed the relative size of drawn objects as a proxy of importance, as objects found more important tend to be drawn larger. While, by themselves, the findings of the mental maps can be used immediately to begin drafting the character of a landscape, we mainly used them to facilitate the construction of a questionnaire in the next phase. Mental mapping and brainstorming of adjectives which describe the landscape, supported by a literature review (Echelberger, 1979; Kaplan, 1985; Kim and Kang, 2009; Natori and Chenoweth, 2008; Zube and Pitt, 1981), facilitated the construction of the semantic differential items for measuring the perceptions of the Búrfell site landscape.

Several authors have argued that people can explain their preferences better by using words than by rating or ranking visual stimuli (Kaymaz, 2012). In the semantic differential technique developed by Osgood et al. (1957), respondents use a series of bipolar adjective pairs to judge a ‘concept’, which – in our case – can be a landscape (as a general concept) or particular landscape scenery (the Búrfell wind farm site). Respondents decide whether a concept is associated more with adjectives such as beautiful or ugly, common or unique, and to what degree. When data are then subject to factor analysis, one factor that emerges can be considered an index of attitudes or an evaluation of the concept. This index can be labelled as the evaluative factor or attitude score (Echelberger, 1979). It can then be tested whether there is a relation between the assessment of specific landscape characteristics and the attitude of respondents to a particular use of land, e.g. to exploit or to preserve it.

Besides a semantic differential list including 20 pairs of adjectives, the constructed questionnaire included two questions asking participants to assess the compatibility of the proposed wind farm with the landscape, and to state their position in terms of approval or non-approval of the project. Another (open-ended) question asked people to explain in greater detail their attitude to the project by listing important arguments for or against it. We also considered the personal characteristics of participants, including gender, age, profession and country of origin. The data from the questionnaires were digitised and analysed using the SPSS software (version 21), providing descriptive statistics, analysis of variance, principal components analysis and correlation analysis.

Finally, it is worth mentioning that we are well aware of some methodological limitations of this study, particularly concerning the overall levels of perceived compatibility and approval of the projects, and the verification of the influence of respondents’ socio-demographic characteristics on perceptions and attitudes. This limitation is caused by the small sample of respondents, which is also relatively homogenous with respect to professional background. This study was, however, not aimed primarily at the estimation of population parameters but rather at exploring specific relative factors and the relationships among them, and testing specific research methods and techniques, albeit for a restricted sample, as noted.

Fig. 4: Participants of the survey with the two operational wind turbines
Photo: T. Bevk

5. Results

5.1 Associations connected to landscapes of Iceland and Búrfell

The most commonly recorded words associated with the Icelandic landscape in general, were diverse and contrasting, open, wild, beautiful, vast and breath-taking. Other frequent adjectives related to the 'potency' of the landscape, such as powerful, energetic, and dynamic. Some adjectives related to specific natural elements which constitute the Icelandic landscape (volcanic, rocky and deserted) were also mentioned by several people. While open, breath-taking and powerful were also oft-mentioned for the Búrfell site, there were also some other key site-specific adjectives, including disturbed, industrial, bleak, desolate and windy. This appears to indicate a difference in perception of the Búrfell site compared to Icelandic scenery in general (see Tab. 1). Differences in perceptions and the experience of a particular place (Búrfell) are also evidenced by the completely contradictory associations often mentioned: while for several people the Búrfell landscape was noisy, dangerous and scary, it impressed others as being rather quiet, relaxing and meditative.

5.2 Interpreting mental maps of the Búrfell landscape

The perception of the Búrfell wind farm site as anthropogenically changed and disturbed (as interpreted from the frequency of recorded adjectives) is also reflected in the mental maps (see Fig. 5). The most common characteristics of the site as drawn were the human interventions (wind turbines, dam, road), but there were also two distinct natural features (Hekla volcano, surrounding hills) that were drawn by all participants. The flat plain on the left of the drawing behind the existing wind turbines was mostly left out with no drawn features. This empty space of the drawing might suggest this area is lacking features that would characterise it, echoing some of the adjectives used in associations such as empty and desolate. The idea of building wind turbines in this "blank" area appeared several times in response to an open question (see Tab. 5).

Icelandic landscape (in general)	Búrfell landscape (specific)	Contrasts (general vs. site-specific)
diverse (contrastful)	open	impulsive–passive
open	disturbed	contrasted–homogeneous
wild	bleak (desolate)	quiet–noisy
beautiful	industrial	beautiful–ugly
vast	windy	unspoiled–industrial
breathtaking (mesmerising)	breath-taking	vulnerable–exploitable
powerful (energetic)	powerful (energetic)	old–innovative
barren (uncultivated)	noisy	
lunar (alien, martian)	innovative (pioneer)	

Tab. 1: The most common perceptions and contrasts of landscapes of Iceland and Búrfell
Source: authors´survey

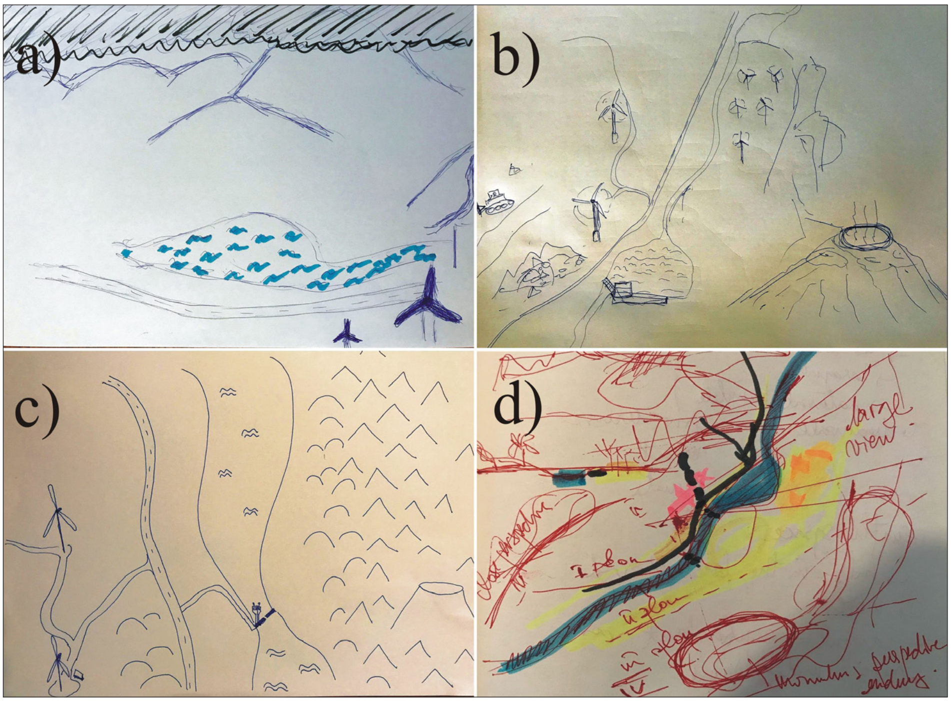

Fig. 5. Mental maps of the Búrfell site
Source: authors' elaboration

The water reservoir appears centrally on all of the drawings suggesting this might be the key characteristic of this site. As the wind turbines are drawn quite large for the scale of the drawings, it is possible to say that observers were focusing on them to a large extent. These two findings might point towards a landscape character defined by the energy infrastructure, but the fact that the drawings were made by experts interested in renewable energy might also explain why such an infrastructure is emphasised. All of the drawings offer a bird's-eye view of the landscape, suggesting a somewhat detached, objectivistic approach to landscape assessment (Ueda et al, 2012).

5.3 Perception of landscape compatibility and project approval

Two closed questions were included in the survey, asking participants to assess (on a 5-point Likert scale) the compatibility of the proposed wind farm with the Búrfell landscape, and their position in terms of approval or non-approval of the project. One half of the respondents considered wind turbines incompatible with the landscape, while about one-third perceived them as compatible. Also almost half of the respondents would rather reject the project, while only about one third would approve it (see Fig. 6). A strong correlation (Spearman's rho = 0.69) was found between the perceived compatibility of the wind farm proposal with the landscape and personal attitude to the project.

In fact, there were only two respondents who would rather disapprove of the project although they considered wind turbines very or rather compatible with the landscape. The reason for such a decision is that they considered the project redundant in the context of Iceland's already large energy production. On the other hand, there were two people who would approve the project even though they considered wind turbines incompatible with the landscape. The reason for such a decision was their support for renewable energy in general and an opinion that although the selected site "is not the best, it is even not the worst". A deeper discussion of the arguments for and against the project approval is presented in section 5.5.

5.4 Semantic differential analysis

The analysis of data from the semantic differential items revealed significant differences in the perception of the Búrfell landscape. The biggest consensus among respondents was that the local landscape is exposed, open, unfriendly, windy and kind of unique. Some people, however, perceived the landscape as natural, diverse, colourful and familiar, while others perceived it rather as man-made, homogenous, monochromatic and alien (see Tab. 2).

Figure 7 visually shows the differences in perceptions of the Búrfell landscape between those who consider the project to be compatible and those who consider it as incompatible with the landscape. People who perceive the landscape as more open, homogenous, industrial, alien and resilient, also evaluate the wind farm as compatible with the landscape. On the other hand, those who perceive the landscape as less open, more diverse, pastoral, familiar and vulnerable consider the project as incompatible with the landscape.

Somewhat paradoxically, people who perceive the landscape as slightly more beautiful, wild and unique consider the project more likely as compatible with the landscape. This difference, however, proved not to be statistically significant. The perceptions of beauty and

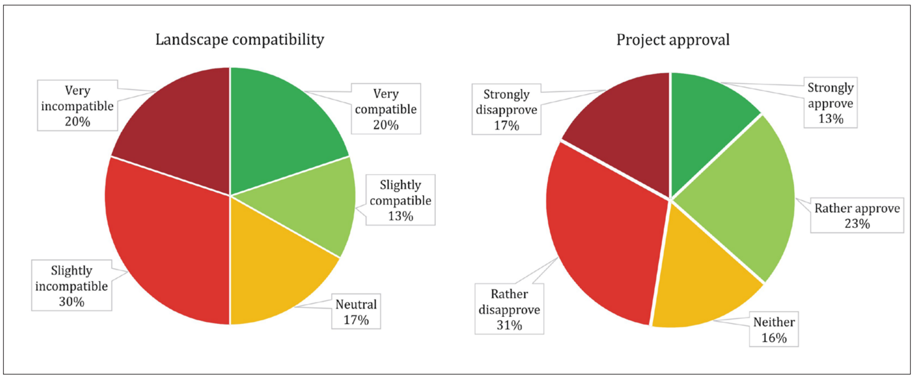

Fig. 6: Perceptions of compatibility of wind farm with the landscape and attitudes to project approval
Source: authors' survey

Adjectives with the lowest rate of variance (Var < 1.0)	**Adjectives with the highest rate of variance (Var > 1.4)[1]**	**Adjectives significantly correlated with the perception of compatibility (value of correlation)[2]**
Exposed	Young / Old	Open (0.37*)
Open	Man-made / Natural	Resilient (0.29*)
Unfriendly	Homogenous / Diverse	Homogenous (0.26*)
Windy	Monochromatic / Colourful	Industrial (0.24*)
Unique	Alien / Familiar	Alien (0.21*)

*Tab. 2: Adjectives related to Búrfell wind farm landscape (Notes: [1]Adjectives with slightly higher degree of preference are underlined; [2]Values of correlation (Somers' d) for the perception of compatibility as dependent variable are significant at * 0.05 level). Source: authors' survey*

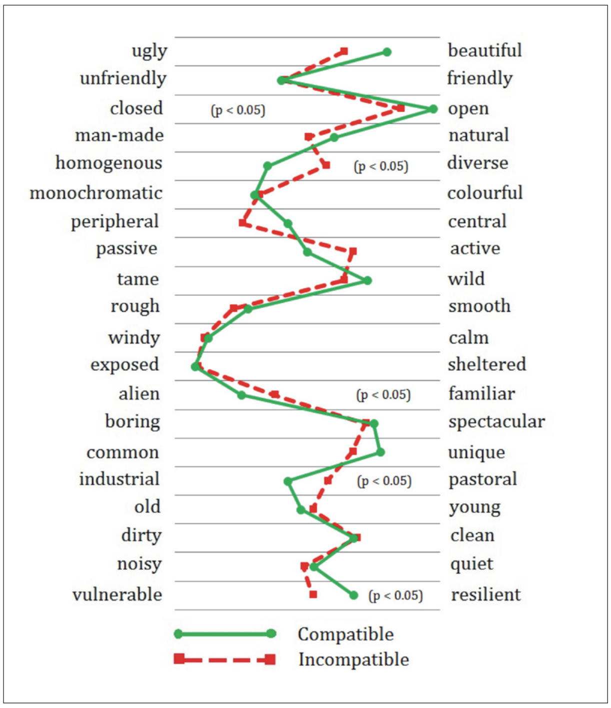

Fig. 7. Differences in perception of the Búrfell wind farm landscape between those who consider the project to be compatible and those considering the project incompatible with the site. Note: Levels of significance (p) for adjectives that significantly correlate with the perception of compatibility.
Source: authors' survey

wilderness (as the most typical characteristics of Icelandic landscape in general, as emphasised in the literature) proved to be strongly correlated (r = 0.56). Besides that, both the perception of beauty and wilderness significantly correlate with the characteristics of natural, spectacular, pastoral and unique.

In order to explore the structure of relations among specific characteristics of landscape and to find out if they can be divided into groups representing more generic 'factors', we applied principal component analysis (PCA). Five items (peripheral/central, passive/active, rough/smooth, familiar/alien, vulnerable/resilient), which correlated weakly (< 0.3) with others, were excluded from the PCA. The results of analysis are presented in Table 3. The presented grouping of items was generated using the Oblimin rotation solution with the measures of the Kaiser-Meyer-Olkin test of sampling adequacy (KMO = 0.71) and Barlett's test of sphericity ($p < 0.001$) confirming appropriateness of the selected variables for the factor analysis. The total variance explained by four extracted components is nearly 70%.

The first component, which can be considered an evaluative factor explains 35% of the total variance. The second component, including characteristics expressing the impact of human activities on the landscape, explains 15% of the total variance. The third component (called potency) explains nearly 11% of total variance and the fourth component (which we called exposure) explains about 7% of total variance. Only the fourth component (including the adjectives of open, noisy and common), however, proved to be significantly correlated with the perceptions of landscape compatibility and project approval.

Adjectives	**Component**			
	Evaluation	Human impact	Potency	Exposure
homogenous / diverse	0.83			
monochromatic / colourful	0.82			
boring / spectacular	0.77			
ugly / beautiful	0.49			0.36
man-made / natural		– 0.91		
old / young	0.38	0.73		
tame / wild		– 0.67		
industrial / pastoral		– 0.61		
windy / calm			– 0.83	
exposed / sheltered			– 0.71	
unfriendly / friendly	0.35		– 0.68	
dirty / clean			– 0.59	
closed / open			0.35	0.73
quiet / noisy				0.63
common / unique	0.40			– 0.45
% of Variance explained	35.1	15.2	10.9	7.4
correlation with landscape compatibility	n.s.	n.s.	n.s.	0.47*
correlation with project approval	n.s.	n.s.	n.s.	0.41*

Tab. 3: The extracted components of landscape characteristics
Notes: Principal Component Analysis, rotation method Oblimin with Kaiser Normalization. Factor loadings lower than 0.3 were excluded. Correlation that is significant at the 0.05 level is indicated with a star (*)
Source: authors' survey and calculations

5.5 Factors affecting landscape perceptions and attitudes

Relationships between perceptions and attitudes and socio-demographic characteristics were also tested. Our results suggest that males were more likely to perceive the proposed wind farm as compatible with the landscape than females (47% versus 20%). The reported difference in the level of approval between genders (the project would be approved by 40% of males but only by 33% of females) proved not to be statistically significant, however (see Tab. 4). Older people (over 30 and especially over 40 years old) are slightly more tolerant to the project than younger persons (up to 30 years). But these differences are also not statistically significant. Any links between personal attitudes and professional background of people were also not found. There is however a significant correlation (even in such a small sample of respondents) between the subjective perception of landscape compatibility and approval of the project and a respondent's country of origin. People from more densely-populated countries and countries with an already developed wind energy industry (e.g. Netherlands, Germany, UK) are much more tolerant of the project.

Nevertheless, the subjective perception of landscape and its compatibility with wind turbines is the dominant factor shaping personal attitude to project approval. This is finally supported also by the analysis of information from the open-ended question asking people to explain their stated attitude to the project by summarising key pros and cons of the project. The key arguments of advocates and opponents of the project are summarised according to their relative frequency in Table 5. The aspects of potential visual impact of the wind farm on the local landscape and the need for the production of more energy emerged as the main points of contention.

6. Discussion and conclusions

In general, our research has confirmed that wind turbines are a controversial element which some people perceive primarily negatively, while others quite positively, whether the landscape is in the Icelandic highlands, part of the rural countryside in Central Europe (Frantál and Kunc, 2011) or on the North Sea coast (Gee, 2010). Landscape perception and experience is a highly subjective and relative phenomenon, influenced by the perceiver's motivations, values and cultural background and their situation in life, as well as the time spent in a place and level of place attachment (i.e. differences in the perceptions by tourists and locals).

Our survey found that half the respondents considered wind turbines incompatible with the landscape, while about one third perceived them compatible. Also almost half of the people would rather reject the project, while more than a third would approve it. Similar contrasting perceptions and attitudes were reported from a questionnaire survey using photo-visualisations of the proposed wind farm, conducted in 2014 and with a sample of some 1,351 tourists in Iceland (Björnsson et al., 2015). While approximately 40% of tourists had generally positive attitudes to wind turbines in the Icelandic nature, 33% had a negative attitude to them, and nearly one fifth reported tending to avoid travelling in areas with wind turbines. Concerning specifically the Búrfell wind farm, about 35% had a positive attitude to

Predictors	Value of correlation with	
	Perceived compatibility	Project approval
Gender	0.36*	n.s.
Age	n.s.	n.s.
Profession	n.s.	n.s.
Country of origin: Population density	0.38*	0.32*
Country of origin: Wind energy capacity per km^2	0.40*	0.38*

*Tab. 4: Factors affecting the perception of landscape compatibility and attitudes to the project. Note: Values of correlation (Somers' d for ordinal variables and Pearson's r for numeric variables) are significant at the *0.05 level Source: authors' survey and calculations*

For approval	For rejection
– no special scenic landscape (similar vast plains with volcanic rocks elsewhere), there will be plenty of opportunities to view Hekla volcano from other places	– the views to the mountains in the east and south will be spoiled (particularly the view on Hekla volcano), negative impact on tourist experiences
– landscape already disturbed by human activities (energy production), existing infrastructure (roads, transmission lines)	– landscape is already changed but still the large wind turbines will disturb and change the existing landscape dramatically
– extraordinary wind potential, energy economically feasible without subsidies (we need to use cheap wind energy where available)	– no need for more energy production in Iceland (we shouldn't produce more energy just because we can)
– empty, deserted, uninhabited land (far from settlements) with low biodiversity	– too big and concentrated project (better more single wind turbines in lowland farming areas)
– wind farm actually does not look bad (wind turbines are beautiful themselves)	– better to construct the wind farm on the other side of the road

Tab. 5: Competing arguments related to Búrfell wind farm
Source: authors' survey

the project while about 40% had a negative attitude (25% were neutral) (Björnsson et al., 2015). Conversely, the study of Stefánsson et al. (2017) reveals that wind turbines are considered inappropriate for some more naturally preserved areas in the eyes of tourists.

Our survey data showed a strong correlation between the perceived project's compatibility with the landscape and attitudes towards the project (section 5.3). This could indicate that a project's perceived 'fit' in the landscape plays a key role in determining attitudes towards it. This may be explained by the types of participants in this study, but it also indirectly supports previous research which has found that people who have spent less time in a place may be more likely to evaluate proposed developments based on their impact on the physical landscape (as well as individuals' emotional attachments to this landscape) than on the proposed development's impact on the local populations (Hidalgo and Hernandez, 2001).

Both the mental mapping exercise and the survey data show that the presence of human-made structures in a landscape are important in shaping public perceptions of the landscape and attitudes to its future use. Individual perceptions of the Búrfell site are, however, rather contradictory: bleak, industrial and scary, but also breathtaking (and for some, even meditative). Nevertheless, our results show that the main values of the Highlands landscape as pointed out by the National Planning Agency in their decision about the project (i.e. wilderness, unspoiled nature, beauty), are not the ones generally perceived by our survey participants at the site. The bone of contention seems to be rather the question of how much the landscape is already disturbed and how the proposed project may further damage the already-disturbed landscape.

Respondents who perceived the landscape as more open, homogenous, alien, industrial and resilient, also evaluate the wind farm as compatible with the landscape. Of further interest is that those who perceive this particular landscape as slightly more beautiful, wild and unique, consider the project more likely to be compatible with the landscape. This finding can indicate that the use of wind energy is not in strict contrast with the perceived beauty, wilderness and uniqueness of the landscape. This perception can be well illustrated by one respondent's statement:

> "I do perceive such wide and wild landscapes (Búrfell), dominated by morphology, as absolute and atemporal landscapes, where the dimensions and the horizons seem to visualise the perpetual movement of the Universe and suggest the renewability of the natural phenomena such as wind (…) In my vision this complex of factors perfectly suits the proposed wind farm".

Similarly, Vorel (2009) suggested that wind turbines can be perceived as compatible with some kinds of landscapes (e.g. segments of visually open cultural landscape, working agricultural landscapes, or post-industrial landscapes) and they can even contribute positive aesthetic values, like a 'hi-tech' product. Such statements call for a search of landscape settings that might have some sort of 'natural' fit with wind turbines, and may therefore not only be less disturbed by them compared to other types of landscape but may even benefit from such installations. In this regard, we might also ask if a new type of landscape is emerging with the spread of renewables – a landscape of renewable energy?

The physical landscape and emotional responses to it are not, however, the only factors that influence attitudes to renewable energy developments. Those advocating a place attachment perspective have emphasised that the social dimensions of place, i.e. current and historical social or cultural attachment to an area, also play a role in shaping opinions of new developments (Raymond et al., 2010; Lin and Lockwood, 2014). As this particular landscape at Búrfell is generally not seen as incredibly beautiful, where nothing should be built, but neither as a completely worthless place, a key piece of information seems to be missing – just how important is this wind farm project for Iceland's energy provision and/or for the local area? As other research has shown (Stefánsson et al., 2017; Llewellyn et al., 2017; van Veelen and Haggett, 2016), local perceptions of renewable energy projects are at least in part based on the ways in which such developments are expected to benefit the local area and for what purposes the produced energy will be used. Without this knowledge it is difficult if not impossible to establish a value system within which the benefits could be compared to damages done to the landscape.

Finally, our survey also found that people from more densely populated countries and countries with an already-developed wind energy industry are much more tolerant to wind turbines in the landscape. This seems to be in contrast to the study by Bishop and Miller (2007), who found that those who lived in areas where turbines had been approved were more negative than those whose localities were still untouched by the wind energy industry, but in line with the findings of Stefánsson et al. (2017) that tourists from Germany, Switzerland and the UK are more tolerant of energy infrastructures than those from Nordic countries.

From the methodological perspective, our research shows that visits to the actual landscape, with the involvement of all sensory organs, can reveal more information than using 'laboratory' methods and static photographs (photo-visualisations). Ribe et al. (2018) have argued that field studies might not be able to provide useful findings about wind energy project perceptions, calling for more rigid and controlled laboratory experiments. While this may be true when searching for universally applicable principles, no development project is carried out in vitro, and each affects a certain landscape and certain people. We would therefore like to add that on-site studies, such as the one reported here, are and should be an indispensable factor in the toolbox for wind power development, especially when it comes to evaluating specific locations.

The experience of 'blowing wind energy' at the site, as well as the perception of the landscape as wide-open, noisy and exposed, were considered by many people to be important aspects of the landscape when they made up their minds about the project. It is necessary to admit that perceptions of actual landscapes can be significantly influenced, for example, by varying weather conditions, the context of the study and researchers' biases, to name a few factors. In this sense, it is desirable to compare the perceptions of one-day visitors with those of locals who have long-term experiences with the landscape. The use of mental mapping helped to reveal which parts of the landscape are recalled and considered important and valuable, and which are perceived as marginal or empty. It brings up the idea of using mental maps as a tool in planning: perhaps the method could be used to identify 'empty spaces' in the landscape and direct developments there.

The combination of qualitative and quantitative research methods described in this article has proved fruitful in terms of both constructing the survey instrument and interpreting the results. We therefore urge and suggest further examination of how such qualitative and quantitative methods can be used jointly to yield informative findings on planning renewable energy projects in the landscape.

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References:

APPLEYARD, D. (1970): Styles and methods of structuring a city. Environment and Behaviour, 2: 100–117.

BAXTER, J., MORZARIA, R., HIRSCH, R. (2013): A case-control study of support/opposition to wind turbines: Perceptions of health risk, economic benefits, and community conflict. Energy Policy, 61: 931–943.

BELL, S. (2012). Landscape: pattern, perception and process. New York, Routledge.

BELL, D., GRAY, T., HAGGETT, C. (2005): The 'social gap' in wind farm siting decisions: explanations and policy responses. Environmental politics, 14(4): 460–477.

BENEDIKTSSON, K. (2007): 'Scenophobia' and the aesthetic politics of landscape. Geografiska Annaler B, 89(3): 203–217.

BĚŤÁKOVÁ, V., VOJAR, J., SKLENIČKA, P. (2015): Wind turbines location: How many and how far? Applied Energy, 151: 23–31.

BEVK, T., MESTRE MARTINEZ, N., BRERETON, P., LALOŠEVIČ, M., PERIČ, M. (2017): Iterative Digital Photo-based Assessment for Rural Landscape Perception: A Small Experiment from County Wicklow, Ireland. Journal of Digital Landscape Architecture, 2017(2): 18–27.

BIDWELL, D. (2013): The role of values in public beliefs and attitudes towards commercial wind energy. Energy Policy, 58: 189–199.

BISHOP, I. D., MILLER, D. R. (2007): Visual assessment of off-shore wind turbines: the influence of distance, contrast, movement and social variables. Renewable Energy, 32(5): 814–831.

BJÖRNSSON, G., SÆÞÓRSDÓTTIR, A. D., ÓLAFSDÓTTIR, R. (2015): The Impact of Wind Farms on Tourist Experience in Iceland's Highlands. Poster presented at the 21st International Symposium on Society and Resource Management, June 13–18, 2015, Charleston, South Carolina, USA.

BRIDGE, G., BOUZAROVSKI, S., BRADSHAW, M., EYRE, N. (2013): Geographies of energy transition: Space, place and the low-carbon economy. Energy Policy, 53: 331–340.

BROTHERTON, B., HIMMETOĞLU, B. (1997). Beyond destinations – special interest tourism. Anatolia, 8(3): 11–30.

CETKOVSKÝ, S., NOVÁKOVÁ, E. (2009): Assessment of the impact of wind turbines on landscape character: Implications for landscape planning. Moravian Geographical Reports, 17(2): 28–34.

DANIEL, T. C., MEITNER, M. M. (2001): Representational Validity of Landscape Visualizations: The Effects of Graphical Realism on Perceived Scenic Beauty of Forest Vistas. Journal of Environmental Psychology, 21(1): 61–72.

DE SOUSA, A. J. G., KASTENHOLZ, E. (2015): Wind farms and the rural tourism experience–problem or possible productive integration? The views of visitors and residents of a Portuguese village. Journal of Sustainable Tourism, 23(8–9): 1236–1256.

DEVINE-WRIGHT, P. (2011): From backyards to places: public engagement and the emplacement of renewable energy technologies. In: Devine-Wright, P. [ed.]: Renewable energy and the public. From NIMBY to participation (pp. 57–74), London, Earthscan.

DEVINE-WRIGHT, P., HOWES, Y. (2010): Disruption of place attachment and the protection of restorative environments: A wind energy case study. Journal of Environmental Psychology, 30(3): 271–280.

EDWARDS, J. A., LLURDÉS, J. C. (1996): Mines and quarries: Industrial heritage tourism. Annals of Tourism Research, 23(2): 341–363.

ECHELBERGER, H. E. (1979): The semantic differential in landscape research. In: Elsner, G. H., Smardon, R. C. [eds.]: Proceedings of our national landscape: a conference on applied techniques for analysis and management of the visual resource (pp. 524–531). [Incline Village, Nev., April 23–25, 1979]. Forest Service, U.S. Department of Agriculture, Berkeley, CA.

FRANTÁL, B., KUNC, J. (2011): Wind turbines in tourism landscapes. Annals of Tourism Research, 38(2): 499–519.

FRANTÁL, B., URBÁNKOVÁ, R. (2017): Energy tourism: An emerging field of study. Current Issues in Tourism, 20 (13): 1395–1412.

GEE, K. (2010): Offshore wind power development as affected by seascape values on the German North Sea coast. Land Use Policy, 27(2): 185–194.

GUNNARSSON, B., GUNNARSSON, M. V. (2002). Iceland's Central Highlands: nature conservation, ecotourism, and energy resource utilization. In: Watson, A. E., Alessa, L., Sproull, J. [eds.]: Wilderness in the circumpolar north: searching for compatibility in ecological, traditional, and ecotourism values. Conference proceedings. Anchorage, 15–16 May 2001 (pp. 54–63). Rocky Mountain Research Station, USDA Forest Service.

GYLFASON, T., WIJKMAN, P. M. (2015): Double diversification with an application to Iceland. CESifo Working Paper Series No. 5386: 2–33.

HARVEY, D. (1994): Justice, nature and the geography of difference. Oxford, Blackwell Publishing.

HIDALGO, M. C., HERNANDEZ, B. (2001): Place attachment: conceptual and empirical questions. Journal of Environmental Psychology, 21(3): 273–281.

JALLOULI, J., MOREAU, G. (2009): An immersive path-based study of wind turbines' landscape: A French case in Plouguin. Renewable Energy, 34(3): 597–607.

KAPLAN, R. (1985). The analysis of perception via preference: a strategy for studying how the environment is experienced. Landscape Planning, 12(2): 161–176.

