



# Geomorphometry of Slovenia's Mountainous Surface

# 4

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## Abstract

Geomorphometry is the science of measuring land surfaces. The basic geomorphometric indicators include surface height, slope, and aspect. Their values were calculated for all of Slovenia and separately for its mountainous and non-mountainous surface, using a 5-m digital elevation model. Slovenia's average surface height is 556.4 m, its average surface slope is 16.5°, and its average surface aspect measured from the south (0°) to the north (180°) is 84.8°. The average height of its non-mountainous surface is 320.0 m and that of its mountainous surface is 735.5 m, the average slope of its non-mountainous and mountainous surface is 9.5° and 21.8°, respectively, and the average aspect of its non-mountainous and mountainous surface is 81.2° and 87.5°, respectively. Slovenia's lowest point is at 0 m on the coast of the Gulf of Trieste and the lowest point of its mountainous surface is at 54 m at the bottom of the Soča Valley north of Nova Gorica. The highest point of Slovenia and its mountainous surface is at 2,864 m at the top of Mount Triglav. Geomorphometric indicators help design landform typologies. Slovenian geographers have produced five so far: the first in 1935 and the

last in 2019. The one created in 1992 is the only typology with a distinct geomorphometric character and the first computer-designed one. It divides Slovenia into 195 geomorphometric units and seven geomorphometric types. Among all Slovenian regions, Haloze has the roughest surface and the Mura Plain has the least rough surface, and among the mountainous regions, the roughest surface is characteristic of the Idrija Hills and the least rough surface can be found in the Dry Carniola and Dobropolje region.

## Keywords

Digital elevation model · Height · Slope · Aspect · Geomorphometric unit · Geomorphometric type · Landform · Landscape

## 4.1 Introduction

Geomorphometry, or the science of measuring the Earth's landforms (from Greek *gê* 'Earth', *morphê* 'form', and *metréō* 'I measure' or *métron* 'measure') is a branch of geomorphology that primarily measures landforms but also explains their connections with other landscape elements. It relies largely on geographic information systems and digital elevation models. The basic geomorphometric indicators are surface slope and aspect. The former shows changes in surface

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height relative to the horizontal plane, and the latter relative to the vertical plane.

A 5 m digital elevation model was used to conduct a geomorphometric analysis of Slovenia's surface. The model was produced in 2023 based on a 0.5-m digital elevation model that the Ljubljana-based company GDi d.o.o. designed in 2021 using data from the point cloud obtained through the laser scanning of Slovenia commissioned by the Slovenian Ministry of Natural Resources and Spatial Planning. The indicators were calculated separately for Slovenia and its mountainous and non-mountainous surface. The following three landscape types (defined by Perko in Chap. 3 of this book), which together account for 57% of Slovenia, were characterized as mountainous surfaces: Alpine mountains, Alpine hills, and Dinaric plateaus. Five landscape types were categorized as non-mountainous surfaces: Alpine plains, Pannonian hills, Pannonian plains, Dinaric lowlands, Mediterranean hills, and Mediterranean plateaus (Perko et al. 2021).

## 4.2 Geomorphometric Indicators

Because the faces of landforms are two-dimensional and the space in which they are located is three-dimensional, each face of a landform can be analyzed in terms of its geomorphometric characteristics relative to the horizontal and vertical plane, especially distance, inclination (describing spatial deviation in distance), and curvature (describing spatial changes in inclination; Perko 2001, 2007; Hrvatín and Perko 2002).

Based on this, six geomorphometric characteristics of landform faces and points can be determined (Perko 2007):

- **Vertical distance** or distance from the horizontal plane. In the geographical sense, this is the same as surface height, which, as a third dimension in addition to longitude and latitude, gives the precise location of all features on the Earth's surface. Its basic unit is the meter.

