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Four dimensions of landscape in mountainous areas

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Abstract: This paper argues that landscape, as the prime study object of landscape ecology, should be perceived and investigated in its four dimensions. The author focuses on certain methodological issues encountered when adopting this approach in mountain landscapes. These arise both from the greater complexity of mountain landscapes as compared to lowland landscapes and a difficulty in displaying a highly varied reality on a two-dimensional map. Additionally, the higher intensity of mountain processes results in extreme phenomena that add to the complexity of study of mountain landscape.

Key words: landscape, dimension, mountainous areas, landscape structure, vertical zonality

Introduction

This paper argues that landscape, as the prime study object of landscape ecology (Richling 2008). The concept of landscape involves numerous meanings, as discussed by A. Richling and J. Solon (1994), and is still being debated by geoecologists (Richling 2010). Among the many dimensions of landscape is its internal complexity, which this paper deals with in particular. While many studies highlight this aspect, it is Maciej Pietrzak (2010), who puts complexity as the number one feature of landscape and adds to it the features of multidimensionality and multifacetedness (essentially describing this complexity).

The multifacetedness of landscape is widely discussed in many studies, and sometimes the term finds its way indirectly into landscape definitions. For example L.S. Berg, in his 1962 study, pointed to a highly specific and unique set of landscape features, including the climate, land relief, waters, soils, vegetation and wildlife. Much later, in 1990, I.S. Zonneveld defined landscape as a system comprising land relief, waters, vegetation, soils, rocks and the atmosphere. This approach, while undeniably correct, puts much emphasis on just one of landscape's dimensions, namely its vertical structure (Przewoźniak 1987). Studies of this kind seldom address the fact that the vertical landscape structure covers a large area, rather than a single point on the surface of the Earth.

On the other hand, numerous studies that propose various breakdowns into nature units, landscape typologies, regionalisations, etc. seem to overlook the vertical landscape dimension. Landscape is often reduced to its two dimensions, and is simplified to the point where it can be depicted on a map. This approach produces what is known as a horizontal landscape structure. Naturally, authors realise that the real landscape is more complex, but choose not to deal with that complexity. Pietrzak (2008) argues that it would be desirable to add the vertical component in this type of studies. One attempt in this direction is a slightly forgotten work by Widacki (1989), who discusses the relationships between environmental components and features in geocomplexes.

However, only the addition of time as a fourth dimension allows a transition from a static description of a structure, which only provides a momentary image of a landscape, or a 'momentary landscape', to a truly holistic landscape research approach that takes into account its functioning, dynamics and change. The understanding

of landscape as a dynamic four-dimensional system (German 1992) should be adopted as a new standard in contemporary landscape ecology.
A four-dimensional landscape in lowlands is much simpler than one in mountainous areas. This study aims to raise awareness of certain methodological difficulties in the research of mountain landscape as a multidimensional object.

Mountainous areas – a two-dimensional landscape

Let us begin by considering a two-dimensional landscape, i.e. a landscape where only two horizontal dimensions are taken into account. For the most part, this structure is depicted on a map where a real-life landform is projected on a flat surface. When deriving a distance between two points on a map of a mountainous area one finds that it is more than just the function of the map's scale, but it depends also on the inclination angle of the terrain between the points (fig. 1). In general horizontal dimensions are the more distorted the steeper the slope of the terrain. For example, the actual length of a watercourse, or an avalanche chute, or a physico-geographical boundary in mountains, is considerably greater than what can be read from its projected map image.
The same effect is even more exaggerated in square area. The difference between a topographical and actual surface grows with the growing terrain slope (tab. 1) and hence surface measurements derived from a map carry a wide error margin. If the slope is 60º the map surface is only half of the actual one, and when a cliff reaches 90º maps utterly fail to adequately represent area.