KARLSDÓTTIR, U. B. (2013): Iceland and the North: an idea of belonging and being apart. In: Jørgensen, D., Sörlin, S. [eds.]: Northscapes: History, Technology and the Making of Northern Environments. Vancouver, UBC Press.

KAYMAZ, I. C. (2012). Landscape perception. In: Ozyavuz, M. [ed.]: Landscape planning. Intech [online]. Available at: http://www.intechopen.com/books/landscape-planning/landscapeperception

KIM, N. H., KANG, H. H. (2009): The aesthetic evaluation of coastal landscape. KSCE Journal of Civil Engineering, 13(2): 65–74.

KONTOGIANNI, A., TOURKOLIAS, C., SKOURTOS, M., DAMIGOS, D. (2014): Planning globally, protesting locally: Patterns in community perceptions towards the installation of wind farms. Renewable Energy, 66: 170–177.

LANDSVIRKJUN (2017): Búrfell Wind Farm EIA report [online]. Available at: http://burfellwindfarm.landsvirkjun.com/

LIN, C.-C., LOCKWOOD, M. (2014): Forms and sources of place attachment: evidence from two protected areas. Geoforum, 53: 74–81.

LLEWELLYN, D. H., ROHSE, M., DAY, R., FYFE, H. (2017): Evolving energy landscapes in the South Wales Valleys: Exploring community perception and participation. Energy Policy, 108: 818–828.

LOTHIAN, A. (2008): Scenic perceptions of the visual effects of wind farms on South Australian landscapes. Geographical Research, 46(2): 196–207.

LYNCH, K. (1960): The image of the city. Cambridge, MIT Press.

MAEHR, A. M., WATTS, G. R., HANRATTY, J., TALMI, D. (2015): Emotional response to images of wind turbines: A psychophysiological study of their visual impact on the landscape. Landscape and Urban Planning, 142: 71–79.

MASSEY, D. (2004): Geographies of responsibilities. Geografiska Annaler, Series B, Human Geography, 86(1): 5–18.

MINISTRY FOR THE ENVIRONMENT AND NATURAL RESOURCES (1999): The Nature Conservation Act no. 44/1999. Article 3: Definitions.

MOLNÁROVÁ, K., SKLENIČKA, P., STIBOREK, J., SVOBODOVÁ, K., ŠÁLEK, M., BRABEC, E. (2012): Visual preferences for wind turbines: Location, numbers and respondent characteristics. Applied Energy, 92: 269–278.

NATORI, Y., CHENOWETH, R. (2008): Differences in rural landscape perceptions and preferences between farmers and naturalists. Journal of Environmental Psychology, 28(3): 250–267.

NOVÁKOVÁ, E., FRANTÁL, B. (2009): Application of visualisation methods in spatial planning: a case of wind power installations. Geodetický a kartografický obzor, 55/97(5): 111–113.

ÓLAFSDÓTTIR, R., RUNNSTRÖM, M. C. (2011): How wild is Iceland? Wilderness quality with respect to nature-based tourism. Tourism Geographies, 13(2): 280–298.

ÓLAFSDÓTTIR, R., GUÐJÓNSDÓTTIR, G. L., SÆÞÓRSDÓTTIR, A. D., STEFÁNSSON, P. (2015): Áhrif vindmylla í Búrfellslundi á ferða þjónustu og íbúa [online]. Available at: http://gogn.lv.is/files/2015/2015-072.pdf

ORKUSTOFNUN [National Energy Authority] (2016): Energy Statistics in Iceland 2015 [online]. Available at: http://os.is/gogn/os-onnur-rit/Orkutolur_2015-enska-utfaersla2.pdf

ORKUSTOFNUN [National Energy Authority] (2017): Orkustofnun Data Repository OS-2017-T015-01 [online]. Available at: http://os.is/gogn/Talnaefni/OS-2017-T015-01.pdf

OSGOOD, C. E., SUCI, G., TANNENBAUM, P. (1957): The measurement of meaning. Urbana, IL: University of Illinois Press.

PALMER, J. F., VANDERHEYDEN, V., ALVES, G., SISMANI, G. (2017): Best Focal Length to Represent a Landscape View Using a Single-Frame Photograph. Journal of Digital Landscape Architecture, (2–2017): 236–243.

PASQUALETTI, M. J. (2011): Social barriers to renewable energy landscapes. Geographical Review, 101(2): 201–223.

PEDERSEN, E., LARSMAN, P (2008): The impact of visual factors on noise annoyance among people living in the vicinity of wind turbines. Journal of Environmental Psychology, 28(4): 379–389.

RAGNARSSON, B. F., ODDSSON, G. V., UNNTHORSSON, R., HRAFNKELSSON, B. (2015): Levelized cost of energy analysis of a wind power generation system at Burfell in Iceland. Energies, 8(9): 9464–9485.

RAMMAÁÆTLUN (2017): The Master Plan for Nature Protection and Energy Utilization. [online]. Available at: http://www.ramma.is/english

RAYMOND, C. M., BROWN, G., WEBER, D. (2010): The measurement of place attachment: personal, community, and environmental connections. Journal of Environmental Psychology 30 (4): 422–434.

RIBE, R. G., MANYOKY, M., WISSEN HAYEK, U., PIEREN, R., HEUTSCHI, K., GRĘT-REGAMEY, A. (2018): Dissecting perceptions of wind energy projects: A laboratory experiment using high-quality audio-visual simulations to analyze experiential versus acceptability ratings and information effects. Landscape and Urban Planning, 169: 131–147.

SKIPULAGSSTOFNUN [National Planning Agency] (2016): Landsskipulagsstefna 2016–2026 [National Planning Strategy 2016–2026] [online]. Available at: http://www.landsskipulag.is/media/pdf-skjol/Landsskipulagsstefna_2015-2026_asamt_greinargerd.pdf

SÆÞÓRSDÓTTIR, A. D. (2010): Tourism struggling as the Icelandic wilderness is developed. Scandinavian Journal of Hospitality and Tourism, 10(3): 334–357.

SÆÞÓRSDÓTTIR, A. D. (2012): Tourism and power plant development: An attempt to solve land use conflicts. Tourism Planning & Development, 9(4): 339–353.

SÆÞÓRSDÓTTIR, A. D., ÓLAFSSON, R. (2010a): Nature tourism assessment in the Icelandic Master Plan for geothermal and hydropower development. Part I: rapid evaluation of nature tourism resources. Journal of Heritage Tourism, 5(4): 311–331.

SÆÞÓRSDÓTTIR, A. D., ÓLAFSSON, R. (2010b): Nature tourism assessment in the Icelandic Master Plan for geothermal and hydropower development. Part II: assessing the impact of proposed power plants on tourism and recreation. Journal of Heritage Tourism, 5(4): 333–349.

SÆÞÓRSDÓTTIR, A. D., SAARINEN, J. (2016): Changing ideas about natural resources: tourists' perspectives on the wilderness and power production in Iceland. Scandinavian Journal of Hospitality and Tourism, 16(4): 404–421.

SCOTT, A., CARTER, C., BROWN, K., WHITE, V. (2009). 'Seeing is Not Everything': Exploring the Landscape Experiences of Different Publics. Landscape Research, 34(4): 397–424.

SIBILLE, A. D. C. T., CLOQUELL-BALLESTER, V. A., CLOQUELL-BALLESTER, V. A., DARTON, R. (2009): Development and validation of a multicriteria indicator for the assessment of objective aesthetic impact of wind farms. Renewable and Sustainable Energy Reviews, 13(1): 40–66.

STEFÁNSSON, Þ., SÆÞÓRSDÓTTIR, A. D., HALL, C. M. (2017): When tourists meet transmission lines: The effects of electric transmission lines on tourism in Iceland. Energy Research & Social Science, 34: 82–92.

SVOBODOVÁ, K., SKLENIČKA, P., MOLNÁROVÁ, 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.

TRESS, B., TRESS, G. (2001): Capitalising on multiplicity: a transdisciplinary systems approach to landscape research. Landscape and urban planning, 57(3): 143–157.

UEDA, H., NAKAJIMA, T., TAKAYAMA, N., PETROVA, E., MATSUSHIMA, H., FURUYA, K., AOKI, Y. (2012): Landscape image sketches of forests in Japan and Russia. Forest Policy and Economics, 19: 20–30.

UUSITALO, M. (2010): Differences in tourists' and local residents' perceptions of tourism landscapes: A case study from Ylläs, Finnish Lapland. Scandinavian Journal of Hospitality and Tourism, 10(3): 310–333.

VAN DER HORST, D. (2007): NIMBY or not? Exploring the relevance of location and the politics of voiced opinions in renewable energy siting controversies. Energy Policy, 35(5): 2705–2714.

VAN VEELEN, B., HAGGETT, C. (2016): Uncommon Ground: The role of different place attachments in explaining community renewable energy projects. Sociologia Ruralis (online first), DOI: 10.1111/soru.12128.

VECCHIATO, D. (2014): How do you like wind farms? Understanding people's preferences about new energy landscapes with choice experiments. Aestimum, 64: 15–37.

VOREL, I. (2009): Větrné elektrárny a charakter, ráz a identita kulturní krajiny. Paper presented at the Workshop Větrné elektrárny a životní prostředí, 10.3.2009, Jindřichův Hradec.

VORKINN, M., RIESE, H. (2001): Environmental Concern in a Local Context: The Significance of Place Attachment. Environment and Behavior, 33(2): 249–263.

WAAGE, E. R. H., JÓHANNESDÓTTIR, G. R. (2017): Whose values? Different perspectives and relations to energy landscapes. Paper presented at the 7th Nordic Geographers Meeting, June 18–21, 2017, Stockholm, Sweden.

WALKER, G. (2011): The role for 'community' in carbon governance. Wiley Interdisciplinary Reviews: Climate Change, 2(5): 777–782.

WHYTE, A. (1977): Guidelines for field studies in environmental perception. (MAB Technical Notes 5). Paris, UNESCO.

WOLSINK, M. (2007): Planning of renewables schemes: Deliberative and fair decision-making on landscape issues instead of reproachful accusations of non-cooperation. Energy Policy, 35(5): 2692–2704.

ZUBE, E. H., PITT, D. G. (1981): Cross-cultural perceptions of scenic and heritage landscapes. Landscape planning, 8(1): 69–87.

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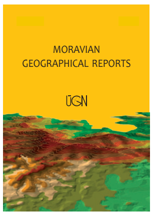

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Wind farms and rural tourism: A Portuguese case study of residents' and visitors' perceptions and attitudes

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Abstract

Residents' and visitors' perceptions of and attitudes towards existing wind farms, as well as the perceived impact of wind farms on tourism, are examined in this article with reference to a built heritage site in the Portuguese countryside. Based on a set of semi-structured interviews, the paper sheds light on the positive impact that the community's or local actors' involvement in the constitution, management and decision-making processes has on the residents' perceptions and attitudes regarding wind farms, and also on the trade-off with the perceived effect of wind farms on local tourism. Moreover, it shows that although most visitors criticised the proximity of wind turbines to medieval architecture, a clear majority of them accepted their presence and virtually all of them stated that these facilities had no impact on their choice of destination.

Keywords: *wind farms; built heritage sites; rural tourism; residents' perceptions; visitors' perceptions; Portugal*

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1. Introduction

In recent decades, we have witnessed a remarkable growth in the generation of electricity through wind power in Europe and other parts of the world (e.g. International Energy Agency, 2015). The growth of wind energy is both part and reflex of the contemporary "energy transition", a technological transition that has impacts on all spheres of life (Smil, 2010), some of which potentially carrying negative dimensions. The issue is that whilst wind energy is considered a sustainable form of electricity generation, the technologies used for its production have potentially negative local impacts, including those on tourism, as demonstrated below.

This article presents a Portuguese case study of the residents' and visitors' perceptions and attitudes towards wind farms, and of the perceived impact of wind farms on tourism, at a rural destination. The article will be developed as follows.

After introducing the state of the art, the article describes the study methods and the context under scrutiny, respectively. The subsequent section presents the empirical evidence, starting with the residents. Then, the article discusses the research results. The main conclusions are put forward in the final section.

2. State of the art

Various scholars (e.g. Barry, Ellis and Robinson, 2008; Bell, Gray and Haggett, 2005; Haggett and Futák-Campbel, 2011) have identified a gap between the widespread support of the production of wind energy and local objections to the siting of wind turbines. Although local objection was at first ascribed to the Not In My Backyard (NIMBY) syndrome (e.g. Wolsink, 1989), that concept has been questioned by several authors (e.g. Bell, Gray and Haggett, 2005; Devine-Wright, 2009; van der Horst, 2007; Wolsink, 2006). Some other scholars (e.g. Pasqualetti, 2004; Sowers, 2006; Warren et al., 2005) even identified the opposite of NIMBY, Please In My Backyard (PIMBY), which emerges when the wind turbines are regarded as a source of revenue.

Despite the existence of other potentially negative local impacts such as noise and birds/bats mortality (e.g. Groothuis, Groothuis and Whitehead, 2008; Pasqualetti, 2011; Warren et al., 2005), tourism is a recurring motivation in the campaigns against wind energy facility siting.

There is concern that the wind farms may adversely affect local tourism, by visually polluting the most valuable tourist resources or products and their settings, above all the landscape (e.g. Brittan Jr., 2001; Devine-Wright and Howes, 2010; Frantál, Pasqualetti and van der Horst, 2014;

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Warren and McFadyen, 2010), but also heritage items or sites (e.g. Clarke, 2009; Jerpåsen and Larsen, 2011), including some in Portugal (e.g. Afonso and Mendes, 2010; 2012; Delicado et al., 2013; 2014).

This is particularly so in the countryside, notably in those areas where tourism has been growing in recent decades, both in terms of demand and of supply, due to the rise of a lifestyle-led and leisure-oriented society, and the widespread mobilisation of tourism as a strategy for rural development and regeneration (Walmsley, 2003). In other words, the "wind turbines – tourism" conflict is particularly pronounced in areas where the productive functions of the countryside come into conflict with the consumptive functions. As Woods (2003, p. 312) mentions, "in the new rural economy, the commodification of rural space, culture and lifestyle is more important than the physical exploitation of rural land". Hence, landscape and heritage items or sites, including historic buildings and vernacular architecture, are now part of "countryside capital", a wide range of rural resources or products that are bought and sold through tourism (Garrod, Wornell and Youell, 2006).

Moreover, although the tourist consumption of rural assets is a multisensory experience (e.g. Daugstad, 2008; Frisvoll, Forbord and Blekesaune, 2016; Woods, 2011, pp. 110–119), the visual dimension is usually considered the most important (e.g. Abram, 2003; Urry, 1992; Woods, 2011, p. 101). Hence, visual change and its potentially negative effects on local tourism are stressed strongly in the campaigns against wind energy development in rural areas.

The relative impact of existing wind turbines on landscape images has been examined by various authors. Research has shown that the fit of wind turbines in the landscape varies significantly according to a number of factors, mainly the type and aesthetic quality of the landscape at stake: potential negative impacts on the images of landscapes are lower in unattractive, industrial or modern agriculture landscapes (e.g. Lothian, 2008; Molnarova et al., 2012; Wolsink, 2006); but also the size of wind farms is a factor, as small-scale development tends to be more positively viewed than large-scale development (e.g. Devine-Wright, 2005; Molnarova et al., 2012; Thayer and Freeman, 1987; Wolsink, 1989). Residents and tourists are also believed to have different viewpoints (Devlin, 2002; Frantál and Kunc, 2011), although findings from Scotland suggest the contrary (Warren and McFadyen, 2010).

The relationships between wind farms and rural tourism have also had considerable scrutiny in the scholarly literature. Research on this topic shows conflicting results: some studies show that wind farms may have a negative effect on tourism demand and tourism expenditures in the affected area (Broekel and Alfken, 2015; Riddington et al., 2010), whereas others demonstrate that they are innocuous in terms of local tourism demand, expenditures and experiences (Aitchison, 2012; Frantál and Kunc, 2011; Sousa and Kastenholz, 2015; Warren and McFadyen, 2010), and can even function as tourist attractions per se in some rural areas (Aitchison, 2012; Frantál and Kunc, 2011; Pasqualetti, 2004).

Most of these studies are specifically concerned with general rural tourism destinations, but the case of heritage items or sites remains largely unexplored. Besides, most of the studies deal with the actual or potential impact of wind energy projects on tourism. Less attention has been devoted to the perceived impact.

Our contribution addresses those gaps. The purpose of this article is twofold. On the one hand, it aims to empirically assess the impact of the community's or local actors' ownership/involvement on the residents' perceptions and attitudes towards wind farms, and the trade-off with the perceived impact of wind farms on tourism. On the other hand, it aims to scrutinise the visitors' perceptions and attitudes regarding wind farms and their effect on destination choice. The primary research question is: Do wind farms adversely affect the attractiveness of heritage-based rural tourism destinations? The study is centred on a Portuguese case.

Portugal has had a very significant investment in the production of wind energy in recent years. The number of wind farms increased from a residual number (8) in 1999 to more than 250 in 2015, while the capacity of wind energy increased from 18 MW to 5,034 MW (Direção Geral de Energia e Geologia, 2012; 2016). All but one of the wind farms are located onshore, mostly in rural areas, as is often the case in Europe and elsewhere in the world (e.g. Frolova, Prados and Nadai, 2015; Munday, Bristow and Cowell, 2011; Pasqualetti, Gipe and Righter, 2002). Unlike other countries (e.g. Toke, 2005; Toke, Breukers and Wolsink, 2008; Munday, Bristol and Cowell, 2011), in Portugal, there are no community-owned wind farms and just five companies hold 76% of the market share. This is because, in the 2000s, the national government opted for a bulk sale of wind energy licences, which favoured concentration over small-scale generation.

In terms of public opinion, according to Eurobarometer data, 70% of Portuguese are in favour of the use of wind energy, in line with the European average (71%) (European Commission, 2007). With respect to agreement with the European Union 2020 targets – to increase the share of renewable energy to 20% (European Commission, 2010), in 2012, just 13% of Portuguese respondents considered them to be too modest, slightly below the European average (17%) (European Commission, 2012).

Although planning permission for wind farms (above a certain size) is subject to environmental impact assessment (EIA) under strict European rules, in contrast to other countries (e.g. Aitken, 2009; Bell, Gray and Haggett, 2005; Devine-Wright, 2005; van der Horst and Toke, 2010; Wolsink, 2007), in Portugal, a clear majority (71%) of wind farm projects that undergo EIA have been approved (Delicado et al., 2014). Direct benefits for the municipal authorities (2.5% of the annual revenue of wind energy facilities) and centralised planning practices have led to low levels of controversy and a high rate of project approval (Delicado, Figueiredo and Silva, 2016). Often public consultation procedures, in most cases deeply flawed in terms of dissemination to potential stakeholders (e.g. Gonçalves, 2002; Lima, 2004), have no participation from civil society (citizens, local business people, environmental non-governmental organisations) and when they do, opinions tend to be divided, some in favour, others against the projects (Delicado et al., 2014).

3. Study methods

This report is part of a broader investigation on rural tourism developed by the lead author in Sortelha (e.g. Silva, 2009; 2014). The case study is grounded on a set of semi-structured interviews conducted in 2012 (one week), 2013 (one week) and 2016 (three weeks), during which the lead author worked and stayed in the village, gradually expanding the network of acquaintances and respondents. Over time, we interviewed 21 residents and 68 visitors. In both cases, the interviews were structured on the respondents' perceptions and attitudes towards wind energy in Portugal and Sortelha, addressing the following topics: wind energy generation and utilisation; utility owned wind farms in the village; concerns; landscape change; wind farms and tourism destination choice; the local opposition movement; and involvement in the wind energy projects.

The interviews with residents were conducted in 2012 and 2016, both with men and women, eight of whom were linked to the tourism sector. In 2012, the work was focused on tourism entrepreneurs while, in 2016, along with the same tourism entrepreneurs, who expressed similar attitudes and opinions in both phases of study, the research was broadened to encompass other residents. The interviews with visitors were conducted in 2013 (40) and 2016 (28). Visitors were selected for interviewing following nationality and basic demographic characteristics. The aim was to include respondents from the two most important visitors' country of origin (in proportion), a balanced gender representation and across the age spectrum.

Table 1 presents the interviewees' profile, both residents and visitors. The visitors interviewed represent the Portuguese and the Spanish markets – who accounted for 78% and 9%, respectively, of the 437,270 visitors registered by the local tourist office between 2007 and 2015[1], mainly urban or periurban dwellers with high education levels, and mostly aged between 31 and 45 years. Residents have low levels of education and are mostly over 46 years old. About half of the interviews with residents and a third of the interviews with visitors were recorded, transcribed and subject to a content analysis, while notes were taken on the remaining ones.

4. Geographical context and background

Sortelha is a village located in a mountainous area, with stone outcrops of granite, in the municipality of Sabugal, some 30 km from the city of Guarda in central eastern Portugal, close to the border with Spain (see Fig. 1). Sortelha includes two separate places: the walled village, a designated built heritage site, and the outskirts of the village, where the great majority of its about 150 permanent residents live[2]. Sortelha has socio-economic features characteristic of many other places in rural Portugal: an ageing population (47% of people are over 65 years old) with low income and low levels of formal education and training (the illiteracy rate is 17%).

The main sources of income for local families are employment in public or municipal administration, small-scale retail, money transfers from pension and retirement payments, and tourism, complemented by a small-scale agriculture for family consumption. Today, tourism occupies 12% of residents – who work in tourist accommodations (8 units, providing a total of 19 bedrooms), restaurants (2), cafés/snack-bars (4), the tourist office, handicrafts, or home-made food products, but also relies on the built heritage site and its rural setting/landscape.

Ideas of historical conservation emerged here in 1910, when the castle was awarded official protection status as a "national monument". Subsequently, in 1933, the pillory was designated a "building of public interest"[3]. Later, in 1996, historical conservation was extended to the whole citadel and the urban fabric became subject to the strict requirements of historical conservation in terms of architecture and building materials. Quickly, the site was restored and rendered "historical" (Silva, 2014)[4], but also discursively associated with the Middle Ages (Silva and Leal, 2015). These were outcomes of the village's integration into the Recovery

	Visitors	Residents
Number of interviewees	68	21
Nationality	53 Portuguese; 15 Spaniards	Portuguese
Gender	36 females; 32 males	10 males; 11 females
Age	16–30 years: 8;	16–30 years: 3;
	31–45 years: 31;	31–45 years: 7;
	46–60 years: 20;	46–60 years: 6;
	≥ 61 years: 9	≥ 61 years: 5
Place of origin	Urban/periurban: 63; Rural: 5	Urban/periurban: 2; Rural: 19
Education level	≤ high school: 13; high school: 55	≤ high school: 19; high school: 2
Number of visits	1st visit: 58; 2nd visit: 4; 3rd visit or more: 6	

Tab. 1: The profile of the interviewees
Source: authors´survey

[1] Whilst the tourist office in Sortelha was created in 2003, the information produced by it until 2007 is unreliable because it did not operate on a daily basis, and its previous location was less visible than its current position at the entrance to the walled village.

[2] The site consists of about 100 stone buildings, most of which are representative of vernacular architecture; with narrow streets, a few cafés and tourism accommodation establishments; a restaurant and a church; as well as pillory and a castle. The built fabric is embraced by well-preserved fortress walls.

[3] An artefact is considered of "public interest" when its protection and enhancement represents a cultural value of national importance, but for which the system of protection for "national monuments" is considered disproportionate.

[4] That was accomplished through the preservation of monuments; the restoration of facades and roofs of buildings; the removal of elements considered "modern" from the facades and roofs of buildings (e.g. television antennas and gutter pipes); the placement of wooden doors and windows in the facades; the uncovering of the stonework of buildings; and the replacement of television antennas and aerial electrical power lines by underground communication and electrical cables (Silva, 2014, p. 621).

Fig. 1: Location of the case study area

Programme for the Historic Villages of Portugal (1995–2006), a state-led programme aiming to renovate the historic buildings and the built environment and to generate tourism revenue for the populations of 12 villages in the eastern side of the Central region of the country.

In 2010–2011, Sortelha witnessed the construction of two wind farms close to the village, the wind farm of São Cornélio (39.1 MW) and the wind farm of Troviscal (18.4 MW). Situated about two kilometres from the citadel of Sortelha, the wind farm of São Cornélio (with 17 wind turbines, 85 metres height) was licensed with a favourable conditional EIA, which required only the monitoring plans for noise and mortality of birds and bats, and small restrictions on the construction (see Fig. 2). There was no landscape or visual impact assessment, even though, according to the Portuguese law of cultural heritage, it is illegal to change

Fig. 2: The wind farm of São Cornélio viewed from the citadel of Sortelha. Photo: L. Silva

Fig. 3: The castle of Sortelha and the wind farm of Troviscal. Photo: L. Silva

the landscaping of built heritage or to significantly disturb its understanding and appreciation (Article 52°, Law No. 107/2001, September 8th 2001). Despite its greater proximity to the citadel of Sortelha (800 metres), the wind farm of Troviscal (with 8 wind turbines, also 85 metres height) was not even subject to an EIA, because it is located outside of the National Ecological Reserve and has less than 10 turbines (see Fig. 3).

Both projects were approved by the Portuguese Institute for the Management of Architectonic and Archaeological Heritage, the Commission for the Development and Coordination of the Central Region, and the Ministry of Economy, on the grounds that wind energy would contribute to balance the national energy trade while abiding by legislation on the protection of built heritage in Portugal, particularly in what concerns the metric distance from the protected artefact (50 metres). The Municipal Government of Sabugal took the same stance, considering the aforementioned factors but also, and above all, the subsequent direct economic benefits for the municipality, then estimated in between 750,000 and 1,000,000 Euros per year (Assembleia Municipal do Sabugal, 2010). These figures include the wider project of which these two wind farms are part, namely, the wind farm of Raia, made up of 50 wind turbines (128.8 MW), all in the municipality of Sabugal. The wind farm of Raia was funded and owned by the company ENEOP2 – Eólicas de Portugal, S.A. until 2015, when the company was split and its assets were allocated to shareholders, in this case the companies Finerge – Gestão de Projectos Energéticos, S.A. and TP – Sociedade Térmica Portuguesa, S.A. But it was constructed and it is managed by the company Eólica do Campanário, created by the first owners and a local partner in the late 2000s.

There was a mandatory public consultation period, held in June 2009, in Sabugal, but this had very scarce participation, as is often the case in Portugal, as noted above. As mentioned in the EIA decision, the project received only two written statements, from the parish council of Sortelha and from a neighbouring parish (Águas Belas), "expressing its full support to the project"[5]. This, despite the existence of an opposition movement, led by the so-called "Let's Save Sortelha [of the wind turbines]" movement, founded in 2010 by a recently arrived resident and a local artisan, both engaged in tourism activities. Through actions on the ground, such as putting up posters in the village and collecting signatures, and in electronic platforms, such as creating a blog (see http://vamossalvarsortelha.blogspot.pt/) and an on-line public petition, the movement sought to prevent the siting of wind turbines in Sortelha, considering them threats to the "historic heritage" and attractiveness of Sortelha (see http://www.petitiononline.com/Sortelha/petition.html). That movement gathered support from outside the village, the municipality and even the country – for example, the on-line petition reached 1,251 signatures, but it mobilised only a few residents (the petition was signed by only half a dozen Sortelha inhabitants).

5. Study results

5.1 The viewpoint of residents

All residents interviewed were supportive of wind energy generation and utilisation in Portugal. The idea that this is a necessity of our time because we need to find sources of energy alternative to fossil fuels, is a recurring refrain in the residents' discourses. They did, however, show conflicting perceptions and attitudes about the siting of the currently existing wind energy facilities in Sortelha. Most of them (14 of 21) declared themselves against it, though only a few (3) have joined the aforementioned opposition movement. Many of the others, when asked why they did not join the opposition movement, stated that it was due to the "lack of credibility" of its founders, including "an outsider", but also for "fearing reprisals" from the people involved in the wind energy business, notably the local promoter and his family. The reasons given for opposition include the environmental justice issue of "fairness of process", distributive justice regarding the allocation of economic benefits, and visual impact. In terms of process, residents complained that the public consultation process was hidden from them. As a resident in his 40s put it: "the public consultation process was carried out in secret; the wind farm of São Cornélio was already under construction when we realised what was going to happen".

Residents also criticised the uneven distribution of direct economic profits resulting from the generation of wind energy, of which the owners of the wind farms and the local partner of the company Eólica do Campanário, along with the municipality of Sabugal and the land owners, are considered the main beneficiaries. An additional catalyst for discord is the upward economic mobility of the local promoter by means considered illegitimate, because, as head of the parish council of Sortelha, he issued a favourable opinion in the public consultation process while being also an interested party in the matter.

Plus, and above all, there is concern with the impact of landscape change as determined by the perceived match or mismatch between the landscape on site and the wind turbines (in the eyes of the beholder) and its impact on tourism. Opponents criticise the installation of wind turbines close to a Historic Village, not because of any potential or actual threat to the physical preservation of heritage, which they consider non-existent, but for other reasons, namely, the anachronism resulting from the visual intrusion of modern technologies, made up of modern materials such as steel and concrete, in a historic environment, built in traditional materials such as stone and wood, and the subsequent negative effects on local tourism. This, for example, is the case with the local co-founder of the "Let's Save Sortelha [of the wind turbines]" movement, according to whom

> "we cannot spoil the best we have and what differentiates us from others, so we can really be players in international tourism. In Sortelha, the wind turbines are an offence to the landscape, […] because these eyesores are out of place. [...] This is a village with medieval characteristics, where there is a kind of return to the past, and, suddenly, anywhere I look, I see these eyesores intruding into the fortress walls".

In addition, according to these residents, in contrast to their initial expectations and fears, the wind turbines do not exert a negative outcome on tourism demand, including on return visits. "Tourists continue to come to Sortelha" is a common refrain in their discourses. However, residents have complained that the wind turbines have a detrimental impact on the tourist experience, because of the contrast between the modern wind turbines and the medieval architecture. For example, a civil servant in his 40s stated that,

[5] All translations by the authors

> "in terms of tourism, the wind turbines are an attack; those on the mount of São Cornélio no, but these ones closer to the walled village are an attack. When people walk around the castle and the fortress walls, people see a historic site with high antennas made up of steel with three blades on the top. One in every two tourists complain about that contradiction".