- **Horizontal distance** or distance from the vertical plane; in geographical terms, this is the distance between two faces (or points) on the Earth's surface. It is measured in meters.
- **Vertical inclination** refers to the change in distance relative to the horizontal plane. It is usually measured in degrees. In the mathematical sense, it corresponds to the first derivative of vertical variation in height, and, in the geographical sense, it is the same as surface slope.
- **Horizontal inclination** refers to the change in distance relative to the vertical plane. It is usually measured in degrees. In the mathematical sense, it corresponds to the first derivative of horizontal variation in height, and, in the geographical sense, it is the same as surface orientation or aspect.
- **Vertical curvature** (also profile curvature or slope curvature) refers to the change in inclination relative to the horizontal plane. It is measured in radians per meter. In the mathematical sense, it corresponds to the first derivative of a vertical change in inclination or the second derivative of a vertical change in distance, and, in the geographical sense, it corresponds to surface concavity or convexity relative to the horizontal plane and indicates the direction of the maximum slope.
- **Horizontal curvature** (also plan curvature, aspect curvature, or contour curvature) refers to the change in surface inclination relative to the vertical plane. It is measured in radians per meter. In the mathematical sense, it corresponds to the first derivative of a horizontal change in inclination or the second derivative of a horizontal change in distance, and, in the geographical sense, it corresponds to surface concavity or convexity relative to the vertical plane and is thus perpendicular to the direction of maximum slope (i.e., parallel to contour lines and surface aspects).

However, it is not only the geomorphometric characteristics of the landforms' faces that is important, but also the geomorphometric characteristics of the faces of the neighboring landforms. Hence, in addition to the six geomorphometric

**Table 4.1** Overview of the basic geomorphometric and geographical indicators of landform characteristics and their spatial variability

Geomorphometric characteristic	Vertical distance	Horizontal distance	Vertical inclination	Horizontal inclination	Vertical curvature	Horizontal curvature
Geographical characteristic	Surface height	–	Surface slope	Surface aspect	–	–
Geomorphometric variability	Spatial variability of vertical distance	Spatial variability of horizontal distance	Spatial variability of vertical inclination	Spatial variability of horizontal inclination	Spatial variability of vertical curvature	Spatial variability of horizontal curvature
Geographical variability	Surface height variability	–	Surface slope variability	Surface aspect variability	–	–
Surface roughness (variability) coefficient	Height coefficient	–	Slope coefficient	Aspect coefficient	–	–

indicators relating to surface distance, inclination, and curvature, a further six geomorphometric indicators of their spatial variability (Table 4.1) can be used to determine surface variability or roughness.

Thus, for example, the vertical inclination or surface slope indicator also includes a surface slope variability indicator, which shows the frequency or speed at which surface slopes change.

The coefficient of variation is among the most suitable statistical indicators for calculating spatial variability. It is the ratio of the standard deviation to the mean of the digital elevation model cells analyzed multiplied by 100, and it shows how much the standard deviation differs from the mean in percentages (Perko 2001). The greater the ratio, the more variable and rougher the surface.

Geomorphometric indicators are important not only for conducting landform analyses, but also for producing a wide range of landform classifications, including landform typologies.

### 4.3 Landform Typologies

So far, Slovenian geographers have produced five landform typologies covering all of Slovenia.

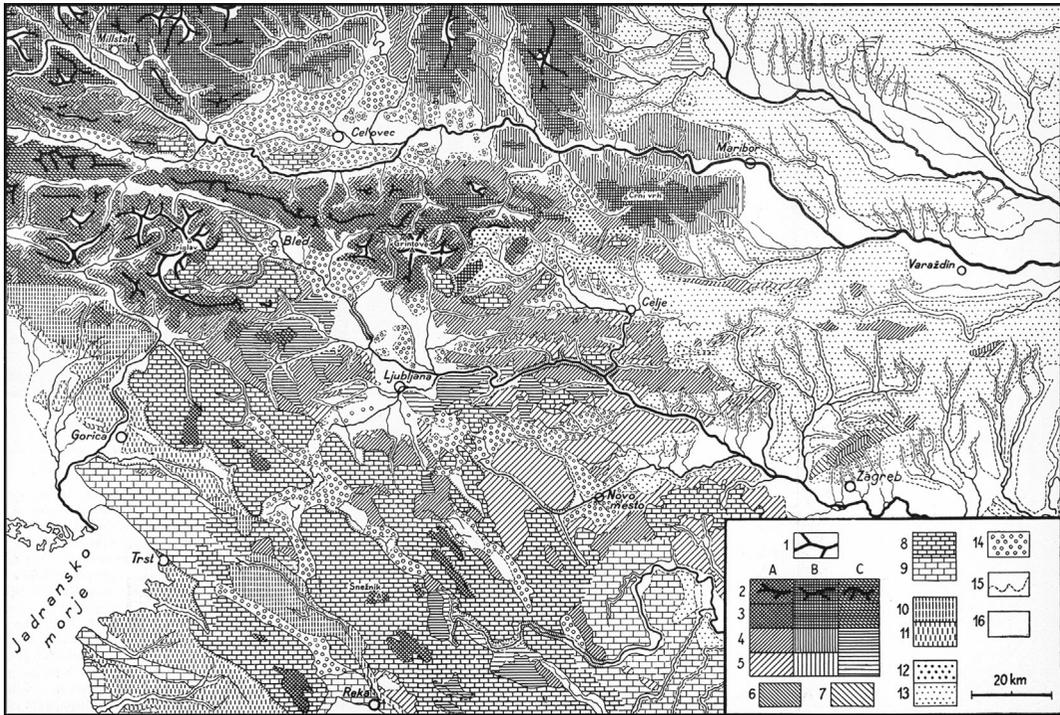
The first one was produced by Anton Melik. He primarily took macro landforms and surface height into account to define the basic types, along with rock types to define the subtypes (Fig. 4.1). He distinguished between sixteen types and twelve subtypes (Melik 1935):