Mountainous areas – a three-dimensional landscape

Serious methodological problems appear in mountains when adding the third, vertical, dimension, or vertical landscape structure. J. Przewoźniak (1983) defines this as containing a certain set of landscape components, their nature and setup, as well as the concurrence of their features. These components include the geology, morphology, climate, water relations, soil, vegetation and wildlife. The vertical landscape structure is defined at certain points along vertical lines (hence the name) perpendicular to the terrain surface (Perelman 1971). In mountains the vertical lines cease to be perpendicular to terrain surface, and sometimes they can become closer to parallel.
The question appears as to whether, in mountainous areas, the vertical landscape structure should be determined along the vertical line or one perpendicular to the Earth's surface. It turns out that some environmental components are linked to the former and others to the latter types of lines (fig. 2). The former is involved in the climate and vegetation, while the latter is undoubtedly involved in the land relief and soils, normally in the geology and predominantly in water relations. Wildlife is debatable, as some animals crawl on (or under) the surface, while others travel erect.
It is worth noting that the environmental components underground are more linked to the perpendicular line, while those components on the surface are linked to the vertical line. This sheds fresh light on the concept of a landscape unit as a solid proposed by Pietrzak (2007). It seems that in mountainous areas the top of a unit is not parallel to its floor, and so the solid is no longer regular in form (fig. 3).
In some cases, such as in landscape units straddling a ridge, there is also the problem that certain sections of the solid should be allocated to two units at the same time (fig. 4).

Table 1. Relationships between actual and topographical surface areas depending on slope angle

Topographic area [m^2]	Angle (^{o})	Actual surface area [m^2]
100	0	100
	30	115.5
	45	141.4
	60	200
	90	$+\infty$

Yet another methodological problem is the vertical landscape zonality occurring in sufficiently high mountainous areas. This is a landscape property that is different from the vertical structure (Balon 2007), but in a way contained in the vertical landscape dimension and demanding separate treatment. It is worth adding here that research available on vertical zonality, whether concerning the climate (Hess 1965), vegetation (Pawłowski 1959) or physical geography (Balon 2000), also considers landscape in two dimensions, even if the zones are stacked on top of one another along the slope profile.