The words of this resident also indicate a good reason to note that – and this one of the few points in which the opinions of opponents have changed over time – critics are now centred on the wind farm of Troviscal, especially on the wind turbines that are located closer to the citadel, where the contrast between the natural/traditional and the modern/industrial elements is more pronounced. Meanwhile, the mount of São Cornélio, which triggered objection, is now considered suitable for the siting of wind turbines because of its relatively greater distance from the built heritage site.

In contrast, a third of the residents interviewed expressed support for the existence of wind farms in Sortelha, with no concerns about it. What is significant is that they all are involved in the wind farms, either directly, as occurs with the local promoter and the owners of the rented land (3), or indirectly, as happens with their relatives (3). The reasons specified for support include the location of the wind turbines outside the citadel and the perceived neutral impact on heritage, the landscape on site and tourism, but also the economic benefits. This group includes some tourism entrepreneurs and tourism workers. In fact, what caused surprise and indignation and still is an object of condemnation amongst many residents, regardless of their occupation, is that the local promoter of wind energy development is himself a tourism entrepreneur who runs, along with his two sons and their wives, three tourist accommodation establishments and a café/snack-bar inside the walled village. Another example can be seen in the words of a tourism worker: "I have one of them [the wind turbines] installed on my land, which provides me about 2,000 Euros per year, and I wish I had more". Another tourism entrepreneur, who opposed wind farm development in the village and signed the petition, similarly commented: "If I owned any land, I would also allow the installation of a wind turbine there to receive the 2,000 Euros of rent per year".

5.2 The viewpoint of visitors

The responses of the Portuguese and Spanish visitors who were interviewed are analysed here as a single group due to their similarity. Virtually all respondents reported having seen the wind farms during their visit to the village, considered them noticeable or quite noticeable and believed that they do not constitute a threat to the physical preservation of the heritage site. But most of them (42 of 68) mentioned concerns with the visual impact, particularly the perceived incongruity between the landscape on site and the wind turbines. In the words of two respondents:

> "The wind turbines are out of place. Here [in the citadel] we have the ancient: granite, stone architecture, typical houses, small stone houses and the castle. The wind turbines in front are modern things" (Portuguese man, 53 years of age);

> "This is [bad]. The wind turbines spoil the aesthetics of the village. This is a medieval village and modern things such as the wind turbines don't fit here" (Spanish man, 44 years of age).

In comparison, these negative perceptions of the presence of wind turbines at the destination were counterbalanced by the positive view of wind energy as a "clean", "environmentally friendly" electricity. Indeed, almost all visitors declared themselves in favour of wind energy generation and utilisation in Portugal, and most of them (43 of 68) accepted the presence of wind turbines in Sortelha. In the words of a visitor in his 30s: "I think that the modern and the ancient co-exist peacefully here. See, what is typical is inside the fortress walls and what is modern is outside". Another interviewee similarly commented: "this [the site] is what interests me: the rustic environment, the stone architecture, the stone houses and the castle, the absence of modern elements […]. I don't care about the wind turbines; they are outside of the fortress walls".

Moreover, a clear majority of the visitors, including most of the returnees, stated that they were unaware of the presence of wind farms before arriving in the village. In addition, almost all of them believed that wind turbines do not interfere with their choice of destination, either positively (attraction effect) or negatively (avoidance effect). See, for example, the following statements:

> "It's possible that they [the wind turbines] destroy the landscape to some people, but not to me. I want to return to Sortelha and I will recommend it, because it's a very beautiful place" (Portuguese woman, 27 years of age);

> "Who has never seen and has never been near a wind turbine, when approaching, one feels the impact of the size. But this is not enough for a person to make a tourism journey" (Portuguese man, 35 years of age).

6. Discussion and conclusions

The study shows that the residents' perceptions and attitudes towards the currently existing wind farms in Sortelha, and their readings of the impact of these wind farms on tourism, diverge, despite the existence of a widespread opinion that they have no impact on local heritage preservation. Most residents showed opposition to wind energy facility siting in the village, criticised the perceived contrast between the landscape on site and the wind turbines, and have a negative view of their impact on the tourism experience. Economic benefits derived from wind energy generation seem to exert far more influence on the attitudes of residents, and its distribution plays a significant role in explaining acceptance and opposition. Exclusion from decision-making, however, also tends to generate negative feelings towards wind farms.

The most significant study finding therefore is that the involvement of the local actors in the establishment, management and decision-making processes generates a positive effect on the residents' perceptions and attitudes towards wind farms, including the perceived impact of wind turbines on tourism. This research finding is consistent with the findings of studies conducted in other countries, where the community's or local actors' ownership increases both local support and the levels of planning acceptance of wind farms, being also more equitable (e.g. Breukers and Wolsink, 2007; Toke, 2005; Toke, Breukers and Wolsink, 2008; Walker and Devine-Wright, 2008; Warren and McFadyen, 2010).

Visitor attitudes are also marked by divergence. Most visitors are appalled by the proximity of wind turbines to medieval buildings, but the majority declared themselves in favour of wind energy generation in both Portugal and

Sortelha. Plus, virtually all visitors stated that wind farms have no impact on their choice of destination. The case of Sortelha thus parallels the findings of other studies in Portugal and in other parts of Europe, where there is no empirical evidence to support the assumption that wind farms are likely to cause negative impacts on tourists' destinations choice (e.g. Aitchison, 2012; Frantál and Kunc, 2011; Sousa and Kastenholz, 2015; Warren and McFadyen, 2010).

Our results, however, do run contrary to the results of other case studies carried out in the country (Delicado et al., 2015), and elsewhere in the world (e.g. Aitchison, 2012; Frantál and Kunc, 2011; Pasqualetti, 2004), where wind farms work as tourist attractions, or, in other words, where there is "energy tourism" (Frantál and Urbánková, 2017). This can be attributed to the specific characteristics of locations. In areas where there is little in terms of cultural or natural heritage or where the landscape is already perceived as "industrialised", wind turbines can be seen as symbols of progress, modernity and green credentials (Cowell, 2010; Firestone, Bates and Knapp, 2015; Selman, 2010; van der Horst, 2007; Warren et al., 2005).

This study has provided empirical evidence from Portugal that wind farms do not make heritage-based rural tourism destinations less attractive. Visitors' perceptions may be considered partly critical, but they have no consequence for the final assessment not to visit the village of Sortelha because of the wind farms. In comparison, the residents' attitudes vary according to the perceived benefits and involvement in the decision-making processes for these wind farms, which are owned by investors from outside the village, large companies, and which were built within an institutional setting favouring investments by community outsiders. It just so happens that the regulation framing large-scale, utility-owned wind farms, seems to impede participation processes: it results in mere consultation – non-participation according to Arnstein (1969) – which in these processes tend to be perceived as "secretive", as in the case under examination.

The implication is strong that decisions on the siting of these facilities ought to be based on more participatory processes. Mostly secretive public consultations may help in maintaining planning approval rates at high levels, but do little to generate acceptance in the communities. When local actors state that they only became aware of the wind farms once they had started to be built, this is a hallmark of very feeble public discussion and engagement. Alternative locations or impact mitigation measures that could have come out of that discussion are thus rendered impossible. A change in the regulation framing of wind farms in the country could therefore promote co-operation or any other kind of civil society participation in initiating and investing in wind energy generation and hence increase the acceptability of wind farms in local communities.

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References:

ABRAM, S. (2003): The rural gaze. In: Cloke, P. [ed.]: Country Visions (pp. 31–48). Harlow, Pearson Education Limited.

AFONSO, A., MENDES, C. (2010): Energía eólica y paisajes protegidos: Controversias en el parque natural de montesinho. Nimbus, 25–26: 5–19.

AFONSO, A., MENDES, C. (2012): Wind power in the Portuguese landscape: Global concerns and local costs. In: Welz, G., Sperling, F., Blum, E. [eds.]: Negotiating Environmental Conflicts. Local Communities, Global Policies (pp. 127–142). Frankfurt, Goethe-University.

AITCHISON, C. (2012): Tourism Impacts of Wind Farms. Edinburgh, University of Edinburgh.

AITKEN, M. (2009): Wind power planning controversies and the construction of "expert" and "lay" knowledges. Science as Culture, 18(1): 47–64.

ARNSTEIN, S. (1969): A ladder of citizen participation. Journal of the American Institute of Planners, 35(4): 216–224.

ASSEMBLEIA MUNICIPAL DO SABUGAL (2010): Acta No. 2, Sessão ordinária realizada no dia 30 de abril. Sabugal, Assembleia Municipal do Sabugal.

BARRY, J., ELLIS, G., ROBINSON, C. (2008): Cool rationalities and hot air: A rhetorical approach to understanding debates on renewable energy. Global Environmental Politics, 8(2): 67–98.

BELL, D., GRAY, T., HAGGETT, C. (2005): The "social gap" in wind farm siting decisions: Explanations and policy responses. Environmental Politics, 14(4): 460–477.

BREUKERS, S., WOLSINK, M. (2007): Wind power implementation in changing institutional landscapes: An international comparison. Energy Policy, 35(5): 2737–2750.

BRITTAN JR., G. (2001): Wind, energy, landscape: Reconciling nature and technology. Philosophy and Geography, 4(2): 169–184.

BROEKEL, T., ALFKEN, C. (2015): Gone with the wind? The impact of wind turbines on tourism demand. Energy Policy, 86: 506–519.

CLARKE, S. (2009): Balancing environmental and cultural impact against the strategic need for wind power. International Journal of Heritage Studies, 15(2–3): 175–191.

COWELL, R. (2010): Wind power, landscape and strategic, spatial planning – The construction of 'acceptable locations' in Wales. Land Use Policy, 27(2): 222–232.

DAUGSTAD, K. (2008): Negotiating landscape in rural tourism. Annals of Tourism Research, 35(2): 402–426.

DELICADO, A., FIGUEIREDO, E., SILVA, L. (2016): Community perceptions of renewable energies in Portugal: Impacts on environment, landscape and local development. Energy Research & Social Science, 13: 84–93.

DELICADO, A., JUNQUEIRA, L., FONSECA, S., TRUNINGER, M., SILVA, L., HORTA, A., FIGUEIREDO, E. (2014): Not in anyone's backyard? Civil society attitudes towards wind power at the national and local level. Science & Technology Studies, 27(2): 49–71.

DELICADO, A., SILVA, L., JUNQUEIRA, L., HORTA, A., FONSECA, S., TRUNINGER, M. (2013): Ambiente, paisagem, património e economia: Os conflitos em torno de parques eólicos em Portugal. Revista Crítica de Cięncias Sociais, 100: 11–36.

DELICADO, A., TRUNINGER, M., FIGUEIREDO, E., SILVA, L., JUNQUEIRA, J., HORTA, A., FONSECA, S., NUNES, M. J., SOARES, F. (2015): Terras de Sol e de Vento. Dinâmicas Sociotécnicas e Aceitação Social das Energias Renováveis em Portugal. Lisbon, Imprensa de Cięncias Sociais.

DEVINE-WRIGHT, P. (2005): Beyond NIMBYism: Towards an integrated framework for understanding public perceptions of wind energy. Wind Energy, 8(2): 125–139.

DEVINE-WRIGHT, P. (2009): Rethinking NIMBYism: The role of place attachment and place identity in explaining place-protective action. Journal of Community & Applied Social Psychology, 19(6): 426–441.

DEVINE-WRIGHT, P., HOWES, Y. (2010): Disruption to place attachment and the protection of restorative environments: A wind energy case study. Journal of Environmental Psychology, 30(3): 271–280.

DEVLIN, E. (2002): Factors affecting public acceptance of wind turbines in Sweden. Lund, Lunds Universitet.

DIREÇĂO GERAL DE ENERGIA E GEOLOGIA (2012): Renováveis. Estatísticas Rápidas, No. 93. Lisbon, DGEG.

DIREÇĂO GERAL DE ENERGIA E GEOLOGIA (2016): Renováveis. Estatísticas Rápidas, No. 137. Lisbon, DGEG.

EUROPEAN COMMISSION (2007): Special Eurobarometer 65.3. Energy Technologies: Knowledge, Perception, Measures. Brussels, European Commission.

EUROPEAN COMMISSION (2010): Europe 2020. A European Strategy for Smart, Sustainable and Inclusive Growth. COM (2010): 2020. Brussels, European Commission.

EUROPEAN COMMISSION (2012): Standard Eurobarometer 77. Brussels, European Commission.

FIRESTONE, J., BATES, A., KNAPP, L. (2015): See me, feel me, touch me, heal me: wind turbines, culture, landscapes, and sound impressions. Land Use Policy, 46: 241–249.

FRANTÁL, B., KUNC, J. (2011): Wind turbines in tourism landscapes: Czech experience. Annals of Tourism Research, 38(2): 499–519.

FRANTÁL, B., PASQUALETTI, M., VAN DER HORST, D. (2014): New trends and challenges for energy geographies: Introduction to the special issue. Moravian Geographical Reports, 22(2): 2–6.

FRANTÁL, B., URBÁNKOVÁ, R. (2017): Energy tourism: An emerging field of study, Current Issues in Tourism, 20(13): 1395–1412.

FRISVOLL, S., FORBORD, M., BLEKESAUNE, A. (2016): An empirical investigation of tourists' consumption of local food in rural tourism. Scandinavian Journal of Hospitality and Tourism, 16(1): 76–93.

FROLOVA, M., PRADOS, M. J., NADAI, A. [eds.]. (2015): Renewable Energies and European Landscapes: Lessons from Southern European Cases. Dordrecht, Springer.

GARROD, G., WORNELL, R., YOUELL, R. (2006): Re-conceptualising rural resources as countryside capital: The case of rural tourism. Journal of Rural Studies, 22(1): 117–128.

GONÇALVES, M. (2002): Implementation of EIA directives in Portugal. How changes in civic culture are challenging political and administrative practice. Environmental Impact Assessment Review, 22(3): 249–269.

GROOTHUIS, P., GROOTHUIS, J., WHITEHEAD, J. (2008): Green vs. green: Measuring the compensation required to site electrical generation windmills in a viewshed. Energy Policy, 36(4): 1545–1550.

HAGGETT, C., FUTÁK-CAMPBELL, B. (2011): Tilting at windmills? Using discourse analysis to understand the attitude-behaviour gap in renewable energy conflicts. Mekhanizm Rehuluvannya Economiky, 1(51): 207–220.

INTERNATIONAL ENERGY AGENCY (2015): World Energy Outlook 2015. Paris: OECD / IEA.

JERPÅSEN, G., LARSEN, K. (2011): Visual impact of wind farms on cultural heritage: A Norwegian case study. Environmental Impact Assessment Review, 31(3): 206–215.

LIMA, M. (2004): Images of the public in the debates about risk: Consequences for participation. Portuguese Journal of Social Sciences, 2(3): 149–163.

LOTHIAN, A. (2008): Scenic perceptions of the visual effects of wind farms on South Australian landscapes. Geographical Research, 46(2): 196–207.

MOLNAROVA, K., SKLENICKA, P. STIBOREK, J., SVOBODOVA, K., SALEK, M. BRABEC, E. (2012): Visual preferences for wind turbines: Location, numbers and respondent characteristics. Applied Energy, 92: 269–278.

MUNDAY, M., BRISTOW, G., COWELL, R. (2011): Wind farms in rural areas: How far do community benefits from wind farms represent a local economic development opportunity? Journal of Rural Studies, 27(1): 1–12.

PASQUALETTI, M. (2004): Wind power: Obstacles and opportunities. Environment: Science and Policy for Sustainable Development, 46(7): 22–38.

PASQUALETTI, M. (2011): Opposing wind energy landscapes: A search for common cause. Annals of the Association of American Geographers, 101(4): 907–917.

PASQUALETTI, M., GIPE, P., RIGHTER, R. (2002): A landscape of power. In: Pasqualetti, M., Gipe, P., Righter, R. [eds.]: Wind Power in View: Energy Landscapes in a Crowded World (pp. 3–16). San Diego, Academic Press.

RIDDINGTON, G., MCARTHUR, D., HARRISON, T., GIBSON, H. (2010): Assessing the economic impact of wind farms on tourism in Scotland: GIS, surveys and policy outcomes. International Journal of Tourism Research, 12(3): 237–252.

SELMAN, P. (2010): Learning to love the landscapes of carbon-neutrality. Landscape Research, 35(2): 157–171.

SILVA, L. (2009): Casas no Campo. Etnografia do Turismo Rural em Portugal. Lisbon, Imprensa de Cięncias Sociais.

SILVA, L. (2014): The two opposing impacts of heritage making on local communities: Residents' perceptions: A Portuguese case. International Journal of Heritage Studies, 20(6): 616–633.

SILVA, L., LEAL, J. (2015): Rural tourism and national identity building in contemporary Europe: Evidence from Portugal. Journal of Rural Studies, 38: 109–119.

SMIL, V. (2010): Energy Transitions: History, Requirements, Prospects. Santa Barbara, CA: Praeger.

SOUSA, A., KASTENHOLZ, E. (2015): Wind farms and the rural tourism experience – problem or possible productive integration? The views of visitors and residents of a Portuguese village. Journal of Sustainable Tourism, 23(8–9): 1236–1256.

SOWERS, J. (2006): Fields of opportunity: Wind machines return to the plains. Great Plains Quarterly, 26(2): 99–112.

THAYER, R., FREEMAN, C. (1987): Altamont: Public perceptions of a wind energy landscape. Landscape and Urban Planning, 14: 379–398.

TOKE, D. (2005): Community wind power in Europe and in the UK. Wind Engineering, 29(3): 301–308.

TOKE, D., BREUKERS, S., WOLSINK, M. (2008): Wind power deployment outcomes: How can we account for the differences? Renewable and Sustainable Energy Reviews, 12(4): 1129–1147.

URRY, J. (1992): The tourist gaze and the "environment". Theory, Culture & Society, 9: 1–26.

VAN DER HORST, D. (2007): NIMBY or not? Exploring the relevance of location and the politics of voiced opinions in renewable energy siting controversies. Energy Policy, 35(5): 270–2714.

VAN DER HORST, D., TOKE, D. (2010): Exploring the landscape of wind farm developments; local area characteristics and planning process outcomes in rural England. Land Use Policy, 27(2): 214–221.

WALKER, G, DEVINE-WRIGHT, P. (2008): Community renewable energy: What should it mean? Energy Policy, 36(2): 497–500.

WALMSLEY, D. (2003): Rural tourism: A case of lifestyle-led opportunities. Australian Geographer, 34(1): 61–72.

WARREN, C., LUMSDEN, C., O'DOWD, S., BIRNIE, R. (2005): "Green On Green": Public perceptions of wind power in Scotland and Ireland. Journal of Environmental Planning and Management, 48(6): 853–875.

WARREN, C., MCFADYEN, M. (2010): Does community ownership affect public attitudes to wind energy? A case study from south-west Scotland. Land Use Policy, 27(2): 204–213.

WOLSINK, M. (1989): Attitudes and expectancies about wind turbines and wind farms. Energy Engineering, 13(4): 196–206.

WOLSINK, M. (2006): Invalid theory impedes our understanding: A critique on the persistence of the language of NIMBY. Transactions of the Institute of British Geographers, 31(1): 85–91.

WOLSINK, M. (2007): Planning of renewables schemes: Deliberative and fair decision-making on landscape issues instead of reproachful accusations of non-cooperation. Energy Policy, 35(5): 2692–2704.

WOODS, M. (2003): Deconstructing rural protest: the emergence of a new social movement. Journal of Rural Studies, 19(3): 309–325.

WOODS, M. (2011): Rural (Key Ideas in Geography). Oxon and New York, Routledge.

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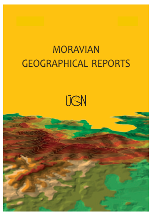

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Landform values for rural sustainability: Recognition and assessment in a Spanish–Portuguese border region case study

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Abstract

Landform assemblages may be used to define sites of geomorphological interest which are resources for rural sustainability. This paper focuses on the valuation and significance of such sites in the context of one European internal border region, illustrated using a case study from the inland mountains of the Spanish-Portuguese border: the Serra do Larouco. The theoretical and methodological approach used includes the recognition, inventory and assessment of a preliminary list of twenty-eight sites. They comprise diverse granitic landforms which characterise the rural inland landscapes in the North West of the Iberian Peninsula. The results from the qualitative and quantitative assessments were the basis for a final selection of nine sites as significant land resources. An analysis of their key values supports the proposal of different use and management options to promote rural sustainability. A review of the methodology applied and the consideration of other case studies provide a means to interpret and discuss the regional and local significance of the selected sites. The conclusions emphasise the crucial role that values linked to landforms can play in little-known mountainous and rural border regions, suggesting a future research agenda.

Keywords: *landforms; geomorphological site; rural sustainability; European border region; Serra do Larouco; Galicia (North West Spain); North of Portugal Mountains*

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1. Introduction

The Europe 2020 strategy focuses on smart, sustainable and inclusive growth across European regions. This approach demands territorial processes of change to face the global crisis, involving regional and local actors (European Commission, 2015). Current challenges for the European regions, however, depend on specific conditions that affect the possibilities of growth. After the 2008 global crisis, regional trends in Europe exhibit a core continental territory – where the impacts have been low or moderately low – surrounded by peripheral areas where the impacts have been high or very high (Crescenzi et al., 2016). Most of the border internal regions of the European Union (EU) are included within the lagging areas, often predominantly rural and mountainous territories (European Commission, 2010). They comprise more limited access to services, higher unemployment and lesser Gross Domestic Product (GDP) per head than the EU average. Following Capello and Caragliu (2016), a place-based scenario focused on the preservation and creative exploitation of local territorial assets, is the best option to decrease these regional disparities in the EU. This development proposal agrees with the new foundations for rural development (Ambrosio-Albalá and Bastiaensen, 2010; OECD, 2006), which emphasise the necessary recognition of the values of territorial assets by authorities, social partners and civil society in order to conceive successful strategies for development.

These perspectives incorporate a region's natural and cultural assets as key resources for the transformation and improvement of the territory. Such processes must have fruitful effects on the whole territorial components and also depend on the rediscovery of the places where distinctive use and management options arise. Moreover, the necessary creation of synergies between socio-economic growth and environmental protection (Naldi et al., 2015) implies the sustainable use and management of the natural and cultural assets, linking regional and place-based strategies. In rural and mountainous areas, the features and quality of the natural assets are defined as important factors for sustainability (Sánchez-Zamora et al., 2014); landforms and landscapes are essential components of their configuration, having a strong influence on their development trajectories.

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Around the northern Spanish-Portuguese border (Fig. 1), the Galicia-North Portugal Euroregion identifies a territory with powerful economic, social and cultural relationships (García-Álvarez and Trillo-Santamaría, 2013). The main conditions as regards the current territorial dynamics are its peripheral position both in the Iberian Peninsula and Europe, population decline and the structural imbalances between coastal and inland areas (Baltà Portolés, 2015). The European programs, especially through INTERREG projects, had more influence on the improvement of the road infrastructures than on the creation of local and regional initiatives for rural development (Domínguez et al., 2013). In this region, the landscape of the inland boundary is characterised by the presence of cross-border mountains. The case study of the Serra do Larouco, one of these mountains, was selected for its particular interest in the framework of peripheral European and Iberian border regions. It represents a rural inland area, affected by severe processes of depopulation.

The Larouco Mountain contains plentiful landforms although they are little known and lack protection. The aim of this study is to enhance the recognition, knowledge and visibility of landforms as key resources for the sustainability of this inland and rural area. There are three specific objectives: (i) to identify and characterise the landforms with highest interest and territorial significance; (ii) to analyse their current conditions in the regional and local context; and (iii) to carry out a study of their values assessment to create sustainable use/management strategies, furnishing significant information for the territorial authorities, stakeholders, residents and visitors.

The paper begins with an explanation of the theoretical and methodological approach. Then the methods applied for the inventory and assessments are described, the results are presented and their significance is explained. Finally, the conclusions synthesise the territorial and policy implications for future development and demonstrate lines of further research.

2. Theoretical background

The recognition and valuation of interest in landforms provide a significant knowledge base to define the priorities of territorial planning towards sustainable growth. This interest of landforms is related to multiple dimensions. Scientific knowledge of them, their conservation degree, uses and management reflect the values conferred on them by human communities through time. When landforms are components of the World Heritage Sites (UNESCO, 2016), the World Protected Areas (IUCN, 2013) or the Global Geosites (IUGS, 2015), a set of outstanding universal values are enhanced. Migoń (2014) summarises landform values at the global scale by their strong significance (as archives of the Earth's history, milestones in geomorphologic research and examples of specific features or processes) and their wider significance, linked to diverse socio-cultural meanings. Outside of these and other protected areas (e.g. Natura 2000 in Europe), landforms also have a set of interests which can provide helpful values for sustainable development.

Besides recording the legacy of the Earth's systems evolution, landforms interests for society include their functions as the physical basis of landscapes and life support. Landforms are a part of the geodiversity (Gray, 2011; Serrano and Ruiz-Flaño, 2007), and may be considered as specific features of a territory at regional or local scales (Panizza, 2009). The main values afforded by society to these geodiversity components are associated with their potential as resources for education, knowledge, recreation, tourism or cultural inspiration (Hjort et al., 2015). Landform assemblages having those scientific, educational, aesthetic, socioeconomic and cultural values define geomorphological sites or geomorphosites (Panizza, 2001; Panizza and Piacente, 2003; Reynard, 2009). These terms involve landforms in the common heritage of a territory, and the recognition of those sites is the first step to promote knowledge of their values, and to become aware of them. Landform identification and characterisation report the sites of geomorphological interest in a territorial context. The assessment procedures guide understanding and promotion of landforms as geomorphosites, which are "forms du relief ayant acquis une valeur scientifique, culturelle et historique, esthétique ou socio-économique, en raison de leur perception ou de leur exploitation par l'homme", being their values "généralement peu connue du grand public et des scientifiques d'autres disciplines" (Reynard and Panizza, 2005, p. 177).

Granitic landforms characterise the landscapes of the North West Iberian Peninsula. Their origin and evolution are related to several geomorphic processes (Migoń, 2006; Twidale and Vidal-Romaní, 2005). During the magma intrusion, cracks with diverse geometry patterns (for instance, polygonal or orthogonal) and systems of discontinuities (pseudo-bedding, sheets and joints) are generated. When the consolidated rock is located in less deep levels, the water flow across the discontinuities guides the sub-superficial processes (rock weathering). Thus, the rock platforms, bornhardts, inselbergs, castle rocks, tors, blocks or cavities (e.g. gnammas, tafoni) would be formed, whose final morphology on the Earth surface reflects the weathering/erosion balance. Once these landforms come into contact with sub-aerial agents (air, water, wind) their diversification and degeneration processes take place. In exogenous environments, other landforms (rills, gutters or potholes in bedrock channels) can be generated. All these landforms are usually identified with respect to their dimensional assortment. The inventory of the geomorphological sites in the study area counted the characteristic landforms in the North of Portugal and Galicia (Pereira et al., 2015; Vidal-Romaní et al., 2014); here the local denominations in the following dimensional categories are added in italics to ease their understanding and comparison:

i. Dimension variable: vein rock; cracking; pseudo-bedding (*pseudo-estratificación*, *pseudo-estratificaçao*); sheet (*laxe*, *laje*); weathering profile, grus (*xiabre*, *jiabre*);
ii. Micro dimension (from cm to m): rock basin, gnamma (*pía*); tafone, cavernous weathering (*cachola*, *cacheira*); rill, runnel (*fendas*, *sulcos*); gutter (*canelura*); block (*bloco*); boulder (*bolo*); block field (*pedregais*); logging stone (*pedra bolideira*) and pedestal rock (*rocha pedestal*); and
iii. Meso-Macro dimension (from m to km): tor, nubbin, castle kopje (*pedra*, *pena*, *penedo*, *outeiro*); dome, bornhardt (*moa*); alveole (*alveolo*); plain (*aplanamento*, *chao*, *chaira*); bedrock river (*cauce rochoso*).

The granitic landforms often inspire much awe in onlookers and they present undeniable scenic and aesthetic values. They receive singular names related to viewers' singular experiences, legends or myths from the local culture. Thus, these components of the territorial system integrate natural and cultural significances, gathering aesthetic, scientific, educational, symbolic, iconographic and socio-economic values (Pena dos Reis and Henriques, 2009). These tangible and intangible values, connected to the assets that comprise the geomorphological sites, keep track of human footprints and shape the territorial identity. The tangible and intangible values of the landforms are viewed as indivisible and interconnected in the formation of the sense of a place, and knowing them is essential for planning a sustainable development (Werlen et al., 2016).

According to the theoretical background, the identification and definition of the geomorphological sites, as well as the valuation of their interests, were based on assessment criteria related to the meanings that granitic landforms could present. The sites assessment was addressed to promote the sustainability of a mountainous and rural territory, located in an internal border region of the EU. The qualitative and quantitative assessment was devised as a tool in order to establish the use and management priorities.