1. High mountains;
2. Low mountains with high mountain ridges (with three subtypes);
3. Low mountains (with three subtypes);
4. High hills (with three subtypes);
5. Low hills (with three subtypes);
6. Pannonian carbonate–shale hills above 550 m;
7. Pannonian carbonate–shale hills below 550 m;
8. Carbonate plateaus above 400 m;
9. Carbonate plateaus below 400 m;
10. Mediterranean flysch high hills;
11. Mediterranean flysch low hills;
12. Pannonian Paleogene hills;
13. Pannonian Neogene hills;
14. Hills in basins and Dinaric lowlands;
15. Pannonian Pleistocene terraces; and
16. Plains.

Types 1 through 8 in particular can be characterized as mountainous areas; they cover a total of 55.2% of Slovenia.

Nearly sixty years later, Drago Perko produced the first computer-designed landform typology. Using the relief coefficient, which is based on the spatial variability of surface height, slope, and aspect (see the following section), he initially defined eight types (Perko 1992, 2001), which he then reduced to seven (Perko 2007; Perko et al. 2015):

1. Gentle plains (areas with a predominant relief coefficient between 0.0 and 0.9);



**Fig. 4.1** Melik's landform typology was the first such typology of Slovenia. (Melik 1935, GIAM ZRC SAZU archive)

2. Rough plains (areas with a predominant relief coefficient between 1.0 and 1.9);
3. Gentle low hills (areas with a predominant relief coefficient between 2.0 and 5.9);
4. Rough low hills (areas with a predominant relief coefficient between 6.0 and 9.9);
5. Gentle high hills (areas with a predominant relief coefficient between 10.0 and 15.9);
6. Rough high hills (areas with a predominant relief coefficient between 16.0 and 19.9); and
7. Gentle and rough mountains (areas with a predominant relief coefficient of 20.0 or more).

Types 5, 6, and 7, in particular, can be characterized as mountainous areas. They cover 33.0%, 5.1%, and 9.6% of Slovenia, respectively, or altogether 47.7% of the country.

A year later, Karel Natek divided Slovenia into eight types, using surface height difference and rock type as the main criteria (Natek 1993):

1. Plains (level areas with a surface height difference up to 30 m, mainly on fluvial and fluvio-glacial sediments);

2. Low hills (ridge-and-valley-dissected areas with a surface height difference between 30 and 200 m, mostly on Miocene and Pliocene rock);
3. High hills (ridge-and-valley-dissected areas with a surface height difference over 200 m, extending to the alpine tree line);
4. Mountains (areas above the alpine tree line, mostly alpine karst);
5. Low karst (predominantly level areas or low hills and depressions between them at lower elevations than the surrounding landscape);
6. High karst (high plateaus and hills with a surface height difference over 200 m, ridges running in a Dinaric direction, and karst depressions between them);
7. Low fluvio-karst (karst areas with predominantly fluvio-denudational landforms at lower elevations than the surrounding landscape); and
8. High fluvio-karst (mostly hills on dolomite rock, with predominantly fluvio-denudational landforms).