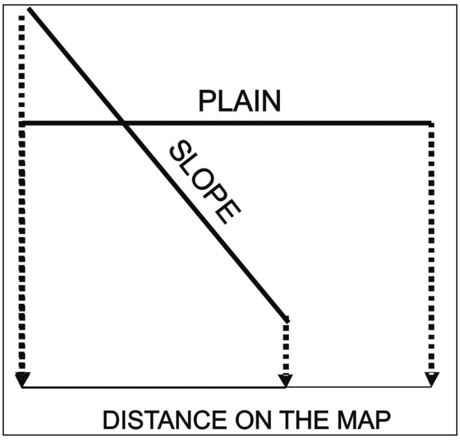

Fig. 1. Variable distances of a map projection in mountainous areas

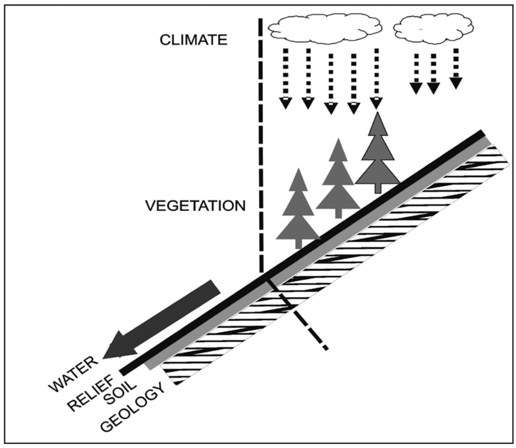

Fig. 2. Components of the vertical landscape structure

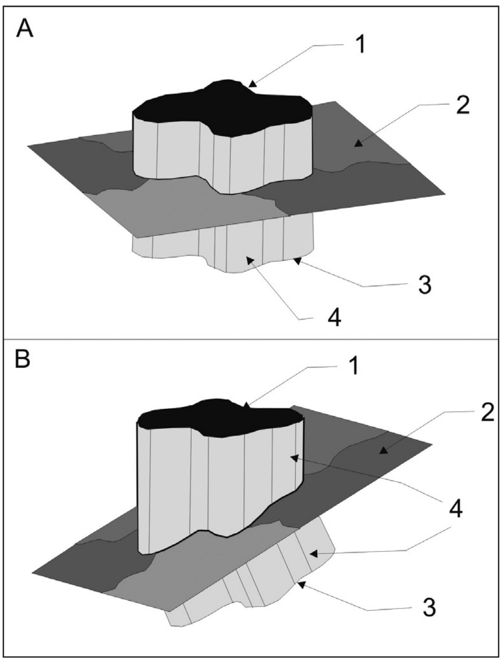

Fig. 3. General schematic of landscape unit solids in flat (A*) vs. mountain areas (B) 1 – top base, 2 – land area, 3 – bottom base, 4 – side
(* Fig. 3A – acc. to M. Pietrzak 2007)

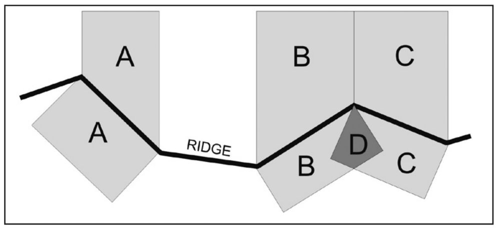

Fig. 4. The issue of double belonging to two neighbouring landscape units
A – landscape unit A, B – – landscape unit B, C – landscape unit C, D – common part B and C units

Finally, mountains pose the problem of a shadow effect that virtually does not exist in the lowlands. In the Polish lowlands the amount of radiation energy delivered to a landscape unit depends primarily on the latitude, exposure and vegetation cover. In mountains, however, two additional factors come into play, namely the altitude (in elevated areas the atmosphere absorbs less radiation) and the slope angle (which determines the sunbeam falling angle).
In flatlands of any latitude the slope angle and exposure are sufficient to derive the potential total solar radiation received. These calculations, however, fail to take into account the shadow effect of nearby mountains (fig. 5). The existence of nearby mountain peaks is bound to result in a significantly lower supply of radiation energy not just in valley bottoms, but also in lower slopes that otherwise have a 'warm' exposure. This is an important effect, as differences in radiation energy received in a landscape differentiate its dynamics and functioning significantly.

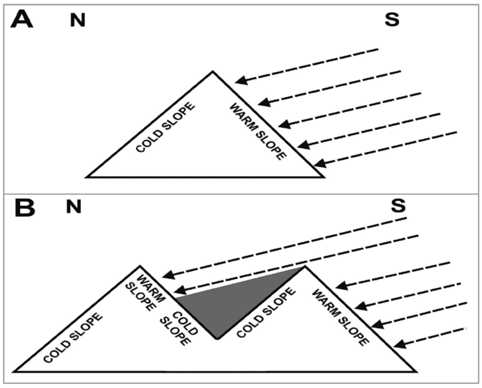

Fig. 5. Schematic of slope shading by nearby mountain peaks A – without shading, B – with shading

Mountain areas – a four-dimensional landscape

The fourth, temporal dimension of a landscape seems to be quite similar in mountains and in lowlands. However, while both in mountains and in lowlands the landscape changes over time, the relevant processes in mountains tend to be far more dynamic and produce a significantly greater pace of landscape change. Among these changes a particular intensity and greater frequency is found in extreme phenomena, often causing dramatic and profound reconstruction of the landscape structure, both horizontal and vertical (German 2007), and changes in its functioning.

Conclusions

1. Understanding of landscape as a four-dimensional dynamic system should become standard in contemporary landscape ecology.
2. A four-dimensional landscape is far more complex in mountains than in lowlands, which adds to the difficulty in study of mountain landscape.
3. In mountain research it is important to consider accurate distances and surfaces, which are normally greater than it would appear from their map image.
4. In mountains the solids of landscape units are more complex than in lowlands.
5. In studies of the functioning of mountain landscape one should take into account the shadow effect, which diminishes the amount of radiation energy received in the unit.
6. Mountainous areas feature higher rates of processes than lowlands, which results in a faster pace of landscape change; this is reflected in the greater frequency of extreme phenomena in the mountains.

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