3. Study area

The Larouco Mountain is located in the NW of the Iberian Peninsula (IP), elongated in the NE-SW direction (Fig. 1). It belongs to the inland border between southern Galicia (Spain) and the North of Portugal, named as *raia seca* (dry border) in contrast with the borderline set by the fluvial watercourse of the lower Miño River. The highest geodiversity values in this IP sector are closely related to their interests for understanding the origin and evolution of the oldest Iberian Massif terrains (Benito-Calvo et al., 2009). The granite intruded the engaging material in the intermediate stage of the Variscan cycle (between 328 and 339 Myr BP). The relief organisation is due mainly to Cenozoic tectonics since the morpho-structures of Galicia and the North of Portugal represent the most western extension of the Southern Pyrenean area in the Alpine Mountain Range (De Vicente and Vegas, 2009). Schmidt-

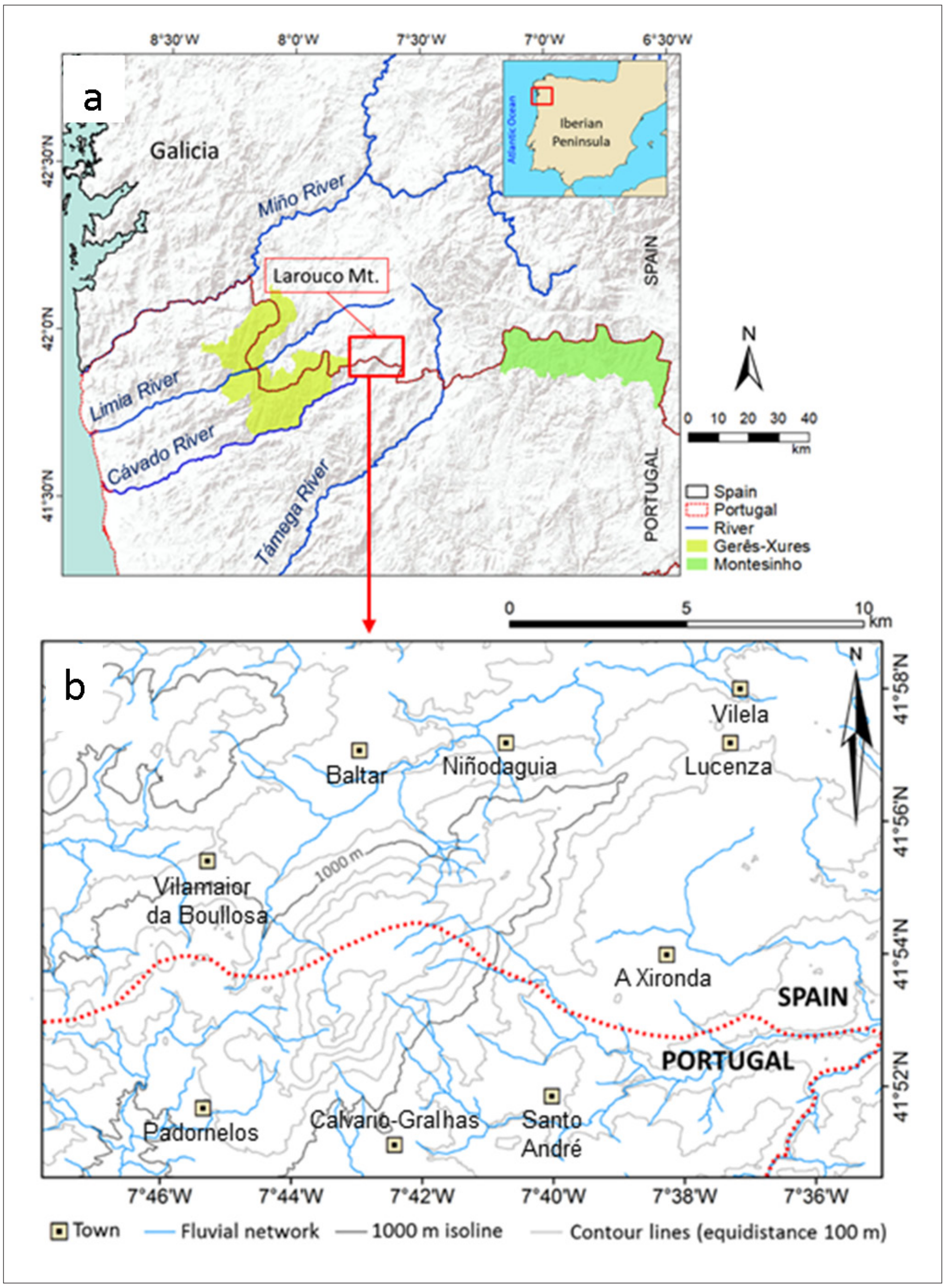

Fig. 1: Location and main features of the study area: a) location in the Iberian Peninsula and b) topographic features with location of towns. Source: authors' elaboration (Base Map ESRI for location and Base Map BTN25 Instituto Geográfico Nacional de España for area configuration)

Thomé (1978) pointed out that the Larouco summits would be affected by glacial processes during the Pleistocene, with two (independent) layers of permanent ice above 1,250 m. In the Portuguese area, Coudé-Gaussen et al. (1983) stated the importance of the snow, without ice formation, and Vieira et al. (2015) mentioned that the main processes would have been periglacial. The absolute dating attests to the presence of small glaciers in the nearby Gerês-Xurés Mountains (Vidal-Romaní et al., 2015), with an age of 300 kyr BP for the stage of maximum glacial advance during the Pleistocene.

The topography of the summit area is flat, slightly tilted from the SW to the NE (Fig. 2). The Larouco Mountain is the watershed between Limia, Támega and Cávado fluvial basins and their maximum altitudes are Pico Larouco (1,538 m) in Portugal and Coto Farelo (1,398 m) in Galicia (Spain). Maximum unevenness between the Mountain summit area and the bottom of the surrounding valleys is 100 m (NE), 500 m (SW), 400 m (E) and 558 m (W). The thermal variation in altitude (Rodríguez Guitián and Ramil-Rego, 2008) determines the bioclimatic zoning between the hill level (average minimum temperature of the coldest month > 0 °C) and the mountain level (average minimum temperature of the coldest month between > 4 °C and 0 °C). The total annual precipitation ranges from 800 mm in the surrounding valleys to 1,500 mm in the summit area (AEMET, 2016). Most of the mountain is covered by bushes, meadows and pastures, with crop fields limited to flat lands near population centres. Native forests (*Quercus robur* and *Quercus pyrenaica*) are found in the NW sector (1,000–1,200 m). Pine trees (*Pinus pinaster*, *Pinus sylvestris* and *Pinus radiata*), introduced by reforestation programs since the end of 1950s, define the forest on the Northern sector (1,150–1,390 m).

Since 2002, a private wind farm has operated in the municipalities of the Spanish territory. The demographic situation is affected by continuous population decline. Between 1980 and 2016 the mountainous area and its surroundings (municipalities of Baltar and Cualedro in Galicia, and part of Montalegre municipality in Northern Portugal) suffered a loss of more than 50% of its human resources (IGE, 2016; INE.pt, 2016). The population density is very low (12 per km^2) and the active population is employed mostly in the services sector (60%), and secondarily in farming (20%). Most of the mountainous territory is under common lands property. The present land uses of the mountain are devoted to cattle pasture; also important on the Portuguese side, there are activities for outdoor recreation.

4. Methodology

Definition of the criteria and indicators to select and assess the geomorphological sites was accomplished after review of the different methods applied. The Italian method (Panizza, 2001) proposed the use of intrinsic values (scientific, educational and paleo-geographical) and added values (scenic, socio-economic and cultural). The indicators of these central (intrinsic) and added values were diversified by the Swiss method (Reynard et al., 2007). Other methods applied to assess Spanish sites (Bruschi and Cendrero, 2009; Serrano-Cañadas and González-Trueba, 2005) pointed up the importance of use and management values (related to the accessibility, observation conditions, potential risks and threats). In Portugal (Pereira, 2006; Vieira, 2008), the sites assessment focused on the geomorphological values (including scientific and additional indicators) and the use/management values defined by the Spanish studies.

These proposals were tested by Erhartič (2010) in an assessment of the Slovene waterfalls, concluding that better selection depends on the research objectives and scale. The method applied by Višnić et al. (2016) looked at the existing ones with slight modifications, attempting to formulate the specific potential of the sites for geotourism. Moreover, the method to select and assess the geomorphological sites in the

Fig. 2: The Larouco Mountain: (a) the mountain seen from SW (Montalegre, Portugal); (b) panoramic view from the summit area towards NW
Photos: E. De Uña-Álvarez

granitic mountains of the Czech Republic (Kubalíková and Kirchner, 2016; Rypl et al., 2014) emphasised the creation of a geomorphological inventory; the assessment is addressed to preserve landforms and to promote sustainable uses in less-known and unprotected areas, considering scientific, educational, economic, conservation and added values. Due to the thematic and spatial overlap of the study area, the methodology used here follows the latest proposals applied in the North of Portugal (Pereira and Pereira, 2010; Vieira et al., 2014), taking into account the necessary approach to the regional scale (Reynard et al., 2016). The methodology has included a qualitative and quantitative assessment; the value scales and maximum scores for the different criteria were adjusted from the Portuguese method. Thus, the criteria chosen and applied were consistent with the approach of research in the Spanish-Portuguese border.

The research was developed in three stages. First, the characterisation of the study area (from bibliographic, cartographic, statistical, spatial data infrastructures and web resources) entailed the identification and recognition of geomorphological sites. The selection, description and mapping of the twenty-eight sites included in the initial list, were carried out by the authors through the development of detailed field work. According to the theoretical and methodological framework, the primary criteria for selecting any landform or landform assemblage as a geomorphological site were as follows: representativeness as a landscape component at the local or regional scale; scientific and scenic interests; relationships with other natural and cultural assets; symbolic significance; and possibilities of observation. An index card was created, including the location data (name, reference code, country, municipality, position, altitude and

Criteria	Indicators	Maximum
Scientific value (Sv)	Local rarity	
	More than five, three-five, two and none similar sites	1.0
	Regional rarity	
	More than five, three-five, two and none similar sites	1.0
	Geomorphological diversity	
	One, two, three and more than three interesting landforms	1.0
	Number of mentions in scientific publications	
	One, two, three-five and more than five	1.0
	Educational exemplarity for curricular contents	
	Primary, secondary, baccalaureate and university levels	1.0
Added value (Av)	Ecological: vegetation and singular ecosystems	
	None, introduced, mixed, natives	1.5
	Cultural: material and immaterial assets diversity	
	One, two, three and more than three cultural assets included	2.0
	Aesthetical: colour, shape, viewpoints and appearance	
	Slightly, medium and high contrast, with panoramic views	1.5
Use value (Uv)	Visibility: observation conditions	
	Only in situ, partially, full from <1 km, full from ≥1 km	1.5
	Accessibility: individual or public transport	
	Walking, cycling, by jeep, car and bus	1.5
	Accommodation and services proximity (spatial radii)	
	More than 30 km, 30 km, 20 km, 10 km	1.5
	Use potential: scientific, educational and socioeconomic uses	
	None, low, medium, high	1.0
	Use limitations in spatial and time scales	
	None, low, medium, high	1.5
Protection value (Pv)	Conservation of the essential features and the surrounding	
	Strong, moderately and little damaged or non-damaged	1.0
	Vulnerability: current exposure and threats	
	Extremely, high, moderate, low	2.0

Tab. 1: Criteria and indicators for the site assessments
Notes: The indicators for the scientific (Sv) and added (Av) values define the geomorphological value (Gv = Sv + Av). The indicators for the use (Uv) and protection (Pv) values define the use/management value (Mv = Uv + Pv). Max is maximum score. The scale to quantify indicators is specified as follows: for Max = 1.0 and four categories is 0.25, 0.50, 0.75 and 1.00; for Max = 1.5 and four categories is 0.25, 0.50, 1.00 and 1.50 (except none = 0); for Max = 2.0 and four categories is 0.50, 1.00, 1.50 and 2.00
Source: Modified by the authors from Pereira and Pereira (2010) and Vieira et al. (2014)

geographic coordinates), the indicators of interest (scientific, educational, ecological, cultural and aesthetic), and the use/management conditions (taking into account potential uses, conservation degree, current exposure and threats), for the sites' field records. At the end section of the index card, a summary description, cartography and images were attached. The criteria and indicators to assess the sites were adapted to the research objectives (Tab. 1).

The second stage of the research was focused on the database creation and qualitative assessment of the sites. In this way, the database was set up by assigning a nominal code to each site from their location in the relief units of valley (v), slope (s) or summit (t). This nominal code and its number provided the preliminary information on the spatial distribution of the selected sites. Then, the spatial distribution and geomorphologic categories (landform types) of the inventoried sites were analysed. The characterisation of the inventory also dealt with their local or regional rarity and interest for science, education, protection or different uses (looking at the current degree of conservation and vulnerability of the sites). The indicators for the scientific (Sv) and added (Av) interests of the sites define their geomorphological value (Gv), while the indicators for the use (Uv) and protection (Pv) interests define their use/management value (Mv). The qualitative labels assigned to the sites, from low to high, were determined by the records obtained during the field work.

In the third stage, the quantitative assessment of the geomorphological sites took place. It began by exploring the distribution of the geomorphological and use/management values. The highest possible score both for Gv (Sv + Av) and Mv (Uv + Pv) is 10 points. Due to its visual impact, proximity to the wind farm resulted in a decrement of 0.25 points in the quantitative assessment of the aesthetic indicator. The frequency analysis comprised five class intervals, established as follows: very low (≤ 2.0 points), low (2.1–4.0 points), medium (4.1–6.0 points), high (6.1–8.0 points) and very high (8.1–10.0 points). Then, statistical analysis was applied to explore the centrality, dispersion and variability of the results, checking for median significance by the application of the non-parametric Mann-Whitney test. This test compares the results of the ordered values and compares their medians: the null hypothesis is that both Gv and Mv medians are equal; the alternative hypothesis that there is a significant difference between the medians.

The total value (V) for the sites was obtained by adding the Gv and Mv results (V = Gv + Mv), so its maximum score is 20 points. The sites classification was determined by clustering with regard to the median of the V data (median method, Euclidean distance). The differentiation inside these groups provided the best available sites to create successful strategies for rural sustainability. In the data processing, robust statistical measures of the assessment criteria (lower quartile, median and upper quartile) were used for the final valuation of the sites. The sites selected as nodes to promote rural sustainability were defined after the interpretation of the qualitative and quantitative assessment, once applied to the preliminary sites list. The database construction, statistical procedures and graphical representations of the data were carried on Stat Graphics Plus software.

5. Results and discussion

5.1 Qualitative assessment: inventory characterisation

The preliminary inventory contained 28 sites, mainly located in the summit and slope units (Fig. 3, Tab. 2). The most representative landforms assemblages with scientific relevance were recognised at the Mountain top (t01, t04, t05, t06, t09, t12, t13, t14) and fluvial headwaters (s03, s08). The Larouco Mountain is mentioned in some studies on periglacial and glacial events in the NW of the Iberian Peninsula. The degree of geomorphological diversity is very high, since more than three interesting landforms were identified in the configuration of 17 sites. They

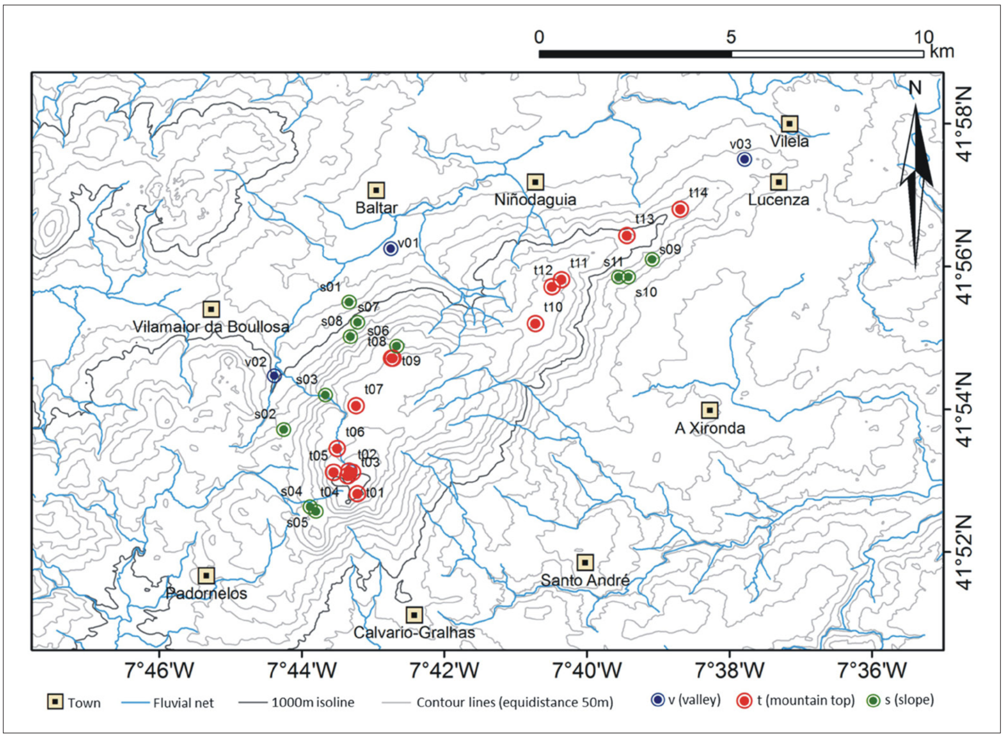

Fig. 3: Location of the inventoried sites
Source: authors' elaboration (Base Map from BTN25 Instituto Geográfico Nacional de España)

Code	Country	Alt	Landforms
v01	Spain	833	tor, boulder
v02	Spain	1001	small bedrock river, spring
v03	Spain	913	tor, boulder
s01	Spain	974	boulder, gnamma
s02	Spain	1133	tor, boulder
s03	Spain	1200	small bedrock river, block field
s04	Portugal	1270	logging stone, gnamma, tafone
s05	Portugal	1312	block, pseudo-bedding
s06	Spain	1321	tor, gnamma
s07	Spain	1114	tor, gnamma, tafone
s08	Spain	1139	torrent, block field
s09	Spain	890	block, logging stone
s10	Spain	906	sheet, boulder, gnamma, tafone
s11	Spain	915	tor, gnamma, tafone
t01	Portugal	1527	tor, pseudo-bedding, gnamma
t02	Portugal	1499	pseudo-bedding, cracking, gnamma
t03	Portugal	1493	plain, peat bog
t04	Portugal	1538	peak, block
t05	Portugal	1477	pseudo-bedding, weathering profile
t06	Portugal	1493	plain, boulder
t07	Border	1491	plain, boulder
t08	Spain	1345	tor, pseudo-bedding, gnamma
t09	Spain	1340	small bedrock channel, cracking
t10	Spain	1118	pseudo-bedding, logging, gnamma
t11	Spain	1160	tor, pseudo-bedding, gnamma
t12	Spain	1180	peak, tor
t13	Spain	1074	pseudo-bedding, block
t14	Spain	991	tor, logging stone, gnamma

Tab. 2: Main references of the inventoried sites (Alt = altitude in m a.s.l. Nominal codes from location: v = valley, s = slope, t = mountain top). Source: authors' elaboration

also have high educational interest, so they can be used at several education levels. Other interests rely on the scenic and aesthetic character (22 sites with panoramic views), although this quality may be affected by proximity to the wind farm (for instance: t10, t11, t12 and t13). The presence of native vegetation (s01, s02, s03 and s08) or singular ecosystems (Peat bog in t03), characterises the principal ecological interests. The Mountain holds a sacred connotation (Olivares Pedreño, 2002) because it could be the domain of a pre-Roman god: this divinity, linked to storms and rivers, endows the name Larouco with a mythical meaning (Lourenço Fontes, 1980). Within the cultural assets linked to landforms, other symbolic meanings related to legends on treasures or wizards (s01, s02, s03 and v01), or archaeological and historical assets (for instance: rock art in s01, snow well in t04, and old shepherd refuges in t07) also stand out.

The observation conditions, accessibility and services proximity are very good for v01, s04, s05, t02 and t03. The potential for recreation and wildlife sports is very high in 18 sites. The degree of deterioration is related to refurbishment works to receive visitors (t01, t04, t05, t12 and t13), and the extraction of granitic blocks for the local building (v01 or v03). The main problems regarding the sites' engagement (as scientific, educational, recreational or cultural resources) derived from the need of preservation measures due to their vulnerability (e.g. Peat bog in t03, block fields in s03 and s08), the presence of remarkable cultural assets (e.g. petroglyphs in s01), and general exposure to deliberate fires.

5.2 Quantitative assessment: geomorphological and use/management values

Most of the inventoried sites present significant use and management values. This statement is supported by the results of the quantitative assessment. The results of the frequency analysis show the prevalence of high geomorphological values and high or very high use/management values within the inventoried sites (Fig. 4). Most of the sites obtained a geomorphological value (Gv) between 5.5–8.0 points and a management value (Mv) between 6.0–9.0 points. The exploratory analysis revealed low standard deviation (0.9) and standard error (0.2), regarding the averages for the Gv data (6.47 points) and Mv data (7.43 points). These statistical measures for data centrality were closer to the results delivered by their position measures: the Gv median (6.75 points) and the Mv median (7.50 points). This condition determined the use of the position statistical measures as the best comprehensive tools for the quantitative assessment. The difference between the medians of the geomorphological and management values is statistically significant, since the computed p-value (0.00053) from the application of the Mann-Whitney test was < 0.05 (95% confidence level).

In spite of the moderate values obtained from their rareness and scientific knowledge ratings, the sites have wider interests. The highest geomorphological values were obtained by eleven sites, with panoramic views, that present several values: assemblies of boulders on plains (t06); pseudo-bedding, polygonal cracking, pitting and weathering profile (t05); pseudo-bedding, tors and gnammas (t01, t04, t08, s01 and s02); block fields in torrent headwaters (s03, s08 and t09); and sheet structures diversified by tafone and gnamma cavities (s11). The highest use/management values were associated with five sites with high geomorphological values (t01, t04, t05, t06 and s02) and other sites that displayed assemblies of boulders, tafoni, gnammas and logging stones. All the inventoried sites obtained a total value ≥ 10 points (the median for $V = 14$ points). These values vary by mountain sector (Fig. 5). The highest total values characterise the sites of the SW mountain top, surrounded by slope sites with high total values. The sites of the NE sector show high total values, but mostly the results are below the V median. In the NW valleys, a high value for V is attained by only one site.

The dendrogram for V (Fig. 6) reveals three groups of sites with regard to the global quantitative assessment. The Va group ($V > 15$ points) links the sites that obtained the highest geomorphological or use/management values in the case study. The Vb group (V between 14 and 15 points) joins sites in which results were above the median both for the geomorphological values (except one site) and the use/management values (except two sites). The Vc group ($V < 14$ points) includes sites that attained assessment

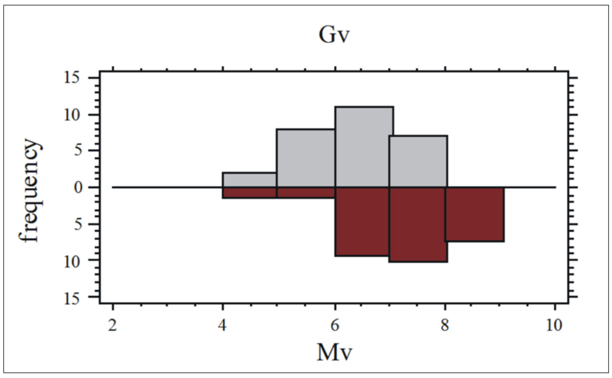

Fig. 4: Frequency distributions for the geomorphological (Gv) and management (Mv) values (The length of the bars represents the number of sites with value within each interval). Source: authors' elaboration

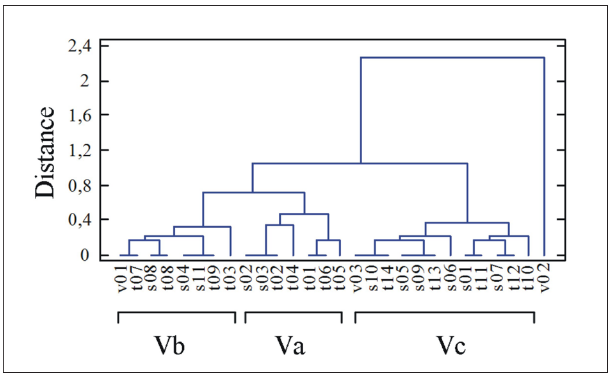

Fig. 6: Clustering by the total value (V) of the sites (Median method, Euclidean distance). Three groups are differentiated: Va (V > 15 points), Vb (V = 14–15 points), and Vc (V < 14 points). Source: authors' elaboration

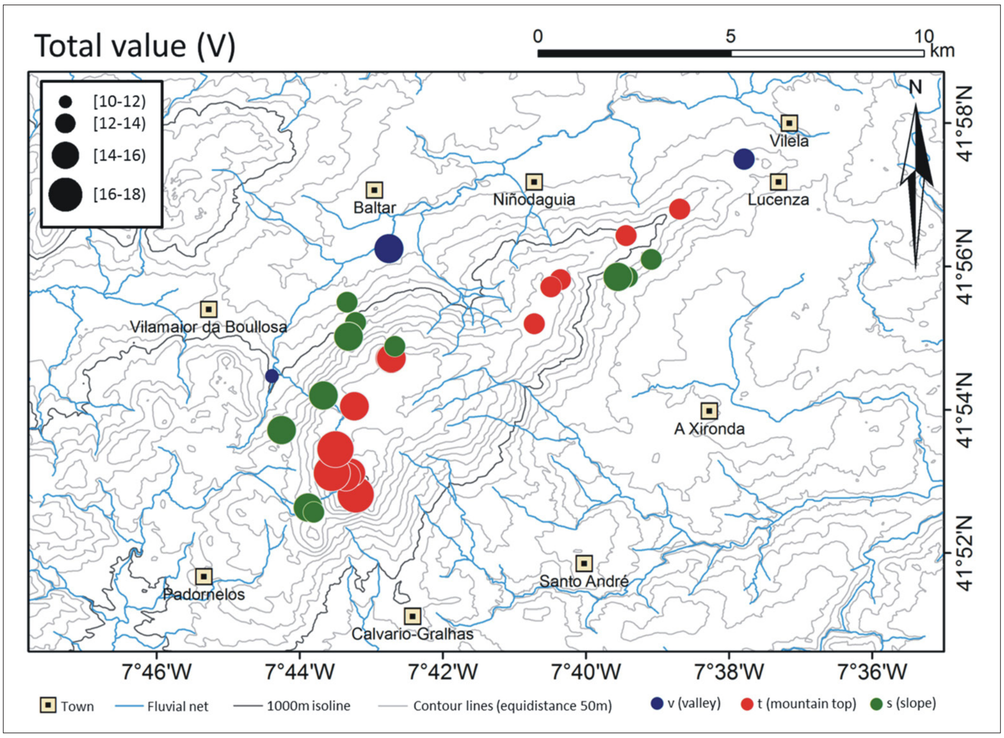

Fig. 5: Spatial distribution of the sites regarding their total value
Source: authors' elaboration (Base Map from BTN25 Instituto Geográfico Nacional de España)

results below the median for the geomorphological values (except one site) and the use/management values (except two sites). One site (v02 with V = 10 points) appears as an outlier to the aforementioned groups, getting the lower geomorphological value and the minimum management value in the study area.

Due to the disparities detected in the internal composition of the V groups, a detailed examination of the scientific, added, use and protection values was accomplished. In this way, the robust statistics of the values from each assessment criteria (Tab. 3) determine the site's ranking. The lower quartile, median, and upper quartile are thresholds demonstrating the relevance of the sites; these thresholds define the rank position with regard to the aforementioned criteria. The first position identifies the sites with results equal to or above the upper quartile of the data (highest values); the second position distinguishes the sites with results between the median and the upper quartile of the data (high values); the third position presents the sites with results equal to or above the lower quartile and below the median of the data (medium values); and the fourth position comprises the sites with results below the lower quartile (low values).

The sites that appear in the first and the second position were selected for the final list, since they hold a strong significance related to their high representativeness, geomorphological diversity and exemplarity for educational activities. Consequently, one site of the Va group (s02) and two sites of the Vb group (s04 and t08), which are in the fourth position for this criterion did not have sufficiently high values to be selected; otherwise, one site of the Vc group (t14) attained a result above the scientific value median, so it was selected. The sites in the fourth position by the results of the added and use criteria were not considered for the final list (for instance t09). The results of the protection criteria

Statistics	Sv	Av	Uv	Pv
Lower quartile	2.75	2.63	4.50	2.00
Median	3.00	3.75	5.00	2.50
Upper quartile	3.50	4.00	5.87	2.50

Tab. 3: Statistical position measures of the data. These robust measures are selected as thresholds for the final valuation of the sites regarding scientific (Sv), added (Av), use (Uv) and protection (Pv) values
Source: authors' elaboration

specified low, moderate or strong limits for the potential uses. After this analysis, nine sites (Table 4) were chosen as key resources for rural sustainability.

5.3 Interpretation and significance for rural sustainability

Assuming that "rural development and environmental sustainability go hand in hand" (OECD, 2016, p. 30), the geomorphological sites may support initiatives which attract population and talent for a smart, sustainable and inclusive growth. But the definition of these territorial assets as key resources for sustainability and development requires knowing their use and management options under particular conditions. The potential to generate territorial advantages comes from a suitable preservation, use and management of these territorial assets. Likewise, the capacity to embrace different activities directly engaged in the environment or in its management – denoted by Courtney et al. (2006), the core activities and dependent activities – must be highlighted. Nine geomorphological sites comprise the focal settings for planning development strategies in the Larouco Mountain and the surrounding rural lands. They integrate the key geomorphological resources in order to propose tourism, leisure and educational priorities for territorial planning, encompassed in the local and regional scales.

The characteristic landforms assemblages of the selected sites are tied to granite deformation, alteration, weathering and erosion processes, together with the presence of water (Fig. 7). The local names express their dimensional and dynamic features: *pedra* or *pena* (castle rocks); *pico* (peak); *alto* (plain); *regata* (small stream); *corgo* (torrent); *turfeira* (peat bog); and *fonte* (spring). Other attached terms from the Galician language such as *dos cabalos* (of the horses), *da mina* (of the mine), and *muller* (woman), are indicative of the uses, legends or appearance of the sites. The SE slope of the Mountain appears as an empty sector of inventoried sites. This fact can be explained by the difficult accessibility and very low possibilities of observation. These conditions also determine the lack of mentions in books, papers and other scientific publications and the low use/management potential.