Types 3, 4, 6, and 8, in particular, can be characterized as mountainous areas. They cover 35.1%,

4.3%, 14.9%, and 8.8% of Slovenia, respectively, or altogether 63.1% of the country.

In 1998, Matej Gabrovec and Mauro Hrvatin produced a genetic and a geomorphometric landform typology of Slovenia. Both include six types. The geomorphometric typology is primarily based on surface height difference and macro landforms, and it comprises the following types (Gabrovec and Hrvatin 1998):

1. Plains;
2. Low hills (a surface height difference of up to 300 m);
3. High hills (a surface height difference between 300 and 1,000 m);
4. Mountains (the peaks and ridges extend over the tree line up to approximately 1,700 m);
5. Low plateaus (up to an elevation of 700 m); and
6. High plateaus (above 700 m in elevation; the peaks may even extend over 1,000 m in elevation).

Types 3, 4, and 6, in particular, can be characterized as mountainous areas. They cover 25.8%, 8.7%, and 22.4% of Slovenia, respectively, or altogether 56.9% of the country.

In 2019, Hrvatin et al. improved this typology, dividing Slovenia into seven types, primarily based on surface height, slope, and dominant landforms (Perko et al. 2024):

1. Plains;
2. Low hills;
3. High hills;
4. Mountains;
5. Corrosion plains;
6. Low plateaus; and
7. High plateaus.

Types 3, 4, and 7, in particular, can be characterized as mountainous areas. They cover 25.0%, 8.3%, and 22.3% of Slovenia, respectively, or altogether 55.6% of the country (Fig. 4.2).

Natek's typology contains the largest share of mountainous surface (63.1%) and Perko's typology contains the smallest share (47.7%),

but roughly all five landform typologies define approximately half of Slovenia as predominantly mountainous (Table 4.2).

#### 4.4 Perko's Geomorphometric Landform Typology

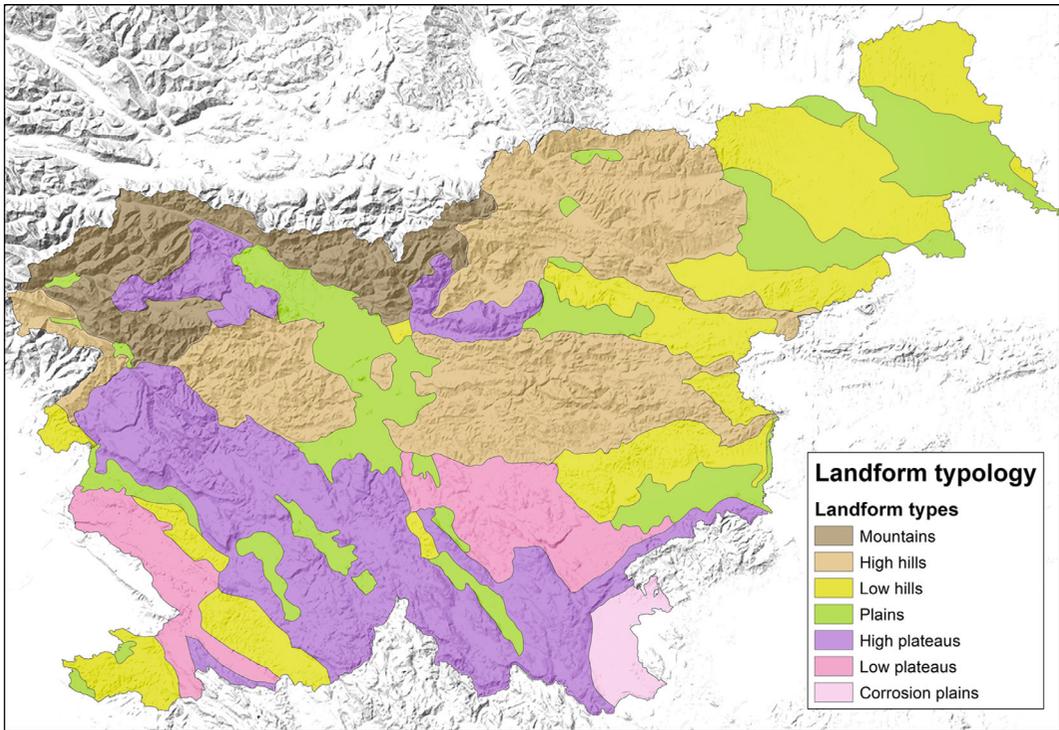
Among the five typologies, only the one produced by Perko is distinctly geomorphometric. It relies on three geomorphometric indicators that show spatial variations in surface height and slope, calculated from a 100-m digital elevation model: the surface height coefficient, the surface slope coefficient, and the relief (combined) coefficient or surface roughness coefficient, or simply the height, slope, and relief coefficients (Perko 1992, 2001, 2002).