In the SW summit area (Montalegre municipality in Portugal), the selected sites show significant examples of the granitic landforms. The main values are related to their geomorphological and cultural diversity, their exemplarity for all educational levels and aesthetical interests (with panoramic views on the surrounding valleys of the Cávado, Limia and Támega Rivers). They have very good

Setting	Code	Local denomination	Sv	Av	Uv	Pv
SW summit	t01	Larouquinho	3.50	4.25	6.50	2.00
	t02	Larouco Cumbre	3.00	3.25	6.50	2.50
	t04	Pico Larouco	3.75	3.25	6.50	2.25
	t05	Fonte Pipa	3.75	4.25	6.50	2.00
	t06	Alto da Veiga	3.75	4.25	5.75	2.50
W slope	s03	Regata dos Cabalos	3.50	4.00	5.75	2.00
	s08	Corgo da Mina	3.50	4.00	5.00	2.00
NE summit/slope	t14	Pena Muller	3.25	3.00	5.00	2.50
	s11	Pedra Redonda	3.00	4.00	5.75	2.50

Tab. 4: Final selected sites with components of geomorphological (Gv) and use/management (Mv) values. The scientific (Sv), added (Av), use (Uv) and protection (Pv) values are detailed
Source: authors' elaboration

conditions for observation, visibility and accessibility, with possibilities for bus parking at the Larouquinho site (t01). Accommodation and services are available less than 10 km away, but these sites present moderate to high deterioration. The present uses focus on outdoor recreation and sports (paragliding and hang gliding), for which the Larouco Portuguese summit represents a national and worldwide reference (Taça Luso-Galaica, World Championship). The whole area may be suitable for scientific, educational and socio-economic uses (recreation and nature-based tourism), considering the necessary safeguarding of the landforms.

Both Regata dos Cabalos (s03) and Corgo da Mina (s08) are located on the Western slope of the Larouco Mountain, belonging to the municipality of Baltar in Spain. Their block fields obtain high rareness rankings, since they are singular landforms not only in the study area but also in the regional context. These sites are mentioned in scientific publications which deliberate the magnitude of the glacial events in the north west of the Iberian Peninsula (e.g. Vidal-Romaní et al., 2015). The assessment of these sites denotes medium geomorphological diversity; nonetheless, their ecological (presence of native forest), aesthetic (appearance and panoramic views), and cultural values (legends of treasures and the maintenance of traditional uses) are prominent. The two sites have good observation conditions and present a good conservation degree. The difficulties of access and vulnerability caution their scientific and educational uses, the latter restricted to baccalaureate and university levels. These proposed uses must look at geo-conservation strategies to manage them.

Other two selected sites are located in the municipality of Cualedro (Spain), in the NE mountain sector. Pena Muller (t14) and Pedra Redonda (s11) rely on very high geomorphological diversity. The contrast in shape and appearance and the panoramic views on the Limia and Tamega valleys offer aesthetic interest. The first site shows singular forms related to strong erosion processes which receive particular names (by their resemblance with animals or people), and also preserve the stone altar to celebrate the Larouco god pilgrimage. The latter, strongly rich in added interests, represents a sheet structure diversified by micro forms (tafoni and gnammas). Both sites have good observation conditions and easy accessibility by jeep or car, though the approach to them must be by walking; the

Fig. 7: Examples of landforms from the selected geomorphological sites: a) Pico Larouco; b) boulders and c) tor in Larouco cumbre; d) weathering profile in Fonte Pipa; e) view of the SW summit landscape; f) pseudobedding and g) gnammas in Larouquinho; h) block field in Corgo da Mina; i) singular landforms in Pena Muller; j) Pedra Redonda site with k) tafone and l) very developed gnammas
Source: Photos by M.C. Cuquejo-Bello

accommodation and services proximity is less than 20 km away. They are suitable for scientific, educational (secondary, baccalaureate and university levels) and leisure uses.

So, the Larouco Mountain retains the legacy of the landforms evolution and landscape dynamics. The selected sites include information on endogenous processes, exposed across the discontinuities of the rock (pseudobedding, polygonal cracking and sheet); furthermore, they provide remarkable examples to understand the granite weathering processes (corestones and grus in a weathering profile), and the landform features through broader dimensional scales (gnammas, tafoni, boulders, tors, block fields, castle rocks, plains and bedrock channels). In the neighbouring protected Mountains of Portugal, similar landforms have been assessed as significant components of the landscape (e.g. Pereira et al., 2015). In the Mountains of the Czech Republic, the aforementioned study cases (Section 4: Methodology), as well as recent contributions (Rypl et al., 2016) state the significance of these landforms as singular features which need to be protected. An important value of the Larouco Mountain is related to its significance for Quaternary research. The sites portrayed by Schmidt-Thomé (1978) as cirque-like niches are located in Fonte Pipa, Alto da Veiga, Regata dos Cabalos and Corgo da Mina, but the abundance of the minor rock basin cavities indicate the absence of glaciation. In the last two places one can find block fields that represent periglacial inheritances. The identification of these landforms brings new evidence for knowledge of the Quaternary processes in the Galicia region – North of Portugal Mountains.

The preservation of these characteristic landscape features has an important public interest since they express the diversity of our common heritage (Council of Europe, 2006). The case study is situated between two protected areas (Fig. 1a): the transboundary Biosphere Reserve of Gerês-Xures (to West) and the Montesinho National Park (to East), where the granitic landforms are promoted as landmarks. The results of this study show that the Serra do Larouco has geomorphological values which justify its protection, as a part of the territorial identity of the Galicia – North of Portugal border. Furthermore, given the results from the use and management indicators, the selected sites may be defined as a set of potential geomorphosites, bridging the gap in environmental protection and the territorial development of this Spanish-Portuguese border. Currently, there is a clear imbalance between Galicia and the North of Portugal, both sharing the study area. In Portugal, territorial management has a strong interpretative imprint led by the activity of the Ecomuseo do Barroso (Montalegre), promoting cultural and rural tourism; in comparison, in Galicia, there is little knowledge of this mountainous space and only isolated initiatives of outdoor recreation and rural tourism are promoted. The recognition of the integrated values from nature and culture at the local scale could diversify and sustain initiatives for balanced rural development in this cross-border mountain.

Geomorphosites might become drivers of sustainable growth involving the relationships between people and place (McGranahan et al, 2011). The main challenge to connect global and local strategies, across well-managed geomorphological sites, is to make "geodiversity relevant to people, where they live and how they live" (Prosser et al, 2011, p. 341). In the European cross-border Mountains, relations based on cooperation are the main scenarios to reinforce links between nature conservation, socio-economic development and people well-being. This framework encourages institutional collaboration, always including education and public awareness, a territorial process fostered above all in the sites that remain 'hidden' for managers (Matthews, 2014). The Galicia-North of Portugal European Grouping of Territorial Cooperation (GNP-EGTC) was established in 2010 as an institutional framework in light of the global and European situation. The objectives of their joint investment programme 2014–2020, based on the territorial sustainability principle, are addressed to improve the shared management of the human environment and to consolidate the common identity. A strategic line, defined as "protection and effective use of the territorial resources", is focused on the increase of cross-border attractiveness and the planning of nature-based tourism. But specific guidelines for inland mountainous areas, related to their environmental values, are unclear. The foremost difficulties for the management of this shared territory concerns the different government systems in Portugal and Spain (Oliveira, 2015). In the North of Portugal, the policy decisions depend on the national government, while Galicia is an autonomous community where determinations hinge on the regional government.

In the context of regional development, the case study and its surrounding area embody the situation of mountainous and rural inland territories in the North of the Spanish--Portuguese border. Local population density is far below the population density of Galicia (93 inhab./km^2) and the North of Portugal (112 inhab./km^2). At present, the main threats at the Larouco Mountain are depopulation, land abandonment and deliberate fires. On the other hand, the main strength is represented by the landforms and landscape significance that evince diverse potentials for sustainable development. Besides this, the existence of an old cross-border identity can be the support for inclusive and smart relationships. The remoteness from the urban coastal settlements, the scarcity of innovation and the poor knowledge of this mountain are undoubted weaknesses for rural development, but sustainable management of their shared geo-resources, which keep the outstanding values, can enable the prompt opportunities by the regional, European and global institutions. Such a change, however, entails a more meaningful involvement of the institutional and social actors in the territory.

6. Conclusions and future research agenda

The inventory of geomorphological sites reveals the diversity of granitic landforms in the Serra do Larouco, which remains little known outside the area. Their assessment reflects several types and degrees of significance in other granitic terrains. The granitic landscape of the study area holds interesting landforms assemblages, although it lacks legal protection. The study area keeps a record of the origin and evolution of the relief in the Galician-Portuguese border. The association of the minor landforms with endogenous structures and the spatial distribution of the macro landforms reflect the control of the rock discontinuities patterns in the genesis and evolution of granitic relief. Landforms are polygenetic, developed by differential processes of weathering and erosion: the last stage in the landforms development relied on the action of periglacial processes during the Quaternary.

The categorisation and characterisation of landforms through the sites assessment provides specific information about landscape features. The method applied in this research allowed us to know the main interests and values of the inventoried assets, helping the comparison not only with other areas located in the South of Galicia (NW Spain) and the North of Portugal, but also with other works in the European territory. Both the characterisation and the qualitative and quantitative analysis of the data establish a set of values which are connected with the identity and function of the territory. As the research achieved in the Portuguese territory indicates, however, it is important to take into account that the variability of the rareness scores is always related to the selected spatial scale. The application of statistical exploratory techniques provides significant results on the data centrality, dispersion and variability, which give support to analyse and explain the assessment results. The summary statistics and position measures limit subjectivity in the interpretation, and make both the understanding and selection of the outstanding sites easier.

In view of the geomorphological and management values of the sites, their preservation is encouraged. It should be addressed to bridge gaps in geo-conservation and other environmental or socio-economic policies that affect rural sustainability of the border area. Proposals for sustainable use and management of such potential geomorphosites endorse several options with respect to planning development strategies. The selected sites symbolise the landscape key resources to sustain local populations, attract new residents or visitors, and improve current territorial conditions. These sites hold important assets which must be recognised and be valued by different stakeholders of the territory.

Consequently, further advances of the present research need to study more deeply the perception and prospects of the main territorial actors in a local and regional context. Moreover, the suitable outreach of the meaningful results from this study is crucial. Due to the symbolic identity of the Serra do Larouco, both in the context of the European border regions and the Spanish-Portuguese border, the forthcoming research will also be focused on the shared environmental policies by the institutional agencies.

References:

AEMET (2016): Open data of the Spanish Meteorological Agency [online]. National Government of Spain: Spanish Meteorological Agency website [cit. 04.12.2016]. Available at: http://www.aemet.es/es/datos_abiertos/catalogo

AMBROSIO-ALBALÁ, M., BASTIAENSEN, J. (2010): The new territorial paradigm of rural development. Antwerp, Publications of the Institute of Development Policy and Management.

BALTÀ PORTOLÉS, J. (2015): Cross-border Cooperation and Cultural Communities in Europe. Brussels, Centre Maurice Coppieters Publishing.

BENITO-CALVO, A., PÉREZ-GONZÁLEZ, A., MAGRI, O., MEZA, P. (2009): Assessing regional geodiversity: the Iberian Peninsula. Earth Surface Processes and Landforms, 34: 1433–1445.

BRUSCHI, V., CENDRERO, A. (2009): Direct and parametric methods for the assessment of geosites and geomorphosites. In: Reynard, E. et al. [eds.]: Geomorphosites (pp. 73–88). München, Pfeil.

CAPELLO, R., CARAGLIU, A. (2016): After crisis scenarios for Europe: alternative evolutions of structural adjustments. Cambridge Journal of Regions, Economy and Society, 9: 81–101.

COUDÉ-GAUSSEN, A., COUDÉ-GAUSSEN, G., DAVEAU, S. (1983): Nouvelles observations sur la glaciation des montagnes du nord-ouest du Portugal. Cadernos do Laboratorio Xeolóxico de Laxe, 5: 381–393.

CRESCENZI, R., LUCA, D., MILIO, S. (2016): The geography of the economic crisis in Europe: national macroeconomic conditions, regional structural factors and short-term economic performance. Cambridge Journal of Regions, Economy and Society, 9: 13–32.

COURTNEY, P., HILL, G., ROBERTS, D. (2006): The role of natural heritage in rural development: An analysis of economic linkages in Scotland. Journal of Rural Studies, 22: 469–484.

COUNCIL OF EUROPE (2006): Landscape and sustainable development: challenges of the European Landscape Convention. Strasbourg, Council of Europe Publishing.

DE VICENTE, G., VEGAS, R. (2009): Large-scale distributed deformation controlled topography along the western Africa-Eurasia limit: Tectonic constraints. Tectonophysics, 474(1–2): 124–143.

DOMÍNGUEZ, L., VIEIRA, E., FERREIRA, P. (2013): The Management of the European Solidarity: The INTERREG Programmes on the Border Region Galicia-North Portugal. Revista Universitaria Europea, 18: 83–102.

EUROPEAN COMMISSION (2010): Investing in Europe´s future. Luxembourg, Publications Office of the European Union.

EUROPEAN COMMISSION (2015): Territorial Agenda 2020 put in practice. Luxembourg, Publications Office of the European Union.

ERHARTIČ, B. (2010): Geomorphosite Assessment. Acta Geographica Slovenica, 50 (2): 295–319.

GARCÍA-ÁLVAREZ, J., TRILLO-SANTAMARÍA, J. M. (2013): Between Regional Spaces and Spaces of Regionalism: Cross-border Region Building in the Spanish "State of the Autonomies". Regional Studies, 47(1): 104–115.

GRAY, M. (2011): Other nature: geodiversity and geosystem services. Environmental Conservation, 38(3): 271–274.

HJORT, J., GORDON, J. E., GRAY, M., HUNTER, M. L. (2015): Why geodiversity matters in valuing nature's stage. Conservation Biology, 00(0): 1–10.

IGE (2016): Open data of the Galician Statistical Institute [online]. Autonomous Government of Galicia: Galician Statistical Institute website [cit. 04.12.2016]. Available at: http://www.ige.eu/igebdt/

INE.pt (2016): Open data of the National Statistical Institute of Portugal [online]. Government of Portugal: Statistics Portugal website [cit. 04.12.2016]. Available at: https://www.ine.pt/xportal/xmain?xpgid=ine_main&xpid=INE

IUCN (2013): Guidelines for Applying Protected Area Management Categories [online]. Best Practice Protected Area Guidelines Series, 21 [cit. 09.01.2017]. Available at: https://www.iucn.org/sites/dev/files/import/downloads/iucn_assignment_1.pdf

IUGS (2015): GeoHeritage Task Group Annual Report and Plan of action for 2016 [online]. IUGS – GeoHeritage Task Group website [cit. 09.01.2017]. Available at: http://geoheritage-iugs.mnhn.fr/media/pays/gtg-2015_report.pdf

KUBALÍKOVÁ, L., KIRCHNER, K. (2016): Geosite and Geomorphosite Assessment as a Tool for Geoconservation and Geotourism Purposes: a Case Study from Vizovická vrchovina Highland (Eastern Part of the Czech Republic). Geoheritage, 8(1): 5–14.

LOURENÇO FONTES, A. (1980): Culto ao deus Larouco, Júpiter e Ategina. Actas do II Seminario de Arqueología do Noroeste Peninsular, Guimarães, 3: 5–20.

MATTHEWS, T. J. (2014): Integrating Geoconservation and Biodiversity Conservation: Theoretical Foundations and Conservation Recommendations in a European Union Context. Geoheritage, 6(1): 57–70.

McGRANAHAN, D., WOJAN, T. R., LAMBERT, D. M. (2011): The rural growth trifecta: outdoor amenities, creative class and entrepreneurial context. Journal of Economic Geography, 11: 529–557.

MIGOŃ, P. (2006): Granite Landscapes of the World. Oxford, University Press.

MIGOŃ, P. (2014): The significance of landforms – the contribution of geomorphology to the World Heritage Programme of UNESCO. Earth Surface Processes and Landforms, 39: 836–843.

NALDI, L., NILSSON, P., WESTLUND, H., WIXE, S. (2015): What is smart rural development? Journal of Rural Studies, 40: 90–101.

OECD (2006): The New Rural Paradigm: Policies and Governance. Rural Development Reports, Paris, OECD Publishing.

OECD (2016): A New Rural Development Paradigm for the 21st Century. Development Centre Studies, Paris, OECD Publishing.

OLIVARES PEDREŃO, J. C. (2002): Los dioses de la Hispania céltica. Alicante, Publicaciones de la Universidad de Alicante.

OLIVEIRA, E. (2015): Constructing regional advantage in branding the cross-border Euroregion Galicia-northern Portugal. Regional Studies, Regional Science, 2(1): 341–349.

PANIZZA, M. (2001): Geomorphosites: concepts, methods and example of geomorphological survey. Chinese Science Bulletin, 46: 4–6.

PANIZZA, M. (2009): The Geomorphodiversity of the Dolomites (Italy): A key of Geoheritage Assessment. Geoheritage 1: 33–42.

PANIZZA, M., PIACENTE, S. (2003): Geomorfologia culturale. Bologna, Pitagora.

PENA DOS REIS, R., HENRIQUES, H. (2009): Approaching an Integrated Qualification and Evaluation System for Geological Heritage. Geoheritage, 1(1): 1–10.

PEREIRA, P. (2006): Património geomorfológico: conceptualizaçao, avaliaçao e divulgaçao. Aplicação ao Parque Natural de Montesinho. PhD Thesis, Universidade do Minho (Portugal).

PEREIRA, P., PEREIRA, D. (2010): Methodological guidelines for geomorphosite assessment. Géomorphologie: relief, processus, environnement, 2: 215–222.

PEREIRA, D. I., PEREIRA, P., BRILHA, J., CUNHA, P. P. (2015): The Iberian Massif Landscape and Fluvial Network in Portugal. Proceedings of the Geologist´ Association, 126: 252–265.

PROSSER, C. D., BRIDGLAND, D. R., BROWN, E. J., LAEWOOD, J. G. (2011): Geoconservation for science and society: challenges and opportunities. Proceedings of the Geologist´Association, 122: 337–342.

REYNARD, E. (2009: Geomorphosites, definitions and characteristics. In: Reynard, E. et al. [eds.]: Geomorphosites (pp. 63–71). Munchen, Pfeil.

REYNARD, E., PANIZZA, M. (2005): Géomorphosites: définition, évaluation et cartographie. Géomorphologie: relief, processus, environnement, 11(3): 177–180.

REYNARD, E., FONTANA, G., KOZLIK, L., SCAPOZZA, C. (2007): A Method for assessing scientific and additional values of Geomorphosites. Geographica Helvetica, 62(3): 148–158.

REYNARD, E., PERRET, A., BUSSARD, J., GRANGIER, L., MARTIN, S. (2016): Integrated Approach for the Inventory and Management of Geomorphological Heritage at the Regional Scale. Geoheritage, 8(1): 43–60.

RYPL, J., KIRCHNER, K., DVOŘÁČKOVÁ, S. (2014): Geomorphological inventory of rock landforms on Mt. Kamenec in the Novohradské hory Mts. (The Czech Republic). Carpathian Journal of Earth and Environmental Sciences, 9(3): 253–260.

RYPL, J., KIRCHNER, K., DVOŘÁČKOVÁ, S. (2016): Geomorphological Inventory as a Tool for Proclaiming Geomorphosite (a Case Study of Mt. Myslivna in the Novohradské hory Mts. – Czech Republic). Geoheritage, 8(4): 393–400.

RODRÍGUEZ GUITIÁN, M. A., RAMIL-REGO, P. (2008): Fitogeografía de Galicia (NW Ibérico): análisis histórico y nueva propuesta corológica. Revista Ibader, 1(4): 19–50.

SÁNCHEZ-ZAMORA, P., GALLARDO-COBOS, R., CEŃA-DELGADO, F. (2014): Rural areas face the economic crisis: Analyzing the determinants of successful territorial dynamics. Journal of Rural Studies, 35: 11–25.

SCHMIDT-THOMÉ, P. (1978): Nuevos testigos de una glaciación würmiense extensa y de altura muy baja en el Noroeste de la Península Ibérica (Orense, Espańa y Minho/Tras-os-Montes, Portugal). Cuadernos do Seminario de Estudos Cerámicos de Sargadelos, 27: 219–243.

SERRANO-CAŃADAS, E., GONZÁLEZ-TRUEBA, J. J. (2005): Assessment of geomorphosites in Protected Natural Areas: the Picos de Europa National Park (Spain). Géomorphologie: relief, processus, environnement, 11(3): 197–208.

SERRANO, E., RUIZ-FLAŃO, P. (2007): Geodiversity. A theoretical and applied concept. Geographica Helvetica, 62(3): 140–147.

TWIDALE, C. R., VIDAL-ROMANÍ, J. R. (2005): Landforms and Geology of Granite Terrains. Leiden, Balkema.

UNESCO (2016): World Heritage Convention and Sustainable Development [online]. Reports of the World Heritage Centre and the Advisory Bodies: WHC/16/40. COM/5C [cit. 09.01.2017]. Available at: http://whc.unesco.org/archive/2016/whc16-40com-5C-en.pdf

VIDAL-ROMANÍ, J. R., VAQUEIRO, M., SANJURJO, J. (2014): Granite Landforms in Galicia. In: Gutiérrez, F., Gutiérrez, M. [eds.]: Landscapes and Landforms of Spain (pp. 63–70). Dordrecht, Springer Science.

VIDAL-ROMANÍ, J. R., FERNÁNDEZ-MOSQUERA, D., MARTI, K. (2015): The glaciation of Serra de Queixa-Invernadoiro and Serra do Gerês-Xurés, NW Iberia. Cadernos do Laboratorio Xeolóxico de Laxe, 38: 25–44.

VIEIRA, A. (2008): Serra de Montemuro: dinámicas geomorfológicas, evoluçao da paisagem e patrimonio natural. PhD Thesis, Universidade de Coimbra (Portugal).

VIEIRA, A., FIGUEIRÓ, A. S., CUNHA, L. (2014): Metodologia de avaliaçao do patrimonio geomorfológico: Aplicaçao á Serra de Montemuro (Portugal). Proceedings I Encontro Luso-Brasileiro de Património Geomorfológico e Geoconservaçao, p. 181–187.

VIEIRA, A., DE SOUSA, A., CUNHA, L., BENTO-GONÇALVES, A. (2015): Vestígios de glaciaçao nas serras do NW de Portugal continental: Síntese dos conhecimentos atuais e perspetivas de investigaçao. Revista Brasileira de Geomorfologia, 16(1): 79–87.

VIŠNIĆ, T., SPASOJEVIĆ, B., VUJIČIĆ, M. (2016): The Potential for Geotourism Development on the Srem Loess Plateau Based on a Preliminary Geosite Assessment Model (GAM). Geoheritage, 8(2): 173–180.

WERLEN, B., OSTERBEEK, L., HENRIQUES, H. (2016): 2016 International Year of Global Understanding: Building bridges between global thinking and local actions. Episodes, 39(4): 604–611.

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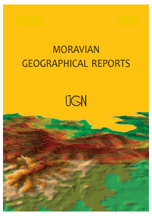

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DE GRUYTER OPEN

Landscape degradation at different spatial scales caused by aridification

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Abstract

Landscape responses to degradation caused by aridification bring the landscape system into a new equilibrium state. The system transformation may entail irreversible changes to its constituting parameters. This paper analyses the impact of aridification on landscape degradation processes in the sand-covered landscapes of the Hungarian Danube-Tisza Interfluve region at the regional, landscape, and local site scales. Changes in groundwater level (well data), lake surface area (Modified Normalized Difference Water Index) and vegetation cover (Enhanced Vegetation Index) were analysed over time periods of 12–60 years. Significant regional variation in decreasing groundwater levels is observed and limits the regional applicability of this indicator. Applying the lake surface area parameter from remote sensing data demonstrated greater utility, identifying several local lakes in the landscapes which have dried out. Analysis of the vegetation response indicated minor changes over the 2000–2014 time period and did not indicate a landscape system change. Landscape degradation as a result of changes in groundwater, vegetation, land cover and land use is clearly identified exclusively in local lake areas, but at the landscape scale, changes in the water balance are found in phases of system stability and transformation. Thresholds are identified to support policy and management towards landscape degradation neutrality.

Keywords: *landscape degradation processes; groundwater level change; vegetation index; Modified Normalized Difference Water Index; Carpathian Basin; Hungary*

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1. Introduction and theoretical background

Landscape degradation and desertification processes are taking place around the world and there is a need to analyse accurately the key regions, landscapes and the impacts of land degradation on local sites, to better understand the climate and global change impacts, including the aridification processes. The on-going aridification in the Carpathian Basin caused by the diverse influences of climate change, global change and land use changes is rarely investigated (Blanka et al., 2013; Kohán, 2014), and it has not yet been analysed with respect to landscape degradation. In general, there is a great diversity of studies and handbooks on land degradation problems and counter-measures both at the local and global scales, but without analysing the spatial and temporal variations of the aridification process (UNEP, 1997; LADA, 2016; Reed et al., 2011). Considering the internal structure of these processes, most of them are cross-scale interactions (Soranno et al., 2014), especially when land use is included in the analysis.

1.1 Landscape systems and landscape degradation

The science of land systems integrates global challenges and local realities (Verburg et al., 2013: 433) by analysing "human-induced transformations of ecosystems and landscapes and the resulting changes in land cover beyond local alterations and pervasive factors of global environmental change".

Landscapes are usually analysed in a system-perspective (Nassauer and Opdam, 2008) at scales ranging from 1:10,000 to 1:100,000, thus from a micro- to a macro-landscape scale. Landscapes are characterised by entities of the earth's surface described by biophysical, social, economic and land use factors with a "homogeneous structure and process mosaic value, where a full integration of the system components (e.g. climate, geology, relief, water, soil, vegetation, fauna, land use, culture and human impacts) exists" (Bastian and Steinhardt, 2002; Neef, 1967). Landscapes are investigated commonly using models of landscape functions (Meyer, 1997) and ecosystem services

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(DeGroot, 1992), linking systematically the biophysical, the social and economic perspectives for management, policy and planning.

A landscape represents a complex and open functioning abstract entity with material and energy flow across its borders and, as such, it is an open and dynamic system with parameters whose interrelationships lead to high complexity (Brunsden, 2001; Usher, 2001). As a system, a landscape has an internal regulation (feedback) of its own, which can shift it partly towards a stable state, i.e. balance, or in the case of positive feedback, towards a state of imbalance. Degradation negatively impacts the ability of the system to return to a stable and balanced state. We understand and define "landscape degradation" as an irreversible or non-resilient system change to a landscape that affects the landscape system components (i.e. their geo-factors, land use and inter-linkages), the natural and cultural capacities of the landscape in terms of structure, processes and landscape functions (productive, ecological and social). Therefore we analyse landscape degradation from a system perspective in terms of sensitivity, stability and resilience, to determine thresholds of landscape change.

Science and policy practices in actual land degradation analysis afford special emphasis to soil and water in land use systems modified by climate change (Buendia et al., 2015). Stocking and Murnaghan (2000) give guidelines for field assessments of land degradation, including examples on how resilience and sensitivity are affected by various factors, but without including the long-term perspective of regional aridification. The cited studies are focused on local problems of land degradation and generally on indicators of land degradation for policy advice at the national scale. At the same time, studies of landscape degradation and aridification are rare and generally investigated with a long-term geomorphological perspective, for example in the aridification analysis of the Holocene (Kertész and Mika, 1999; Kirchner, 2014; Albert, 2015). These studies do not reflect the actual ongoing climate change and land use changes in short-term periods of a few decades. Other studies are based on climate data time series and statistical analysis of changes between reference periods (e.g. 1961 to 1990), the actual status and scenario futures through 2100 by linking the results of regional climate change modelling and the biophysical modelling of landscape function, to understand ongoing and expected degradation problems (Rannow et al., 2010; Mezősi et al., 2013; Blanka et al., 2013).

1.2 Aridification in the Carpathian Basin

The Carpathian Basin has experienced increasing temperature and a changing precipitation distribution over the past century (Bartholy et al., 2011). An increasing number of hydro-climatic hazards causing extensive damages over the past decades are verified (Bartholy and Pongrácz, 2010). Furthermore, the development of extensive drainage systems in the middle of the 20th century and groundwater overexploitation contributed to changing hydrological conditions, characterised by decreasing groundwater levels and a changed surface water distribution pattern, especially in the elevated region between the Danube and Tisza Rivers (Kuti et al., 2002; Rakonczai, 2007). Rakonczai (2007) has emphasised that in 10% of this region, aridification had caused irreversible impacts because the groundwater resources could not regenerate even after extreme humid periods.

In the Hungarian - Serbian cross-border region, Fiala et al. (2014) found a statistically significant threshold level change of PaDI (Pálfai drought index), based on the mean air temperature of the April–August period (° C) and the weighted sum of precipitation (mm) from October - August in the 1961–2012 period. This analysis found a phase change at approximately 1987 as the mean PaDI increased from 4.76 in the 1961–1987 period (equilibrium I) to 5.65 in the 1988–2012 period (equilibrium II). This observation has been supported by the Hungarian regional landscape drought map (Blanka et al., 2013), also based on the PaDI, and shows the highest actual and future drought exposure in the Great Hungarian Plain and the Danube - Tisza Interfluve region. The future scenario for climate change impacts on droughts, developed in the same study, resulted in extremely high PaDI values of 6–7 in the 2012–2050 period and values higher than 8 in the 2071–2100 period, indicating increasing aridification problems (Blanka et al., 2013). In addition, regional climate models also predict the increasing frequency and duration of drought events (Blanka et al., 2013), and suggest that the Great Hungarian Plain will be the most drought-prone area in Hungary at the end of the 21st century.

Aridification refers therefore generally to a regional drier environment caused by climate change and human impacts. Over the last century, the Carpathian Basin received at least 100 mm less annual average precipitation; therefore, aridification is one of the most important hazards in this area. The consequences are partly known and include a decreasing water supply causing changes in vegetation, reducing biological productivity, lowering the groundwater table, reducing agricultural productivity and leading to the occurrence of soil degradation (Mezősi et al., 2013). Literature analyses of the potential landscape degradation caused by aridification, with respect to ecological and social landscape functions, as well as provisioning, regulating, cultural and supporting ecosystem services, mostly concern solutions to local problems. The implicit policy in landscape ecology of avoiding degradation on a meso-scale refers at the same time to models of ecosystem functions in heterogeneous landscapes (Lovett et al., 2005), including landscape system analysis using landscape functions as indicators (Meyer and Grabaum, 2008).