Perko first used the *Idrisi* geographic information system (now *Terraset*) to calculate the following parameters for each cell based on its height and the heights of its eight neighboring cells:

- The height coefficient, which is the ratio between the standard deviation of surface height of nine neighboring cells and the average surface height of all cells multiplied by 100;
- The slope coefficient, which is the ratio between the standard deviation of surface slopes of nine neighboring cells and the average surface slopes of all cells multiplied by 100; and
- The relief or surface roughness coefficient, which is the geometric mean of the height and slope coefficients.

The lowest relief coefficient established was 0, the highest was 111.5, and the average was 9.3. The share of cells with a relief coefficient below 1 was 11.0%, that with a relief coefficient below 10 already rose to 59.1%, and the share of cells with a relief coefficient below 20 even reached 93.7%.

After reviewing the relief coefficients of the most typical Slovenian plains, low hills, high hills, and mountains, Perko logically combined their values into the following eight classes:



**Fig. 4.2** Hrvatin et al.'s landform typology is the last such typology of Slovenia. (Perko et al. 2026)

**Table 4.2** Comparison of landform macrotypologies of Slovenia

Author(s)	Year	No. of basic types	Average basic type size (km <sup>2</sup> )	No. of mountainous types	Proportion of no. of mountainous types (%)	Area of mountainous types (km <sup>2</sup> )	Proportion of area of mountainous types (%)
Melik	1935	16	1,267	8	50.0	11,189	55.2
Perko	1992	7	2,896	3	42.9	9,671	47.7
Natek	1993	8	2,534	4	50.0	12,791	63.1
Gabrovec and Hrvatin	1998	6	3,379	3	50.0	11,535	56.9
Hrvatin et al	2019	7	2,896	3	42.9	11,282	55.6

- Surfaces with relief coefficients between 0.0 and 0.9 (11.0% of Slovenia);
  - Surfaces with relief coefficients between 1.0 and 1.9 (2.8% of Slovenia);
  - Surfaces with relief coefficients between 2.0 and 5.9 (20.4% of Slovenia);
  - Surfaces with relief coefficients between 6.0 and 9.9 (24.9% of Slovenia);
  - Surfaces with relief coefficients between 10.0 and 15.9 (26.4% of Slovenia);
  - Surfaces with relief coefficients between 16.0 and 19.9 (8.2% of Slovenia);
  - Surfaces with relief coefficients between 20.0 and 39.9 (6.1% of Slovenia); and
  - Surfaces with relief coefficients of 40.0 or more (0.2% of Slovenia).
- He then filtered the layer with the relief coefficient classes three times using the modus inside of a moving 3 × 3 cell square window, obtaining

195 larger and spatially separate homogenous cores with similar values. He printed these cores on a 1:250,000 scale map and manually plotted their boundaries, mostly along geomorphological boundaries and larger watercourses. In the end, he combined these 195 manually delineated geomorphometric units into eight geomorphometric landform types (Perko 1992, 2001).