1.3 System changes in landscape degradation indicators

System changes of water functions occur faster than system changes in vegetation or in the soil structure (Farina, 2006). Thresholds are commonly used to specify the rate of internal regulation and to clarify levels of a system change. We are currently unable to specify the integrative numerical threshold applicable to a landscape (as a system); therefore, the state of degradation is estimated on the basis of individual thresholds of inherent landscape parameters as indicators. Indicators such as groundwater level change, soil erosion and vegetation degradation are well known (Bridges and Oldeman, 1999; Kairis at al., 2014; Salvati and Forino, 2014). Landscape degradation, in this context, refers to the decline of the synthesis of all parameters (Kertész, 2009). Since all parameters are never available at the landscape or regional scale, meaningful parameters or indicators to differentiate landscape degradation have to be found, including the intrinsic landscape heterogeneity.

In the Carpathian Basin aridification may result in groundwater level and water surface area changes, potentially modifying the local site or the landscape scale level through a complete ecological transformation. Through its impact on landscape parameters, the aridification may cause parameters or indicators to change or the landscape or regional system may change to reach a modified balance state. For example, the vegetation in a landscape includes the soils change as a result of aridification, by physical-chemical modification, which may in turn increase the sensitivity of the landscape to certain processes (e.g. wind and water erosion), and occasionally results in a system transformation to another equilibrium state (White et al., 1992; Mezősi et al., 2015). Monitoring the continuous change in land use is a useful tool for measuring the transformation process by thresholds, e.g. by the groundwater depth level changes in a landscape in conditions of aridification.

Our study therefore investigates land degradation case studies in Central Hungary at three scales: the regional, meso- and local-scale. The objectives are: (1) to analyse aridification resulting in landscape degradation by applying different indicators; and (2) to clarify linkages between landscape degradation and aridification by meaningful parameters, based on the time series of different data sets. The analysis of indicators in a systems context should help to understand and to develop thresholds of aridification-caused changes in landscape degradation.

2. Material and Methods

2.1 Study Area

The ongoing climatic aridification process in the Carpathian Basin, which causes groundwater shortages, lower lake levels and vegetation degradation in the lake surroundings, was analysed using regional-, landscape-, and local-scale examples. The climatologic conditions yield homogenous aridification throughout the Danube - Tisza Interfluve region in Central Hungary. The regional example is the Danube-Tisza Interfluve region (4,708 km^2); the landscape examples are the Illancs and Bugac landscapes (221 km^2 and 1,114 km^2); and the local area example is Lake Kunfehértó (3.6 km^2) within the Bugac landscape (Fig. 1).

The Danube-Tisza Interfluve region under investigation is a plain formed in the Pleistocene and Holocene by the Danube River, and large areas are typically overlaid by aeolian sands and loess sediments on the alluvial fan. The heterogeneous lithological sites are configured into a mosaic of patchy distributed land uses holding heterogeneous site sensitivities to aridification, also controlled by the distance to the Danube and Tisza rivers. The central parts of the region are elevated 20–30 m higher than the river-flats. Sand dune stretches are interspersed with saliferous depressions, wet meadows, and 255 small lakes are included. The groundwater is typically 3–7 m below the surface and often even deeper in loess covered areas.

The Illancs landscape is located orographically higher than the Bugac landscape on the plain. It is homogeneously covered by non-active sand dunes, causing a fissured orography without lakes due to the direct infiltration of precipitation into the groundwater. Nevertheless, water shortage is considerable here, and the shortage in the water supply is one of the causes of the groundwater level decrease. The years with higher precipitation since 2000 failed to recharge the groundwater (Szalai, 2014). In contrast to Illancs, the Bugac landscape has high spatial site heterogeneity, including 63 lakes in depressions between the sand dunes.

The saliferous Lake Kunfehértó is located approximately 30 m orographically higher than the actual river valleys of the Danube and Tisza in the southwest of the Bugac landscape, near the landscape border of the Illancs landscape. The lake is located in a depression between sand dunes, and the actual size of the lake has decreased as a result of widespread drought because the lake was formally mainly supplied by rainfall. From time to time water is pumped into the lake to manage it for recreational purposes.

2.2 Methods, data and indicators

Climatic changes and aridification are the principal causes influencing the indicators of landscape degradation analysed in our study: (1) the groundwater level change

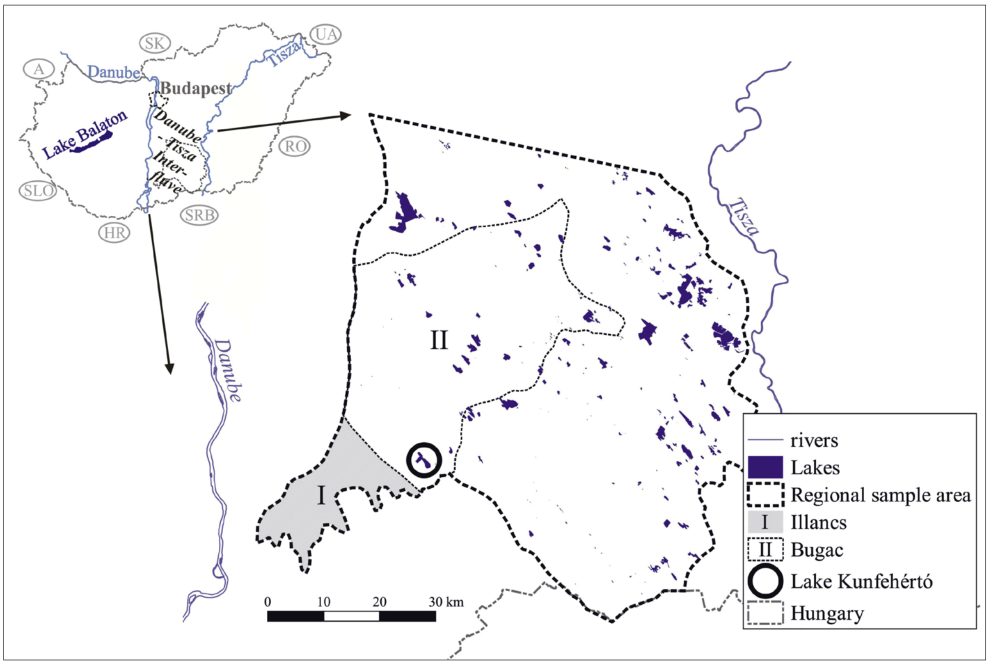

Fig. 1: The Danube-Tisza Interfluve region in Hungary, including the Illancs and Bugac landscapes, lakes and local research area at Lake Kunfehértó. Source: authors' elaboration

caused by the shortage of water; (2) the lake surface area change caused by the shortage of water; and (3) the vegetation vitality change in the lake surroundings due to long-term water shortage (Tab. 1). The indicators are used therefore to identify thresholds and system behaviour on regional, landscape and local scales.

Information on climate, climate change and aridification, including drought, is taken from earlier studies by the authors' group for this study (Blanka et al., 2013; Mezősi et al., 2013; Fiala et al., 2014), as described in the Introduction. Blanka et al. (2013) provide detailed information on the measurement, data and calculation of the Pálfai Drought Index (PaDI aridity index) for the 1985–2012 period. The aridity map was prepared using the PaDI with the aim of describing the drying climate and the related changes (Pálfai and Herceg, 2011). Precipitation data in the 1951–2013 period are analysed based on two Hungarian Meteorological Service stations for Lake Kunfehértó. The results of Blanka et al. (2013) expect that the lake area is an appropriate parameter for determining the threshold of landscape degradation caused by its sensitivity to precipitation and evaporation change, and the fast system response in water household.

The groundwater depth is one of the most important parameters in the analysis of system changes for aridification and landscape degradation problems. The groundwater level/shortage of water indicator analysed in our study is based on the data from the monitoring network of OVF (the Hungarian national water authority). Well data have been recorded in Hungary since the 1930s and have been used to evaluate the landscape according to lithological and topographical conditions to assess regional differences and the extent of water shortages. For several wells in the Illancs and Bugac landscapes, data from 1951 to the present are available. The rate of change is based on the monitoring wells (3 wells in Illancs, 11 wells in Bugac, 1 well for Lake Kunfehértó), which is then taken to analyse differences in the groundwater level and, therefore, the potentially lacking groundwater recharge. The related value is considered as a threshold because changes in groundwater depth are considered a key parameter of water sensitive systems. Trend analysis was applied using SPSS software to assess the groundwater depth and the rate of groundwater recharge. Groundwater depth data therefore are used to clarify regional, landscape and local thresholds, and to identify changes caused by aridification by applying known relationships between the water supply and vegetation cover in the lake surroundings.

The size, area and number of lakes at different time steps was measured by using up to thirty years time series of remote sensing data obtained with the methods described as follows (Tab. 1). The lake surface area/shortage of water indicator was analysed by Landsat time series of lake surface development based on the Modified Normalized Difference Water Index (MNDWI) (Xu, 2006). MNDWI was also employed for the analysis of the vegetation status because a qualitative change in vegetation (on association level) is a precondition for landscape degradation. The Landsat data time series is available for the 1985–2015 period.

The vegetation in the lake surroundings indicator is analysed using the Enhanced Vegetation Index (EVI) (Huete et al, 2002), based on data drawn from MODIS (Moderate Resolution Imaging Spectroradiometer) for the time period between 2000 and 2014. For both indicators, MNDWI and EVI, the sum and the variation are analysed.

3. Results and discussion

We analysed the landscape degradation potentially caused by aridification at three different spatial scales, by regional, landscape and local examples in a spatially nested approach, using the groundwater level, the lake surface area and vegetation indicators as system proxies. For a better understanding of landscape degradation, special emphasis is given to the length of the time series and the different reaction times of the indicators to aridification impacts.

Indicator and data	Regional scale Danube-Tisza Interfluve	Landscape scale Illancs and Bugac	Local scale Lake Kunfehértó
Area	4,708 km^2	221 km^2 and 1,114 km^2	3.6 km^2
Climate/Aridification (subject of previous studies by the authors' group)	PaDI Aridity index; 1985–2012; Hungarian drought map on regional landscape scale (Blanka et al., 2013)	PaDI Aridity index; 1985–2012; Hungarian drought map on regional landscape scale (Blanka et al., 2013)	Precipitation; 1951–2013; 2 Hungarian Meteorological Service stations
Groundwater level/ shortage of water	Groundwater level; 1970–2014; OVF well data (Szalai et al. 2014)	Groundwater level; 1953–2007; OVF well data: 11 wells (Bugac), 3 wells (Illancs)	Groundwater level; 1951–2012; OVF data: 1 well
Lake surface/ shortage of water	Lake surfaces; MNDWI index; 1985–2015; Landsat data	Lake surfaces; MNDWI index; 1985–2015; Landsat data	Lake surfaces; MNDWI index; 1985–2015; Landsat data
Vegetation	Vegetation in the lake surroundings 100 m buffer; EVI index; 2000–2014; MODIS data	Vegetation in the lake surroundings 100 m buffer; EVI index; 2000–2014; MODIS data	

Tab. 1: Data and methods used at regional, landscape and local scales (Note: For abbreviations: see text)
Source: authors´ conceptualisation

3.1 Landscape degradation in the Danube-Tisza Interfluve Region

Figure 2 demonstrates in most parts of the regional investigation area, a substantial decrease in groundwater indicator levels in May in comparing the 1971–2000 period average with that level in 2014. Crucial hotspots of groundwater decline are observed by a groundwater level decrease larger than 2 m.

The lake surface area indicator in the region in the period 1986–2015 shows a significant decrease until the mid-1990s (remote sensing data have been available since 1986). After the mid-1990s, no further decrease is recorded below the 6% lake surface area level and the indicator is stable overall between 2002 and 2015, but lower than the 7–8% recorded from 1986 to the mid-1990s (Tab. 2). Consequently, aridification in the region does not result in a degradation of all lakes, as more than 25% of the lakes surface area decrease is observed.

The findings for the periods from 2002 to 2005 are confirmed through the EVI analysis of the MODIS satellite June data in the 2000–2014 period (Fig. 3). The annual EVI sum does not show any significant changes of the vegetation in the lake surroundings indicator as well, despite considerable drought periods recorded in the late spring of 2003, in the summer of 2007, and in autumn and winter of 2011 (Blanka et al., 2013). The minima and maxima of EVI vary without significant tendency of change. Hence, this indicator is used to clarify whether the temporal water shortage effects of droughts exceed a regional system threshold during the analysed (short) period of only 14 years.

3.2 Landscape degradation in the Bugac and Illancs landscapes

As mentioned above, the Bugac landscape has the same lithological and pedological structure, vegetation coverage and land use configuration as the Danube-Tisza Interfluve region. Here, open water surfaces, including a 100 m buffer zone around the lakes, cover approximately 3,500 ha or 3% of the landscape. Due to a scarcity of Landsat images suitable for a qualitative measure of the lakes, it is difficult to create a series of continuous change; nevertheless, 7 data records are available (Fig. 4). As the average percentage of open water surface suggests, the changes are identical to the trend in the lake surface area indicator found for the region (Tab. 2). A change phase between 1986 and 1991 is followed by ongoing fluctuations in lake surfaces area after 1991. As far as the state of the vegetation in the lake surroundings is concerned, some changes are noted without

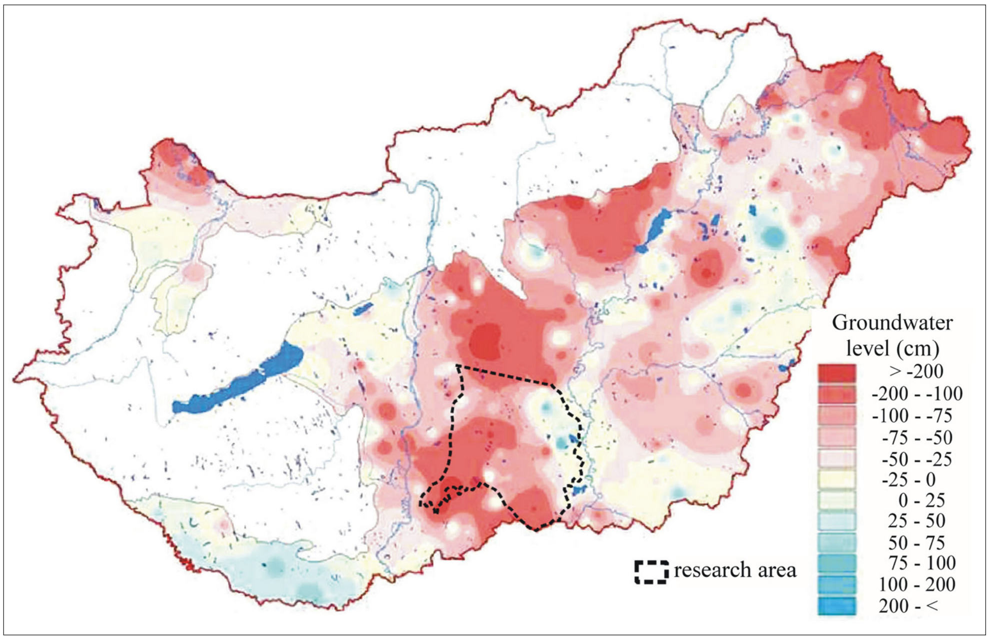

Fig. 2: Change of groundwater levels in May (cm); the average of the period 1971–2000 is compared to that of 2014
Source: Map is based on OVF well data pubished by Szalai et al., (2014)

Time	Danube-Tisza Interfluve Region	Bugac Landscape	Illancs Landscape	Lake Kunfehértó Local site
19.06.1986	8.1	3.2	–	20.0
08.07.1987	7.3	3.1	–	19.0
17.06.1991	6.8	2.6	–	3.1
15.06.2002	5.7	2.6	–	1.7
26.06.2006	5.4	2.0	–	1.7
13.06.2013	5.2	2.6	–	1.7
05.07.2015	6.0	2.5	–	1.8

Tab. 2: Lake surface indicator
Source: Open surface water (in %) based on Landsat data using MNDWI at different scales from 1986–2015

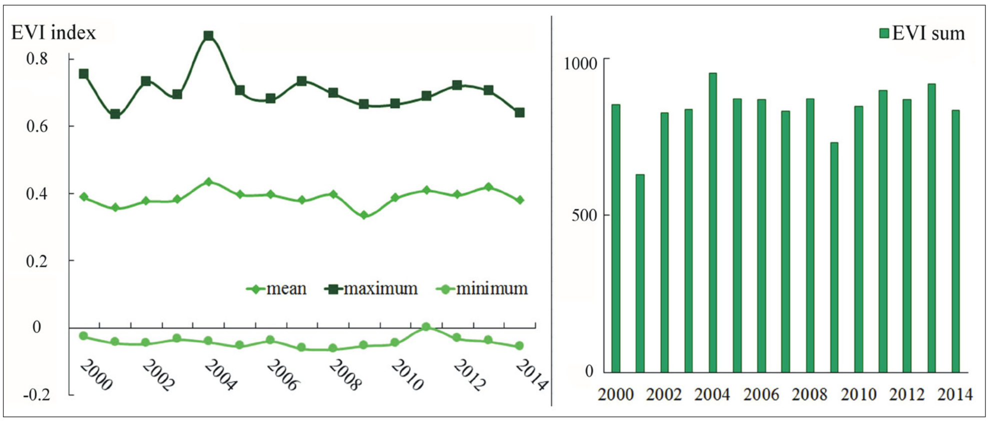

Fig. 3: Vegetation indicator: MODIS EVI variation and EVI sum of the Danube-Tisza Interfluve region from 2000 to 2014. Source: authors´ calculation based on MODIS data 2000–2014

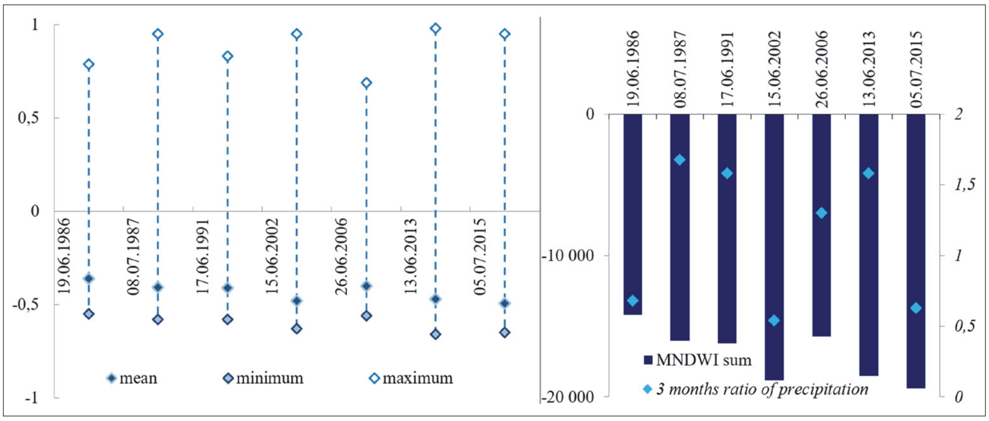

Fig. 4: Lake surface indicator: MNDWI variation and sum in the Bugac landscape
Source(s): authors´ calculation based on Landsat 1986–2015 data

a clear trend in the MNDWI index values (Fig. 4). In the Illancs landscape, no lake area is found by Landsat data; therefore, no changes are detected.

The Bugac landscape is characterised by multiple sand dunes, and the surface form is oriented by NW-SE winds, creating a characteristic parabolic shape and influencing the vegetation distribution. Nevertheless, these land forms are levelled out by agriculture and silviculture. Changes in the hydrological regime and shortage in water quantity modify the extent and the species composition of the wetlands. According to Ladányi et al. (2011a; 2011b), in this landscape aridification was interpreted and confirmed by a decreasing extent of wetlands, the increasing number of *Crataegus monogyna Jacq.* in Molinia meadows, and also in the shift of vegetation zones in wetland study areas of the Illancs landscape. The spread of invasive species (e.g. *Amorpha fruticosa L.* and *Asclepias syriaca L.*) and the fragmentation are threatening factors for transforming wetlands into dry steppes (Ladányi et al., 2011a; 2011b). The general trend of aridification is confirmed by the lake surface area decrease and, after the mid-1990s, by a new and lower stable state equilibrium observed that also includes a higher variability of the lake level area.

Figure 5 demonstrates the same trend as described above, with a significant decrease in the groundwater level indicator since 1970 in the Illancs landscape. The decrease of up to 20 m is confirmed in comparison to the Bugac landscape and measured at a higher orographical position of the Danube--Tisza Interfluve Region (but only confirmed by a short data row for well 4145) and compared to the groundwater levels measured in 1970 at the wells 1425 and 3617. The groundwater level at well 1425 decreased after 1980, which is significant when analysed with the data measured since 1960 at well 3617. An ongoing decrease of groundwater levels is observed but not fully explained by the regional aridification because groundwater pumping for irrigation purposes was applied in the same landscape. Other studies indicate that between 1950 and 2010, there was a 0.002–0.003 km^3 / km^2 average yearly reduction in the available groundwater recharge in the Illancs landscape (Rakonczai, 2015). It is rather difficult to formulate threshold estimates due to the large number of potential parameters influencing the groundwater level decrease involved.

Another study showed that out of the natural parameters, first the change in the amount of precipitation and second the altitude of the landscape, should be considered to specify that a slight decreasing trend in annual precipitation is confirmed between 1950 and 2010 for the investigated area (Mezősi et al., 2014). From the same study in the same time period, with steadily increasing temperature and evaporation, no increase in the water supply is predicted in the long term. Thus, the threshold for the elevated surfaces is expected at a groundwater level to range widely between 12 and 16 m, as suggested by the extensive precipitation that occurred in 2000 and 2010. We interpret the well data with respect to landscape degradation here by a steady decrease of available water to allow the groundwater level to regenerate. These values may change considerably also due to land management effects, especially with respect to potential land use changes. The fairly slow process of landscape degradation first manifests itself in the direction indicated by the water household changes, later followed by vegetation changes, including potential changes in the chemical soil properties.

3.3 Landscape degradation for the local example of Lake Kunfehértó

The Lake Kunfehértó data record from the groundwater monitoring wells suggests that the extensive and steady drop in the water level may have resulted in irreversible dry out. Apparently, the natural state of the lake has come to an end, caused by the lack of water inflow. The lake surface area decreased dramatically to only 10% of the area observed in 1986 (Tab. 2). Water is essentially pumped in by management from external resources (e.g. by using groundwater) in limited amounts due to the need to maintain a recreation-based investment (Fig. 6).

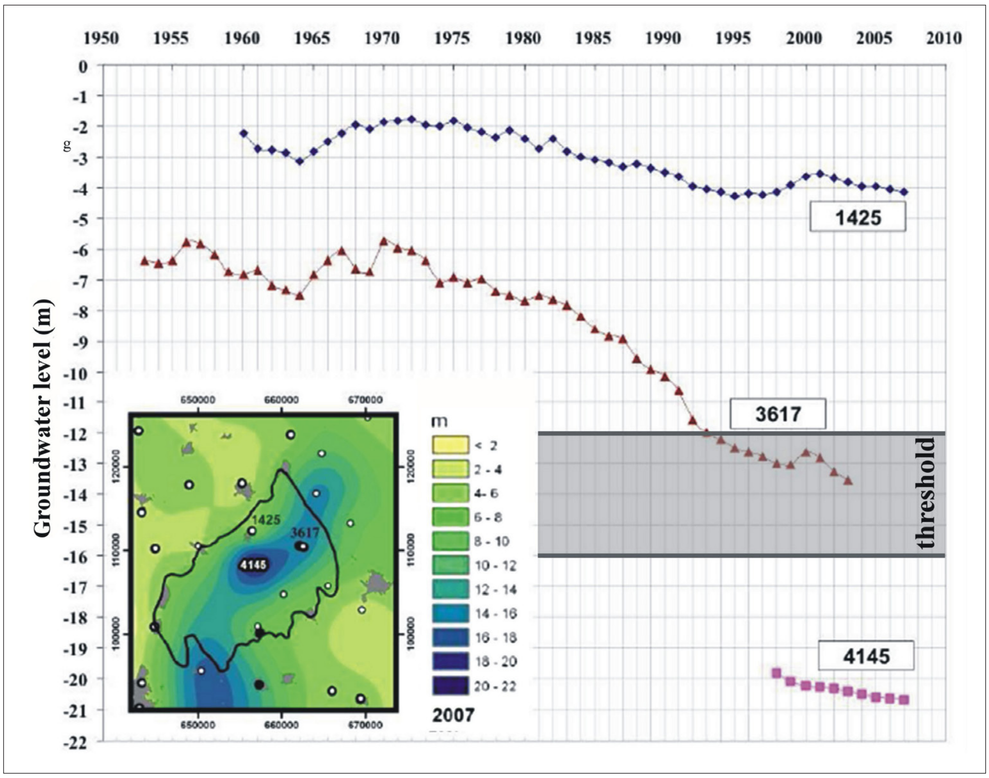

Fig. 5: Groundwater level indicator decrease and threshold (average values of monitoring wells No. 1425, 3617 and 4145 in the Illancs landscape based on OVF data from 1953–2008
Source: authors´ elaboration using Groundwater level 1953–2007 of OVF well data, Szalai (2012) map and interpretation of Ladanyi et al (2011b)

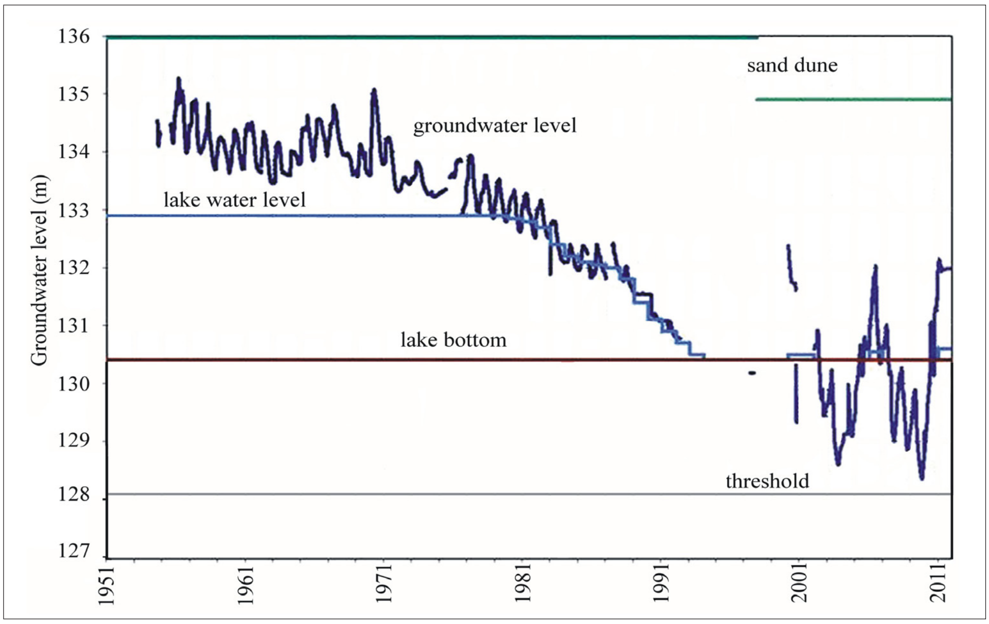

Fig. 6. Lake Kunfehértó: Water level decrease and dry-out periods since 1993. The threshold line indicates the system level change in degradation signal. The water household of the lake is artificially maintained and regulated
Source(s): Groundwater level; 1951–2012; OVF data: 1 well, (based on the figure from Szalai, 2014, changed)

The question arises as to whether the notion of landscape degradation is applicable to this local and managed example. Even without landscape analysis, it is evident that the natural state of the lake would be dried out, followed by conversion into another land-use type, such as wet forest or grassland. The major question is whether the result was caused by aridification/water shortage, which is well explained by the more than 1,000 mm precipitation reduction in the period of 1970–1990 compared to the average precipitation of the 1900–1970 period in the Danube-Tisza Interfluve region (Szalai et al., 2014). In addition to aridification, the transformation of the lake is influenced by a number of anthropogenic causes, which have been assessed by Rakonczai (2011). Using a number of parameters, geo-statistical methods have allowed researchers to identify and rank the lowered groundwater level: aridification, the increase in forests in the catchment area and increased water uptake are the main contributing parameters (Szalai et al., 2014). As a result of the combined effects of aridification and the above parameters, the groundwater level has declined by 3.5 m since 1970, the lake dried out and water was pumped to the area for maintenance (Fig. 6). The threshold value calculated in Figure 6 by trend analysis shows that the decrease in groundwater level has not yet reached the extent to which the restitution of the water level is doubtful. The water household of the lake is artificially maintained and regulated by management. Aridification and anthropogenic intervention (water management, forestation) contributed to the higher sensitivity of the area to environmental impacts. Of the variables influencing the lake system, only the groundwater level indicator is analysed in Figure 6, and the impact of aridification is studied from this perspective. Here, by using data supplied by groundwater monitoring wells and by performing a trend analysis using SPSS, an estimated groundwater level threshold of at least 128 m (3.0 m below the lake bottom) is defined to determine an irreversible system change.

It should be stressed again that this lake no longer functions as a natural system supplied by rainfall, and its functioning is predominantly managed. Hence, land degradation cannot be interpreted in this local example without the external parameters of aridification and anthropogenic parameters including water management, canalisation, forestation and building activities serving recreation purposes. The larger landscape scale may help to better understand the lake in its surrounding context.

3.4 Aridification causing system level changes for landscape degradation indicators

The objective of the analysis was to establish whether aridification could lead to landscape degradation and whether such degradation manifested itself by making the plains of the Carpathian Basin sensitive to changes. In other words, did we encounter a state where landscape components made up a system with a new type of stability? This landscape-based integrated approach to the issue is a further development of the spatial interpretation of land degradation.

The study considered three scale levels, i.e. regional, landscape, and local sites. The key parameter suitable for change detection is the groundwater level and water supply, and the status of the lake surface area. For the Illancs landscape, the last parameter is not applied due to the lack of lakes on the sandy surface. Crucial changes in open surface water were found on the neighbouring Bugac landscape. Regarding lakes, the decrease in open surface water surface predominantly occurred during the 1970–1995 period. Since then, no signals of major new and persistent change were recorded. Lake surface area stabilised at a lower level in approximately 1995, and a regional and landscape system with this new stability level was interpreted. Simultaneously, no change was recorded in the area of the local lake Kunfehértó over recent decades due to the water level being artificially maintained.

Therefore, water depth data from the groundwater monitoring wells were analysed as a key parameter. Data derived from groundwater monitoring wells are, however, difficult to generalise, especially for the landscape and regional systems, due to their heterogeneity in lithology, orography and land use. The analysis of effects of documented land use changes on the albedo of Eastern Hungary from 1951 to 1993 presents minor evidence of groundwater influence by land use by an increasing evapotranspiration of 8 mm or a 3% change in evaporation based on an average of 280 mm (April–October) in the respective period (Mika et al., 2001). Other studies underline the significance of regional land use changes caused by the abandonment of agricultural land, followed by natural reforestation and affecting, for example, the water resources in catchments and the river morphology in the Dragonja basin, South Western Slovenia, (Keesstra et al., 2005). Keesstra (2007) also found a threshold for sediment deposition change in the lower part of the same catchment area: 95 per cent less sediment deposition during 1986–2001 compared with the 1960–1986 period, caused by a modified openness of the soil surfaces from the changed vegetation cover. Land use changes in mountain zones with a torrential run-off regime influence the river floodplain in the short term, as well as by extreme events dynamics (Sanjuán et al., 2016). Nevertheless, large parts of our investigation area, with the exception of the Danube and the Tisza River floodplains in the surroundings, are not influenced by external factors of inflowing water, and land use change is a factor not yet analysed on a long time series basis in the context of landscape degradation in this region.

In our study, changes in the groundwater levels indicator follow the same pattern as noted for lake surface area variation using the MNDWI index. In principle, a threshold of groundwater depth may be interpreted for a landscape and a local site. That is, if groundwater levels are maintained below the threshold level for a long time and the original state will not be regained, even after major groundwater recharge during a wet period. This trend indicates the recharge potential of groundwater levels at monitoring wells now operating for longer than 50 years. While that value is also estimated in local cases, the anthropogenic impact on the lake water balance appears to override this effect at local scale for Lake Kunfehértó (Tab. 2). As far as the Illancs landscape is concerned, aridification is again associated with water shortage and the decline of the groundwater level. The number of groundwater monitoring wells with recording periods longer than 50 years is small, only two; therefore, the estimated threshold is statistically rather uninformative.

Other parameters, e.g. the changes in MNDWI (Tab. 2) confirm the occurrence of land degradation in the Bugac region in the period between 1986 and 1991. Nevertheless, the variation and the MNDWI sum in the Bugac landscape on lake surfaces indicate no clear tendency in land degradation after this major change in the mentioned period, since the systems state change (Fig. 4). We also note a data gap for reliable statistical analysis when interpreting the remote sensing information of MNDWI by the systems change around the year 1987 by Landsat data. The interpretation of the vegetation indicator by MODIS EVI variation and EVI sum of the Danube-Tisza Interfluve region is also based on too short a time period for aridification caused landscape degradation analysis, since the data are available starting from 2000 till 2014 when using MODIS system (Fig. 3).

A full statistical linkage of aridification and landscape degradation, analysed as irreversible system-level changes and measured by thresholds, is still difficult to verify due to complex interlinkages and the multiple potential indicators and variables influencing the landscape system. A system-level change caused by aridification is confirmed by regional climate change modelling and the aridity index PaDI, in which a crucial system-level change occurred in approximately 1987 as a reaction to increasing drought periods (Fiala et al., 2014). The mean PaDI was 4.76 in the 1961–1987 period and increased to 5.65 in the 1988–2012 period (Fiala et al., 2014).

The first proxies of aridification given in this study causing landscape degradation, are verified by the indicators of groundwater level decrease based on groundwater wells data, and by the decrease in lake areas surfaces based on Landsat data investigated for time periods long enough to find a system level change. The MODIS remote sensing data-based vegetation indicators analysis does not have a time series long enough to verify such systems level change.

4. Conclusions

The present study did not intend to analyse the systems changes of aridification impacts on landscape degradation in total. The intention was to estimate the state of change in the complex system from the new meso-scale landscape degradation perspective, based on the selected parameters and indicators of land degradation. It is important to present those changes that sometimes appear to be irreversible. The main aim of our research was not a new description of degradation in the Carpathian Basin, but the goal was to estimate the state of the desertification/ landscape degradation processes. In this context, it is important to focus on aridification as a key driver in the Carpathian Basin in inducing land degradation impacts. The clarification of the tendency to degradation it is not easy to interpret, as indicators and parameters change in terms of system level changes. Here we discuss and offer some new thresholds proposing a groundwater level example and lake surface area, as we have found threshold level changes indicating (an irreversible?) landscape degradation signal caused by aridification.

Significant groundwater level decreases in the Danube-Tisza Interfluve region as an important indicator of land degradation are confirmed by our study. In large areas, the groundwater level is very deep below the surface, especially in the Illancs landscape, where the change is the most obvious. Nevertheless, we must investigate further the linkages between aridification, groundwater level and land uses to better understand the change in terms of landscape degradation. We may observe landscape degradation on the regional and landscape scales. Here, the landscape level threshold is defined by a long-term groundwater level decrease greater than 2 m, as observed in the larger parts of the region, but not at all wells located in the landscape. A comparable interpretation is achieved for the lake surface area response to aridification on all scales, as a sharp decrease caused by droughts is observed between 1986 and 1991, and followed by new system status and behaviour and smaller lake surface areas in general.

Therefore, the key parameters of landscape degradation influenced by aridification as verified in this study are the open surface waters and lakes and the groundwater table. For long-term interpretation, some indicators, such as the vegetation around the lakes, do not (yet) show degradation since the data series based on remote sensing data from the MODIS satellite is too short to verify any system-level change. A further more detailed investigation of land use changes using a longer time series would help to better understand the systems behaviour of long- term changes in water and groundwater balances, as well as in vegetation indicators changes. Finally, on the landscape scale, further investigation should be performed with respect to the ecological, productive and social functions, and the provisioning, regulating, cultural, and supporting ecosystem services affected or degraded by aridification. We must further elucidate the national policy dimensions through general supply and demand descriptors of land degradation, and the functioning of the landscape influenced by local land management measures applied at local scale levels. A systems perspective, including thresholds development, may help to better understand degradation processes and may help to develop landscape degradation neutrality indicators.

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References:

ALBERT, B. M. (2015): Holocene aridification, vegetation change, sedimentation regime and limits of carbon isotope data as indicated by the alluvial pollen sites of Arroyo Grande and El Molino in North-Central Mexico. Quaternary International, 377(7): 2–17.

BARTHOLY, J., PONGRÁCZ, R. (2010): Analysis of precipitation conditions for the Carpathian Basin based on extreme indices in the 20th century and climate simulations for the 21st century. Physics and Chemistry of the Earth Parts A/B/C 35(1): 43–51.

BARTHOLY, J., PONGRÁCZ, R., KIS, A., MIKLÓS, E. (2011): Analysis of possible regional climate change in the Carpathian Basin on the basis of ENSEMBLES model simulations. Geophysical Research Abstracts 13: 11449.

BASTIAN, O., STEINHARDT, U. [eds.] (2002): Development and Perspectives of Landscape Ecology. Dordrecht, Springer.

BLANKA, V., MEZŐSI, G., MEYER, B. C. (2013): Projected changes in the drought hazard in Hungary due to climate change. Időjárás 117(2): 219–237.

BRIDGES, E. M., OLDEMAN, L. R. (1999): Global assessment of human-induced land degradation. Arid Soil Research and Rehabilitation 13(4): 319–325.

BRUNSDEN, D. (2001): A critical assessment of the sensitivity concept in geomorphology. Catena 42(2–4): 99–123.

BUENDIA, C., BATALLA, R. J., SABATER, S., PALAU, A., MARCE, R. (2015): Runoff Trends Driven by Climate and Afforestation in a Pyrenean Basin. Land Degradation & Development, 27(3): 823–838.

DEGROOT, R. S. (1992): Functions of Nature. Groningen, Wolters-Noordhoff.

FARINA, A. (2006): Principles and Methods in Landscape Ecology. Towards a Science of the Landscape. Springer, Landscape Series 3.

FIALA, K., BLANKA, V., LADÁNYI, Z., SZILASSI, P., BENYHE, B., DOLINAJ, D., PÁLFAI, P. (2014): Drought Severity and its Effect on Agricultural Production in the Hungarian-Serbian Cross-Border Area. Journal of Environment Geography 7(3–4): 43–51.

HUETE, A., DIDAN, K., MIURA, T., RODRIGUEZ, E. P., GAO, X., FERREIRA, L. G. (2002): Overview of the radiometric and biophysical performance of the MODIS vegetation indices. Remote Sensing of Environment 83(1–2): 195–213.

KAIRIS, O., KOSMAS, C., KARAVITIS, C., RITSEMA, C., SALVATI, L. et al. (2014): Evaluation and selection of indicators for land degradation and desertification monitoring: types of degradation, causes, and implications for management. Environmental Management 54(5): 971–982.

KEESSTRA, S. D, VAN HUISSTEDEN, J., VANDENBERGHE, J., VAN DAM, O., DE GIER, J., PLEIZIER, I. D. (2005): Evolution of the morphology of the river Dragonja (SW Slovenia) due to land-use changes. Geomorphology 69(1–4): 191–207.

KEESSTRA, S. D. (2007): Impact of natural reforestation on floodplain sedimentation in the Dragonja basin, SW Slovenia. Earth Surface Processes and Landforms 32(1): 49–65.

KERTÉSZ, Á. (2009): The global problem of land degradation and desertification. Hungarian Geographical Bulletin 58(1): 19–31.

KERTÉSZ, Á., MIKA, J. (1999): Aridification - Climate Change in South-Eastern Europe. Physics and Chemistry of the Earth Part A: Solid Earth and Geodesy 24(10): 913–920.

KIRCHNER, A. (2014): Rekonstruktion der spätpleistozänen und holozänen Landschaftsgenese im Guapi-Macacu Einzugsgebiet, Rio de Janeiro, Südostbrasilien. Dissertation Leipzig University.

KOHÁN, B. (2014): GIS-based Analyses of the Aridification of the Danube-Tisza Interfluve. Theses of the PhD Doctoral Dissertation, Budapest, Eötvös Loránd University.

KUTI, L., VATAI, J., MÜLLER, T., KERÉK, B. (2002): Change of the groundwater level on the Danube-Tisza Hilly Region. Földtani Közlöny 132 (Special Issue): 317–325.

LADA (2016): Field Manual for Local Level Land Degradation Assessment in Drylands. LADA-L Part 1: Methodological Approach, Planning and Analysis. Rome, FAO.

LADÁNYI, Z., RAKONCZAI, J., DEÁK, J. Á. (2011a): A Hungarian landscape under strong natural and human impact in the last century. Carpathian Journal of Earth and Environmental Sciences 6(2): 35–44.

LADÁNYI, Z., RAKONCZAI, J., VAN LEEUWEN, B. (2011b): Evaluation of precipitation-vegetation interaction on a climate-sensitive landscape using vegetation indices. Journal of Applied Remote Sensing 5: 053519 (Apr 14).

LOVETT, G. M., TURNER, M. G., JONES, C. G., WEATHERS, K. C. [eds.] (2005): Ecosystem function in heterogeneous landscapes. New York, Springer.

MEYER, B. C. (1997): Landschaftsstrukturen und Regulationsfunktionen in Intensivagrarlandschaften im Raum Leipzig-Halle. Regionalisierte Umweltqualitätsziele – Funktionsbewertungen – multikriterielle Landschaftsoptimierung unter Verwendung von GIS. Dissertation. Leipzig, UFZ-Bericht 24/1997.

MEYER, B. C., GRABAUM, R. (2008): MULBO – Model framework for multicritieria landscape assessment and optimisation – A support system for spatial land use decision. Landscape Research 33(2): 155–179.

MEZŐSI, G., BATA, T., MEYER, B. C., BLANKA, V., LADÁNYI, Z. (2014): Climate Change Impacts on Environmental Hazards on the Great Hungarian Plain, Carpathian Basin. International Journal of Disaster Risk Science 5(2): 136–146.

MEZŐSI, G., BLANKA, V., BATA, T., KOVÁCS, F., MEYER, B. C. (2015): Estimation of regional differences in wind erosion sensitivity in Hungary. Natural Hazards and Earth System Sciences 15: 97–107.

MEZŐSI, G., BLANKA, V., LADÁNYI, Z., BATA, T., URDEA, P., FRANK, A., MEYER, B. C. (2016): Expected mid- and long-term changes in drought hazard for the south-eastern Carpathian basin. Carpathian Journal of Earth and Environmental Sciences 11(2): 355–366.

MEZŐSI, G., MEYER, B. C., LOIBL, W., AUBRECHT, C., CSORBA, P., BATA, T. (2013): Assessment of regional climate change impacts on Hungarian landscapes. Regional Environmental Change 13(4): 797–811.

MIKA, J., HORVÁTH, S. Z., MAKRA, L. (2001): Impact of documented land use changes on the surface albedo and evapotranspiration in a plain watershed. Physics and Chemistry of the Earth Part B: Hydrology Oceans and Atmosphere 26(7): 601–606.

NASSAUER, J. I., OPDAM, P. (2008): Design in science: extending the landscape ecology paradigm. Landscape Ecology 23: 633–644.

NEEF, E. (1967): Die theoretischen Grundlagen der Landschaftslehre. Haack VEB, Gotha.

PÁLFAI, I., HERCEG, Á. (2011): Droughtness of Hungary and Balkan Peninsula. Riscuri si Catastrofe 9: 145–154.

RAKONCZAI, J. (2007): Global change and landscape change in Hungary. Geografia fisica e dinamica quaternaria 30(2): 229–232.

RAKONCZAI, J. (2011): Effects and consequences of global climate change in the Carpathian Basin. In: Blanco, J., Kheradmand, H. [eds.]: Climate Change – Geophysical Foundations and Ecological Effects (pp. 297–322). Rijeka, InTech.

RAKONCZAI, J, FEHÉR, Z. (2015): Function in change of climatic in the temporal change on the groundwater supply in the Hungarian Plain. Hidrológiai Közlöny 95(1): 1–16. (in Hungarian).

RANNOW, S., LOIBL, W., GREIVING, S., GRUEHN, D., MEYER, B. C. (2010): Potential impacts of climate change in Germany – identifying regional priorities for adaptation activities in spatial planning. Landscape and Urban Planning. 98(3–4): 160–171.

REED, M. S., BUENEMANN, M., ATLHOPHENG, J., AKHTAR-SCHUSTER, M., BACHMANN, F. et al. (2011): Cross-scale monitoring and assessment of land degradation and sustainable land management: a methodological framework for knowledge management. Land Degradation and Development 22: 261–271.

SALVATI, L., FORINO, G. (2014): A 'laboratory' of landscape degradation: social and economical implications for sustainable development in peri-urban areas. International Journal of Innovation Sustainable Development 8(3): 232–249.

SANJUÁN, Y., GÓMEZ-VILLAR, A., NADAL-ROMERO, E., ÁLVAREZ-MARTÍNEZ, J., ARNÁEZ, J. et al. (2016): Linking Land Cover Changes in the Sub-Alpine and Montane Belts to Changes in a Torrential River. Land Degradation and Development 27(2): 179–189.

SORANNO, P. A., CHERUVELIL, K. S., BISSELL, E. G., BREMIGAN, M. T., DOWNING, J. A. et al. (2014): Cross-scale interactions: quantifying multiscaled cause – effect relationships in macrosystems. Frontiers in Ecology and Environment 12(1): 65–73.

STOCKING, M., MURNAGHAN, N. (2000): Land Degradation – Guidelines for field Assessment. University of East Anglia, Norwich, UK Available at: http://archive.unu.edu/env/plec/l-degrade/index-toc.html

SZALAI, J. (2012): The effect of weather extremes on the development of the groundwater flow of the Danube-Tisza River. VI. Hungarian Geoscientific Conference, Szeged: pp. 804–812. [cit.20.01.2017]. Available at: http://geography.hu/mfk2012/pdf/Szalai_jozsef.pdf (in Hungarian).

SZALAI, J. (2014): The changes in groundwater system in Hungary. 2nd Wahastrat Conference, Szeged, Hungary: 28. [cit.20.01.2017]. Available at: https://wahastrat.vizugy.hu/esemeny/20140616a/Szalai_20140616.pdf (in Hungarian).

SZALAI, J., KOHÁN, B., NAGY, G. (2014): Space Statistic Analysis of the Groundwater Level Detection Network of the Danube-Tisza River 32. Hidrológiai Konferencia, Szeged: 14. [cit.20.01.2017]. Available at: http://www.hidrologia.hu/vandorgyules/32/dolgozatok/word/0712_szalai_jozsef.pdf (in Hungarian).

UNEP (1997): World atlas of desertification, 2nd Edition, Middleton, N., Thomas, D. [eds.]. London, Arnold.

USHER, M. B. (2001): Landscape sensitivity: from theory to practice. Catena 42(2–4): 375–383.

VERBURG, P. H., ERB, K. H., MERTZ, O., ESPINDOLA, G. (2013): Land System Science: between global challenges and local realities. Current Opinion in Environmental Sustainability 5(5): 433–437.

XU, H. (2006): Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. International Journal of Remote Sensing 27(14): 3025–3033.

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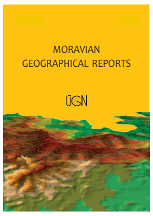

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Effects of light pollution on tree phenology in the urban environment

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Abstract

Research on urban climates has been an important topic in recent years, given the growing number of city inhabitants and significant influences of climate on health. Nevertheless, far less research has focused on the impacts of light pollution, not only on humans, but also on plants and animals in the landscape. This paper reports a study measuring the intensity of light pollution and its impact on the autumn phenological phases of tree species in the town of Zvolen (Slovakia). The research was carried out at two housing estates and in the central part of the town in the period 2013–2016. The intensity of ambient nocturnal light at 18 measurement points was greater under cloudy weather than in clear weather conditions. Comparison with the ecological standard for Slovakia showed that average night light values in the town centre and in the housing estate with an older type of public lighting, exceeded the threshold value by 5 lux. Two tree species, sycamore maple (Acer pseudoplatanus L.) and staghorn sumac (Rhus typhina L.), demonstrated sensitivity to light pollution. The average onset of the autumn phenophases in the crown parts situated next to the light sources was delayed by 13 to 22 days, and their duration was prolonged by 6 to 9 days. There are three major results: (i) the effects of light pollution on organisms in the urban environment are documented; (ii) the results provide support for a theoretical and practical basis for better urban planning policies to mitigate light pollution effects on organisms; and (iii) some limits of the use of plant phenology as a bioindicator of climate change are presented.

Keywords: *intensity of illumination, phenology, sycamore maple (Acer pseudoplatanus L.), staghorn sumac (Rhus typhina L.), urban climates, bioindicators, Zvolen, Slovakia*

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1. Introduction and theoretical departures

The environment affects the complete set of physiological and psychological reactions of living organisms. Their everyday life is threatened by pollution of the basic components of the environment, i.e. soil, water and air (Hreško et al., 2015). Humans with demands for intensive night lighting disturb the environment and influence the biorhythms of living organisms. Increasing attention has been paid to this issue since the 1970s as a reaction to increasing urbanisation (see e.g. Riegel, 1973; White, 1974; Verheijen, 1985). New questions about light pollution have been posed, together with effective and efficient solutions, which are dealt by experts in the fields of psychology, architecture, construction, engineering and environmental hygiene. According to Gaston et al. (2013), future research will focus on the determination of threshold values beyond which light pollution has negative ecological impacts on the composition and trophic structures of ecosystems and species growing in an urban environment.

Worldwide artificial lighting is rapidly increasing by around 2.2% per year (Kyba et al., 2017). Bennie et al. (2014) showed that regionally significant decreases, as well as widespread increases, in the brightness of night time lights are occurring across Europe. In the Slovak Republic, the data show widespread decreases in observed brightness across small towns and villages, as many municipalities began switching off public lighting for part or all of the night for financial reasons during this period. The capital, Bratislava, and several towns that experienced renovation of their lighting systems do not show an equivalent decrease. Following the regulation of the European Commission (ES No. 245/2009), the term "pollution" is generally understood

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as a contamination of the environment by artificial lighting sources with negative impacts on the environment (Official Book of the European Union, 2009). Light influences several natural processes, and has a significant impact on the biological and ecological processes of many species (Rich and Longcore, 2006; Solano and Kocifaj, 2013). The International Dark-Sky Association (IDA) defines light pollution as: "any undesirable impact of artificial lighting causing excessive sky brightness, radiance, infiltration of excessive light into houses, reduced visibility on roads and wasteful energy consumption" (IDA, 2013). Light pollution can be best observed in towns and large residential agglomerations. Light directed towards the sky is reflected from atmospheric particles (dust, water vapour) and is spread far beyond the place of its origin. It results in a visibly clearer sky at night even at a greater distance from the source, especially in populated areas.

Excessive artificial light added to the nocturnal landscape is a serious ecological burden on the environment, with adverse impacts on the biorhythms of living organisms (Longcore and Rich, 2004). Natural darkness is needed for living organisms that are active during a day, and also for humans to have rest and to ensure the correct course of their circadian rhythms. Excessive light is a problem for animals with increased night activity. The lack of darkness disrupts their natural life cycle, which they have become adapted to over millions of years during evolution. Birds living in towns have problems to recognise that night is approaching. Light pollution alters the phenology of dawn and dusk singing of the songbirds (Da Silva et al., 2015), which begin to nest at the wrong time, and to move to non-native habitats. Flying through over-illuminated zones causes their disorientation and frequent collisions with obstructions such as towers and buildings (Rich and Longcore, 2006).

Plant growth and development are influenced by light spectral quality, quantity and duration. The plant photoreceptors – phytochromes, cryptochromes, phototropins and FkF1 photoreceptor – mediate physiological and developmental responses in plants (Briggs, 2006). The phytochrome is blue-green plant pigment which regulates plant development, seed germination, flowering and leaf expansion. The phytochrome system allows plants to grow towards light. Sometimes photoreceptors act independently, sometimes redundantly, sometimes cooperatively, sometimes antagonistically, sometimes at the same stage of development, and sometimes at different stages of development. Moreover, some of these responses are incredibly sensitive (Briggs, 2006).

Some plants and tree species also react to strong light sources and to changes in the day/night length. Approximately 80% of flowering plants are sensitive to photo-periodism (Samach and Gover, 2001; Searle and Coupland, 2004). Naturally, their blossom, bud-burst and leaf fall occur in appropriate seasons. Within less than 10 minutes after changing the radiation intensity, the plant reacts by altering its transpiration (Klimešová and Středa, 2016). The change in photoperiod can influence flowering response, as well as their entrance into bud dormancy, or their initiation of leaf senescence. Artificial light in the night-time environment is sufficiently bright to induce a physiological response in plants, affecting their phenology, growth form and resource allocation (Briggs, 2006; Bennie et al., 2016). In temperate zones, many woody plants normally undergo a flush of vegetative growth induced by some environmental change, such as an increase in temperature or the onset of a rainy season. In due time, however, the buds stop producing normal leaves and commence instead to produce bud scales. Ultimately, the buds cease producing any new organs and enter complete dormancy. Seedlings on long days continue growing far longer than seedlings on short days before the buds go into dormancy. Hence, artificially extending the day length can significantly increase the length of time during which active growth and production of true leaves takes place (Briggs, 2006).

Artificial red light changes phenology and research results show that artificial yellow lighting has a similar impact (Cathey and Campbell, 1975). The leaf stomata of some tree species are open at night and closed during the day to protect plants from wilting, which would occur during the day. Trees growing near artificial lights react to autumn cooling and low temperatures with a delay. Their leaves do not change their colour, but often freeze fully green. Ice and snow, which is captured on their surface, can cause breaking of branches. Maples, birches, poplars and sycamores are sensitive to night light (Chaney, 2002).

Johnston et al. (1969) found that brightly illuminated plants under a wide spectrum fluorescent lamps had had more seeds, nodes, pods, branches, pods per node, seeds per pod and a higher oil content, than normal plants. Protein content and seed size were decreased by adding light. Okamoto et al. (1997) and Lee et al. (2010) showed accelerating grown of lettuce seedlings under fluorescent light. Phenological monitoring can detect several types of changes occurring in the natural environment, such as toxic emissions in the air or climate change, which has been examined in the study region by a number of authors (e.g. Bednářová et al., 2013; Hájková et al., 2012; Chuchma et al., 2016; Stehnová and Středová, 2016). The impact of light pollution on phenological phases of plants has been studied to a much lesser extent.

This paper deals with the monitoring of light pollution intensity in the urbanised parts of the town of Zvolen, situated in Central Slovakia. The research project aims to assess the effect of light pollution on the autumn phenological phases of selected tree species in urban conditions.

2. Material and methods

The measurements of light pollution intensity were carried out in the town of Zvolen in Central Slovakia (Central Europe) from 2013 to 2016. The town is situated at an elevation of 293 m a.s.l. (48°34′42″N, 19°07′24″E). It belongs to a warm climatic region, slightly moist sub-region, and is a type of valley climate with frequent temperature inversions and an average annual precipitation total of 703 mm (Lapin et al., 2002). The average annual air temperature is 8.2 °C: the coldest month is January with mean temperature of − 3.4 °C, and the warmest month is July with temperature 18.8 °C. The maximum precipitation amount falls in June (82 mm), with a second maximum of precipitation in November (66 mm; Střelcová, 2013). For a detailed description of the natural conditions of Zvolen and its surroundings: see Belaček and Bebej (2013).

Measurements of light pollution intensity and phenological monitoring of tree species were made at three sites (Fig. 1).

Site 1 (Tepličky) is a relatively new housing estate, which was built at the end of the 1980s on the right bank of the river Hron. To the north, it is adjacent to a shopping

Fig. 1: Location of the research sites in the town of Zvolen, Slovak Republic: 1) Tepličky housing estate; 2) Zlatý potok housing estate, 3) Town centre
Source: authors´ elaboration

centre and a small industrial zone. It has a lower night light intensity with more modern lighting. Tree species were planted either individually or in small groups and are 20 to 25 years old on average. Site 2 (Zlatý potok) is an older housing estate from the 1960s and 1970s. It is located in the foothills of the Zvolen highlands in the eastern part of the town. It is adjacent to a commercial and industrial zone which, together with an older type of lighting, causes a higher level of night-time brightness. Trees create smaller park zones and alleys. They are approximately 30 to 40 years old. Site 3 represents the town centre with its historical part, square, transport corridors, bus and railway stations, administrative and commercial buildings. It is the most intensely lit part of the town. The trees are of different ages – from young peripheral plantings (younger than 10 years) up to several old town parks with trees aged more than 80 years. Following the methodology of Effelsen (1991), urban terrain zones (UTZ) were identified according to the criteria of a structure, street pattern, lot configuration, building placement on the lot, building density, building construction type and age of construction. The local climate zones (LCZ) were identified following the methodology of Stewart and Oke (2012) according to local temperature regime and surface cover. The LCZ classification can be used easily and properly as a basic source of information about the nature of the area around a station, and it can be efficiently used for representative documentation of the neighbourhood of the climate stations (Lehnert et al., 2015). Finally, urban climate zones (UCZ) were identified following Oke (2006) – see Table 1.

In general, the artificial luminance of the sky in urban environments is being measured by various types of sky quality meters. They measure luminance (surface brightness) for a patch of the sky, in units of magnitudes per square arc second (mag.arcsec^{-2}). Nevertheless our measurement dealt with available sensors that measure the light in lux. These units of light pollution are comparable with the valid norm. Light pollution intensity was measured with Lux Meter Velleman DVM 1300 (Company Dertronics B.V. Netherlands) under two different weather conditions (clear and cloudy sky).

The measurements were carried out just under the light sources adjacent to the planted woody plants along pavements or roads. The sensors were placed at the height of 1.3 m to enable an accurate reading of the data on the lux meter sensor’s display. The data therefore do not represent the maximum at the level of treetops regarding their height. Therefore, neither the measurement on lighted and unlighted sides of the treetop were carried out. Only a phenological reaction on a negative factor was recorded.

Site	GPS location	Ellefsen (1991) UTZ classification	Stewart & Oke (2012) LCZ classification	Oke (2006) UCZ classification
1	48°34'49" N 19°06'31" E	Dc3	LCZ 1A (Compact high-rise with dense trees)	UCZ 1
2	48°34'51" N 19°08'48"E	Dc3	LCZ 1A (Compact high-rise with dense trees)	UCZ 1
3	48°34'34" N 19°07'39"E	A1	LCZ 3B (compact low-rise with scattered trees)	UCZ 2

Tab. 1: Characteristics of the site’s environments
Source: authors' elaboration

The measurement device itself was not equipped with a cosine shield limiting incoming radiation. Thus, the values of artificial luminance of the sky contain also direct and diffuse radiation of the atmosphere. We used the following methodological principles:

i. no obstacles that can cast shadows shall be between the instrument and the sky (a building, or a tree);

ii. the measurements shall not be performed at the places where light sources directly cast shadows; and

iii. the worker performing measurements shall not stand at the place directly lit by the light flux from the source (e.g. under the lamp).

The individual sites were divided into a square grid of 100 × 100 m in GIS software (ArcGIS). The measurement points were selected within the grid created in GIS. At each site, we selected 6 measuring points adjacent to light sources of different types and intensity. At each measuring point, we performed 20 partial measurements under every type of weather condition, from which we calculated the arithmetic mean to obtain the final values of light pollution.

The measurements were carried out only after an appropriate warming up and stabilisation of artificial lights and at complete darkness after 10 pm local time. High pressure sodium lamps with spherical diffusers and top covers, and LED lighting with flat diffusers, were used at every site. At site 3, the town centre, there were also ground lights for the pedestrian zone, which illuminated historical buildings and park greenery. Decree No. 539/2007 Coll. based on STN EN 12464-2 technical standard was adopted in the Slovak Republic in order to protect and enhance the night environment and to control disturbing light (known as light pollution), which can cause physiological and ecological problems in the surrounding environment and for people. An equivalent standard based on the EU Regulation 245/2009 is valid also in the neighbouring country of the Czech Republic. According to the standard, the highest allowed values of disturbing light in the town centres and residential suburbs fluctuate between 2–5 lux depending on the urbanisation type, which corresponds with the conditions in the researched town.

The phenological data were gathered following the methodology of the Slovak hydro-meteorological institute (Kolektív, 1984). We observed the following autumn vegetative phenological phases:

i. leaf colouring LC (BBCH 92) – leaves change their colour to yellow up to yellow-brown;

ii. leaf fall LF (BBCH 93) – yellow leaves fall even in still air. The 10, 50 and 100% occurrence of each phenological phase was observed on both the lit and the unlit parts of tree crowns. We determined the length of the phenophase duration as a difference between 10% and 100% onset. As a control sample, we used individuals of the particular species of the observed group or located in an alley beyond the lighting.

3. Results and discussion

Changes in the onset of phenophases cannot be caused simply by the urban heat island (i.e. temperature differences between city centre and the outskirts by up to 5 °C caused by intensive warming of artificial surfaces by incoming solar radiation). Such a possibility has been described and quantified for similar geographic and urban conditions to this study by Pokladníková et al. (2009), Geletič and Vysoudil (2012), Středová et al. (2015) and Vysoudil et al. (2016). Changes of phenology are too large to be explained by increases in temperature alone – the effect of light pollution is evident (French-Constant et al., 2016; Da Silva et al., 2015).

3.1 Light pollution intensity

The measurements of light pollution intensity (lux) were performed under different weather conditions. The measured values are presented in Table 2.

We found a difference between the weather conditions and the intensity of light pollution. Under higher air humidity and cloudy sky conditions, the average light intensity of every site was higher (1.8–8.5 lx) than under clear sky conditions (1.1–6.5 lx). This is due to the higher reflectance of light from water drops or aerosols (Tuhárska et al., 2016; Kyba et al., 2011). The same conclusions were stated by Bujalský et al. (2014), who found five-times higher pollution intensity under foggy and cloudy conditions than under clear skies (see also: Kyba et al., 2011). See the note under 'Conclusions' below. The highest average value of light intensity was found at site 3, the town centre, regardless of the weather conditions – due to the type of lights used and other lighting elements (ground lighting, advertisement panels, etc.). The lowest values were observed at site 1, which is the most recent housing estate with modern types of lights.

The measured data were compared with the standard (Decree No. 539/2007). Following the standard, sites 1 and 2 in the housing estates belong to an E3 ecological zone – an urbanised area with moderate brightness (housing suburbs of small towns), for which the maximum threshold value is 2 lux. The site of the Zvolen town centre is in the E4 ecological zone with high brightness and a threshold value of 5 lux. The comparison of our values with the standard values showed that the 'best' situation was in the modern and newest housing estate, "Západ" (site 1 – Tepličky), at which the measured average values of light pollution in the years 2013 and 2014 did not exceed the standard threshold values under any studied weather conditions. The situation at this site changed in the years 2015 and 2016, when the threshold was exceeded

Weather conditions	Clear sky				Cloudy sky			
Site/year	2013	2014	2015	2016	2013	2014	2015	2016
1	1.1	1.2	4.2	4.8	1.8	1.9	6.7	6.2
2	3.1	3.3	5.7	5.2	4.1	4.6	7.8	7.1
3	6.0	6.3	7.1	6.5	6.4	6.6	8.5	7.9

Tab. 2: Intensity of average values of light pollution in lux (lx) at the selected sites in the town of Zvolen under different weather conditions in the years 2013–2016
Source: authors' measurements

by 2.2–4.7 lux. These greater values than the threshold (1 to 2 times) were caused by the replacement of public lighting in some parts of the housing estate. In the case of some measurements, mostly under cloudy and rainy weather conditions, the illumination values ranged from 16 to 24 lux, which greatly exceeded the threshold values. Despite the most appropriate type of lamps with flat diffusers, the high luminance of LED bulbs resulted in a threshold value that was exceeded 8–12 times. Similar situations were observed also in the town centre, where the light pollution most significantly affected tree species planted in rows. It would be preferable to use lights with shades installed horizontally or with minimum inclination directed at target spots.

The basic statistical characteristics of light intensity are presented in Table 3. We found that the smallest adverse impact on the surrounding environment was at site 1 with the lowest values of illumination. The greatest variation (CV = 35.4%) resulted from the change of lights at some streets during the last two years. The worst situation was in the town centre, where the lowest variation of 12.5% was due to the same type of lights during the whole analysed period. The highest light pollution resulted from the light sources with spherical diffusers and a greater number of light elements at the pedestrian zone.

3.2 Light pollution and tree species

We observed adverse impacts of light on the phenological phases of tree species. More specifically, we examined the impact of light on the development of autumn phenological phases on the tree crowns situated directly under the light sources and further from the light sources. Different tree species were the subject of observations. The most common were individuals of the staghorn sumac (*Rhus typhina* L.) and the sycamore maple (*Acer pseudoplatanus* L.). We observed the onset and the duration of individual phenological phases on five (5) individuals of each species. Intensive night illumination caused the delay of the autumn phenological phase of leaf colouring on the lit crown part of the staghorn sumac (*Rhus typhina* L.) (see Fig. 2). The shift in the phenological phase was observed under all types of lights installed in the town of Zvolen.

Table 4 presents an overview of the basic statistical characteristics of the onset of autumn phenological phases. It is clear from these values that the dry and warm summer in 2015 caused the earliest onset of phenophases in both species, while the latest onset of most of the phenophases in 2014 indicates more favourable conditions for these species in the summer. Previous research has also been confirmed in light pollution conditions but with lower variability, as shown by lower variation coefficients. The statistical significance of the differences has not been confirmed for such a short period of time.

At the crown part situated close to the light source, the average onset of leaf colouring of the sycamore (*Acer pseudoplatanus* L.) was delayed by 13 to 22 days, and of the staghorn sumac (*Rhus typhina* L.) by 16 to 18 days (Fig. 3). The differences in the leaf fall between the lit and the unlit crown parts were from 13 to 20 days, depending on the tree

Site	$\bar{x}$	Max	Min	SD	CV	SEM
1	2.9	10.2	0.8	1.0	35.4	0.27
2	6.5	16.3	1.8	1.5	23.1	0.40
3	9.6	24.3	3.2	1.2	12.5	0.32

Tab. 3: Statistical characteristics of light pollution intensity in the sites of Zvolen in the period from 2013 to 2016; represented are: arithmetic mean ($\bar{x}$), largest (Max) and smallest (Min) value, standard deviation (SD), coefficient of variation (CV) and standard error of the mean (SEM). Source: authors' calculation

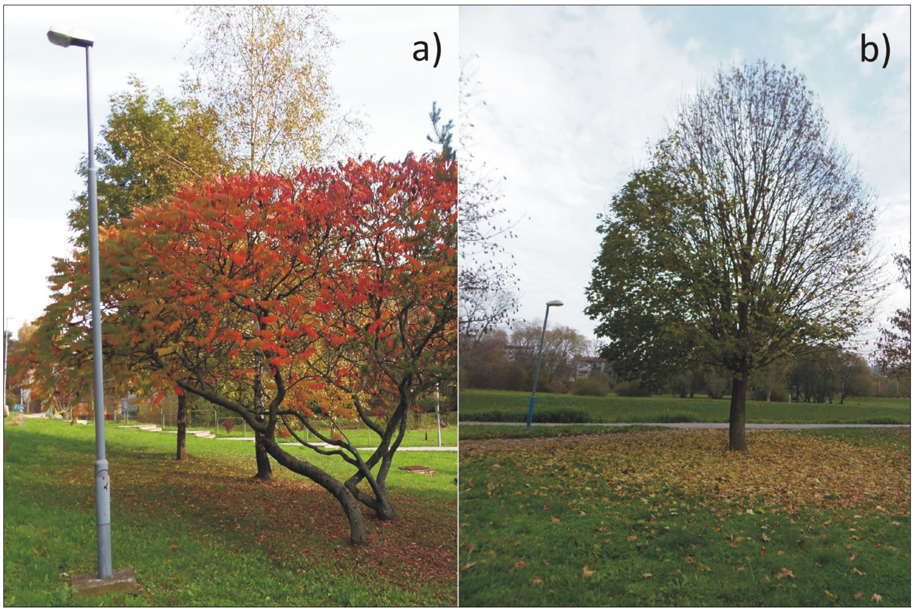

Fig. 2: (a) Difference in the onset of leaf colouring phenological phase of the staghorn sumac (Rhus typhina L.) at site 3, and (b) Sycamore maple (Acer pseudoplatanus L.) at site 1. The light source (left) caused the delay of the leaf fall phenological phase. Photos: M. Tuhárska

Phenological Phases	Lighted part			Non-lighted part		
	Min	Max	CV	Min	Max	CV
Rhus typhina						
LC 10%	3.10.2015	5.11.2014	1.26	25.9.2015	20.10.2014	1.38
LC 50%	14.10.2015	15.11.2014	1.22	6.10.2015	31.10.2014	1.30
LF 10%	26.10.2015	20.11.2014	1.31	18.10.2015	6.11.2013	1.45
Acer pseudoplatanus						
LC 10%	4.10.2015	26.10.2014	1.31	15.9.2015	8.10.2014	1.42
LC 50%	13.10.2015	8.11.2013	1.25	25.9.2015	16.10.2014	1.34
LF 10%	16.10.2015	10.11.2014	1.38	3.10.2015	24.10.2014	1.47

Tab. 4: Statistical characteristics of autumn phenological phases tree species during the period 2013–2015 (largest (Max), smallest (Min) values, coefficient of variation (CV))
Source: authors' calculation

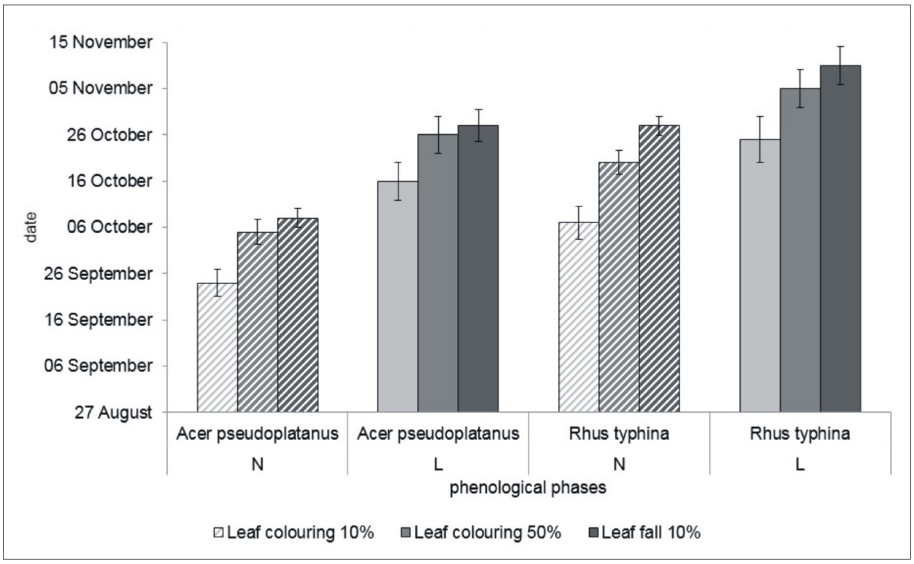

Fig. 3: Average onset (± SEM – standard error of the mean) of three autumn phenological phases of the sycamore maple (Acer pseudoplatanus L.) and the staghorn sumac (Rhus typhina L.) in Zvolen from the years 2013 to 2015; where: non-lighted part (N – hatched bars) and lighted part (L – filled bars)
Source: authors' calculation

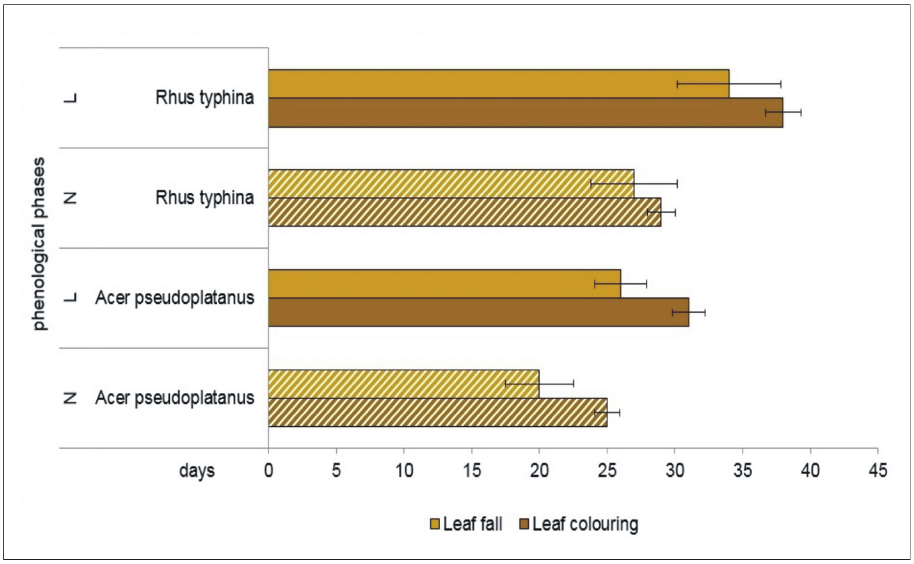

Fig. 4: Average length (± SEM Quercus robur L., Fraxinus excelsior L. – standard error of the mean) of two autumn phenological phases of the sycamore maple (Acer pseudoplatanus L.) and the staghorn sumac (Rhus typhina L.) in Zvolen from the years 2013 to 2015; where: non-lighted part (N – hatched bars) and lighted part (L – filled bars)
Source: authors' calculation

species. Figure 4 shows the temporal shift of the phenological phases equal to the length of two phases (from leafing to leaf fall) on the sycamore crown. Hollan (2004) found that the leaf fall of *Platanus* × *hispanica* Mill. was delayed by almost one month, i.e. to the first half of December, due to the light pollution in the central part of Brno. The differences in the intensity between the lit and the unlit part were 60 lux. The author did not state the distance of the crown from the artificial lights, hence it is not possible to compare these data with our observations.

The work of French-Constant et al. (2016) presented similar reactions also in the case of vegetative spring phenophases. Due to light pollution, leaf unfolding of *Acer pseudoplatanus* L., *Fagus sylvatica* L., *Quercus robur* L., *Fraxinus excelsior* L. started 7.5 days earlier than on the places without night lights. Chaney (2002) classified several species of *Acer* and *Fagus* genus growing in current conditions as highly sensitive to light pollution. This annually repeated phenomenon can cause the overall weakening of the tree and the reduction of its life span or worsening of its ability to withstand stress (drought, frost).

Sensitivity of other tree species (*Betula pendula* Roth, *Negundo aceroides* Moench) to artificial lighting was also observed, but due to the small number of individuals we did not evaluate the differences in the onset of their phenophases. Cathey and Campbell (1975) stated that these species belong to groups that are very sensitive to light pollution.

We also observed the duration of the phenological phases of leaf colouring and leaf fall. The phase started when its occurrence frequency was 10% and finished at 100% occurrence frequency. The development of the phenophase duration is presented in Figure 4. Due to lighting, leaf colouring was prolonged by 6 to 9 days on average, and leaf fall by 6 to 7 days.

Depending on radiation intensity, its wavelength and exposition, there are many possibilities to evaluate how to prevent the occurrence of light pollution or at least to eliminate its negative impact on tree species. Woody plants utilise various wavelengths for physiological processes. Photoperiodism affects production of phytochrome, which causes the absorption of red and infrared light with wavelength of 625 to 850 (Briggs, 2006). If this spectrum is emitted also by artificial sources, this kind of source can cause the day to be perceived as longer. As demonstrated on lighted leaves by longer periods with open stomas, higher sensitivity to pollution and a subsequent weakening of a tree's vitality is possible. For artificial lighting is therefore very important to use the light source with the lowest possible impact on the physiological processes in trees. To do this, Chaneys (2002) recommends using lamps with mercury vapour and metal halide, fluorescent lamps. French-Constant et al. (2016) state that the harmfulness of light might be decreased by reduced colour, the temperature of the lighting, along with limited planting of woody plants, mainly bushes, under the light source. In our case, the suitable solution would be fluorescent or discharge tubes with lower intensity of radiation and with orientation out of treetops. Another possibility is the installation of time-switches reacting to movement, or lamps with flat diffusor lighting towards the ground.

Cathey and Campbell (1975) have recommend switching off light sources throughout the first part of the evening for 2 to 4 hours. The woody plants thus can retain their natural biorhythm. For the planting of woody plants near light sources, it would be preferable to use less sensitive coniferous species or to use places out of the reach of lighting. Future research needs to be focused on the dependence of the phenological responses of the trees to various wavelengths of light.

4. Conclusions

At higher air humidity and cloudy weather, the average intensity of light pollution was 1 to 2 times greater than under clear sky conditions at all sites. According to the standard valid for Slovakia, after 10:00 pm. the highest permissible value of disturbing light is 5 lux, and in housing suburbs it is 2 lux. In the years 2015 and 2016, this standard was exceeded by 2.2 to 4.7 lux due to the replacement of the public lighting at some streets of the housing estates. For some measurements, usually under cloudy weather conditions, maximum values of the measured light were between 16 and 24 lux, which greatly exceeded the threshold values. The light pollution affected the biorhythm of *Acer pseudoplatanus* L. and *Rhus typhina* L. It caused the delay of the onset of autumn vegetative phenological phases at crown parts under the lights by 13 to 22 days on average. Due to the lighting, the duration of leaf colouring was prolonged by 6 to 9 days, and the duration of leaf fall by 6 to 7 days. These tree species belong to groups that are highly sensitive to light pollution. These findings should be taken into account by planning authorities.

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References:

ASTOLFI, S., MARIANELLO, C., GREGO, S., BELLAROSA, R. (2012): Preliminary investigation of LED lighting as growth light for seedlings from different tree species in growth chambers. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 40(2): 31–38.

BEDNÁŘOVÁ, E., SLOVÍKOVÁ, K., TRUPAROVÁ, S., MERKLOVÁ, L. (2013): Results of a phenological study of the European larch (Larix decidua Mill.) growing in a mixed stand. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 61(5): 1239–1246.

BELÁČEK, B., BEBEJ, J. (2013): Poloha a geomorfologické pomery. Geologické pomery a geologický vývoj Zvolenskej kotliny. In: Bebej, J. [ed.]: Príroda, Monografia mesta Zvolen (pp. 12–19). Zvolen, Mestský úrad Zvolen.

BENNIE, J., DAVIES, T. W., CRUSE, D., GASTON, K. J. (2016): Ecological effects of artificial light at night on wild plants. Journal of Ecology, 104(3): 611–620.

BENNIE, J., DAVIES, T. W., DUFFY, J. P., INGER, R., GASTON, K. J. (2014): Contrasting trends in light pollution across Europe based on satellite observed night time lights. Scientific Reports, 4: 3789.

BRIGGS, W. R. (2006): Physiology of Plant Responses to Artificial Lighting. In: Rich, C., Longcore, T. [eds.]:

Ecological consequences of artificial night lighting (pp. 389–411), Washington, Island Press.

BUJALSKÝ, L., BŘEZINA, S., MATĚJÍČEK, L., FROUZ, J. (2014): Light pollution caused by artificial illumination on downhill ski tracks in the Krkonoše Mts National park. Opera Corcontica, 51: 109–124.

BULA, R. J., MORROW, R. C., TIBBITTS, T. W., BARTA, D. J., IGNATIUS, R. W., MARTIN, T. S. (1991): Light emitting diodes as a radiation source for plants. HortScience, 26: 203–205.

CASHAMORE, A. R. (2003): Cryptochromes: Enabling Plants and Animals to Determine Circadian Time. Cell, 114: 537–543.

CATHEY, H. M., CAMPBELL, L. E. (1975): Security lighting and its impact on the landscape. Journal of Arboriculture, 1(10): 181–187.

CHANEY, W. (2002): Does night lighting harm trees? Circular FNR-FAQ-17, Department of Forestry and Natural Resources, Purdue University [online]. [cit. 13.11.2016]. Available at: https://www.extension.purdue.edu/extmedia/fnr/fnr-faq-17.pdf

CHUCHMA, F., STŘEDOVÁ, H., STŘEDA, T. (2016): Bioindication of climate development on the basis of long-term phenological observation. In: MendelNet 2016 (pp. 380–383), Brno, Mendel University.

Commission Regulation (EC): No.245/2009 [online]. [cit.16.8.2016]. Available at: http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:076:0017:0044:CS:pdf

DA SILVA, A., VALCU, M., KEMPENAERS, B. (2015): Light pollution alters the phenology of dawn and dusk singing in common European songbirds. Philosophical Transactions of the Royal Society B-Biological Sciences, 370(1667): 20140126.

ELLEFSEN, R. (1991): Mapping and measuring buildings in the canopy boundary layer in the U.S. cities. Energy and Buildings, 15–16(3–4): 1025–1046.

FRENCH-CONSTANT, R., YEATES, R. S., BENNIE, J., ECONOMOU, T., HODGSON, D., SPALDING. A., McGREGOR. P. (2016): Light pollution is associated with earlier tree budburst across the United Kingdom. Proceedings of the Royal Society B-Biological Sciences, 283(1833): 20160813.

GASTON, K. J., BENNIE, J., DAVIES, T. V., HOPKINS, J. (2013): The ecological impacts of night time light pollution: a mechanistic appraisal. Biological Reviews, 88(4): 912–927.

GELETIČ, J., VYSOUDIL, M. (2012): Analysis of surface temperatures in urban and suburban landscapes from satellite thermal images: a case study of Olomouc and its environs, Czech Republic. Moravian Geographical Reports, 20(1): 2–15.

HÁJKOVÁ, L., KOŽNAROVÁ, V., SULOVSKÁ, S., RICHTEROVÁ, D. (2012): The temporal and spatial variability of phenological phases of the Norway spruce (Picea abies (L.) Karsten) in the Czech Republic. Folia Oecologica, 39(1): 10–17.

HÖLKER, F., MOSS, T., GRIEFAHN, B., KLOAS, W., VOIGT, C. C., HENCKEL, D., HÄNEL, A., KAPPELER, P. M., VÖLKER, S., SCHWOPE, A., FRANKE, S., UHRLANDT, D., FISCHER, J., KLENKE, R., WOLTER, C., TOCKNER, K. (2010): The dark side of light: a transdisciplinary research agenda for light pollution policy. Ecology and Society, 15(4): 13.

HOLLAN, J. (2004): Mapování světelného znečištění a negativní vlivy osvětlování umělým světlem na živou přírodu na území České republiky. Výzkumná správa. Brno, Masarykova univerzita.

HREŠKO, J., PETROVIČ, F., MIŠOVIČOVÁ, R. (2015): Mountain landscape archetypes of the Western Carpathians (Slovakia). Biodiversity and Conservation, 24(13): 3269–3283.

IDA (2013): International Dark-Sky Asociation. [online] [cit.16.8.2016]. Available at: http://www.darksky.org

JOHNSTON, T. J., PENDLETON, J. W., PETERS, D. B., HICKS, D. R. (1969): Influence of Supplemental Light on Apparent Photosynthesis, Yield, and Yield Components of Soybeans (Glycine max L.) 1. Crop Science, 9: 577–581.

KLIMEŠOVÁ, J., STŘEDA, T. (2016): Agrometeorological and biological aspects of maize transpiration. In: Brzezina et al. [eds.]: Mendel and Bioclimatology (pp. 150–156), Mendel University in Brno, Brno.

KOLEKTÍV (1984): Návod pre fenologické pozorovanie lesných rastlín. Bratislava, Slovak Hydrometeorological Institute.

KRUK, B., INSAUSTI, P., RAZUL, A., BENECH-ARNOLD, R. (2006): Light and thermal environments as modified by a wheat crop: effects on weed seed germination. Journal of Applied Ecology, 43: 227–236.

KYBA, C. C. M., RUHTZ, T., FISCHER, J. (2011): Cloud Coverage Acts as an Amplifier for Ecological Light Pollution in Urban Ecosystems. PLoS ONE, 6(3): e17307.

KYBA, C. C. M., KUESTER, T., DE MIGUEL, A. S., BAUGH, K., JECHOW, A., HÖLKER, F., BENNIE, J., ELVIDGE, C. D., GASTON, K. J., GUANTER, L. (2017): Artificially Lit Surface of Earth at Night Increasing in Radiance and Extent. Science Advances, 3(11): e1701528.

LAPIN, M., FAŠKO, P., MELO, M., ŠŤASTNÝ, P., TOMLAIN, J. (2002): Climatic regions. Landscape atlas of the Slovak Republic. Primary landscape structure. 1st ed. Ministry of Environment of the Slovak Republic Bratislava, Slovak Environmental Agency Banská Bystrica.

LEHNERT, M., GELETIČ, J., HUSÁK, J., VYSOUDIL, M. (2015): Urban field classification by "local climate zones" in a medium-sized Central European city: the case of Olomouc (Czech Republic). Theoretical and Applied Climatology, 122(3–4): 531–541.

LONGCORE, T., RICH, C. (2004): Ecological light pollution. Frontiers in Ecology and the Environment, 2(4): 191–198.

McLAUREN, J. S., SMITH, H. (1978): The function of phytochrome in the natural environment. V. Phytochrome control of the growth and development of Rumex obtusifolius under simulated canopy light environments. Plant, Cell and Environment, 1: 61–67.

OKAMOTO, K., YANAGI, T., KONDO, S. (1997): Growth and morphogenesis of lettuce seedlings raised under different combinations of red and blue light Available at: http://www.actahort.org/books/435/435_14.htm

OKE, T. R. (2006): Initial guidance to obtain representative meteorological observations at urban sites. Instruments and Observing Methods, Report No. 81. Geneva, WMO.

POKLADNÍKOVÁ, H., FUKALOVÁ, P., ROŽNOVSKÝ, J., STŘEDA, T. (2009): Specifics of temperature extremes in the conditions of the urban climate. In: Pribullová and Bičárová [eds.]: Sustainable Development and Bioclimate (pp. 217–218), Stará Lesna, Geophysical Institute of the SAS.

RICH, C., LONGCORE, T. (2006): Ecological consequences of artificial night lighting. Washington, Island Press.

RIEGEL, K. W. (1973): Light pollution: outdoor lighting is a growing threat to astronomy. Science, 179: 1285–1291.

SABZALIAN, M. R., HEYDARIZADEH, P., MORTEZA, Z., BOROOMAND, A., AGHAROKH, M. (2014): High performance of vegetables, flowers, and medical plants in a red-blue incubator for indoor plant production. Agronomy for Suitable Development, 34(4): 879–886.

SAMACH, A., GOVER, A. (2001). Photoperiodism: The Consistent Use of Constans. Current Biology, 11: 651–654.

SEARLE, I., COUPLAND, G. (2004): Induction of Flowering by Seasonal Changes in Photoperiod. The Embo Journal, 23: 1217–1222.

SOLANO LAMPHAR, H. A., KOCIFAJ, M. (2013): Light pollution in ultraviolet and visible spectrum: Effect on different visual perceptions. Plos One, 8(2): e56563.

SONG, Y. H., SMITH, R. W., TO, B. J., MILLAR, A. J., IMAIZUMI, T. (2012): FKF1 Conveys Timing Information for CONSTANS Stabilization in Photoperiodic Flowering. Science, 336: 1045–1049.

STEHNOVÁ, E., STŘEDOVÁ, H. (2016): Fenologie řepy cukrové v kontextu rizika vodní eroze. Listy cukrovarnické a řepařské. 132(12): 380–386.

STEWART, I. D., OKE, T. R. (2012): Local climate zones for urban temperature studies. Bulletin of American Meteorological Society, 93(12): 1879–1900.

STN EN 12464-2 (2014): Svetlo a osvetlenie. Osvetlenie pracovísk. Časť 2: Vonkajšie pracoviská. Available at: http://www.svetelneznecistenie.sk/aktualne/135-legislativa-na-slovensku.html?start=2

STŘEDOVÁ, H., STŘEDA, T., LITSCHMANN, T. (2015): Smart tools of urban climate evaluation for smart spatial planning. Moravian Geographical Reports, 23(3): 47–57.

STŘELCOVÁ, K. (2013): Klimatické pomery vo Zvolene a okolí. In: Bebej, J. [ed.]: Príroda, Monografia mesta Zvolen (pp. 22–35), Zvolen, Mestský úrad Zvolen.

TAKEMIYA, A., INONE, S-I., DOI, M., KINOSHITA, T., SHIMAZAKI, K-I. (2005): Phototropins Promote Plant Growth in Response to Blue Light in Low Light Environments. The Plant Cell, 17: 1120–1127.

TUHÁRSKA, M., KRNÁČOVÁ, D., ŠKVARENINOVÁ, J., HRÍBIK, M. (2016): Intensity of light pollution and its impact on phenological phases of trees. In: Brzezina, J. et al. [eds.]: Mendel and Bioclimatology (pp. 398–403), Brno, Mendel University.

VERHEIJEN, F. J. (1985): Photopollution: artificial light optic spatial control systems fail to cope with. Incidents, causations, remedies. Experimental Biology, 44(1): 1–18.

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VYSOUDIL, M., LEHNERT, M., KLADIVO, P. (2016): Heat Stress in the Urban and Suburban Landscape and its Spatial Differentiation through the Example of a Medium-Sized City. Dela, 46: 163–182.

WHITE, A. G. (1974): Excessive light as a form of urban-created pollution: a selected bibliography. Monticello, Illinois, Council of Planning Librarians.

YEH, N., CHUNG, J. P. (2009): High-brightness LEDs: energy efficient lighting sources and their potential in indoor plant cultivation. Renewable and Sustainable Energy Reviews, 13(8): 2175–2180.

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Fig. 8: Minor landforms and Pico Larouco (Photo: E. De Uña-Álvarez)

Fig. 9: General view of the summit area (Photo: M. C. Cuquejo-Bello)

Illustrations related to the paper by E. De Uña-Álvarez et al.