The eight landform types were the following:

1. Gentle plains (areas with predominance of the first class or relief coefficients between 0.0 and 0.9, comprising twenty-one units and covering 9.5% of Slovenia);
2. Rough plains (areas with relief coefficients predominantly between 1.0 and 1.9, comprising twenty-nine units and covering 5.8% of Slovenia);
3. Gentle low hills (areas with relief coefficients predominantly between 2.0 and 5.9, comprising forty-two units and covering 24.0% of Slovenia);
4. Rough low hills (areas with relief coefficients predominantly between 6.0 and 9.9, comprising twenty-two units and covering 12.9% of Slovenia);
5. Gentle high hills (areas with relief coefficients predominantly between 10.0 and 15.9, comprising forty-one units and covering 31.8% of Slovenia);
6. Rough high hills (areas with relief coefficients predominantly between 16.0 and 19.9, comprising eleven units and covering 5.1% of Slovenia);
7. Gentle and rough mountains (areas with relief coefficients predominantly of 20.0 or more, comprising twenty-four units and covering 9.5% of Slovenia); and
8. Large valleys (large areas between mountains and high hills with relief coefficients predominantly below 10.0, which were able to be drawn on a 1:250,000 map, comprising five units and covering 1.4% of Slovenia).

When a 25-m digital elevation model became available for all of Slovenia, Perko used a moving  $11 \times 11$  cell square window to recalculate the height, slope, aspect, and relief coefficients (Perko

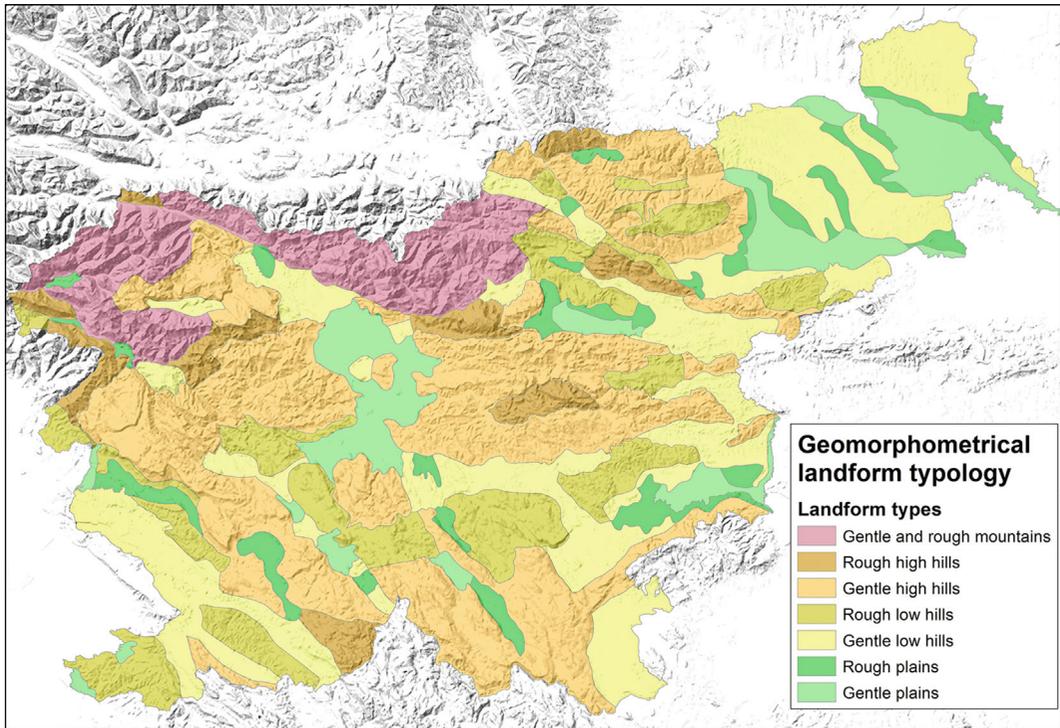
2007), reducing the number of types to seven (Fig. 4.3) by logically assigning the large valleys type to other types (Perko et al. 2015). The analysis of differences between the 100 m and 25 m digital elevation models showed that the average values of individual geomorphometric indicators for Slovenia and its landscape types and regions remained almost the same, but their minimum and maximum values increased (Hrvatín and Perko 2005).

Initially, Perko (1992, 2001) used the height and slope coefficients (i.e., two vertical surface roughness indicators) to calculate the relief coefficient, whereas the second time (Perko 2007) he used the slope and aspect coefficients (i.e., one vertical and one horizontal surface roughness indicator) because a combination of the two better shows their mutual or combined surface roughness relative to the horizontal and vertical plane.

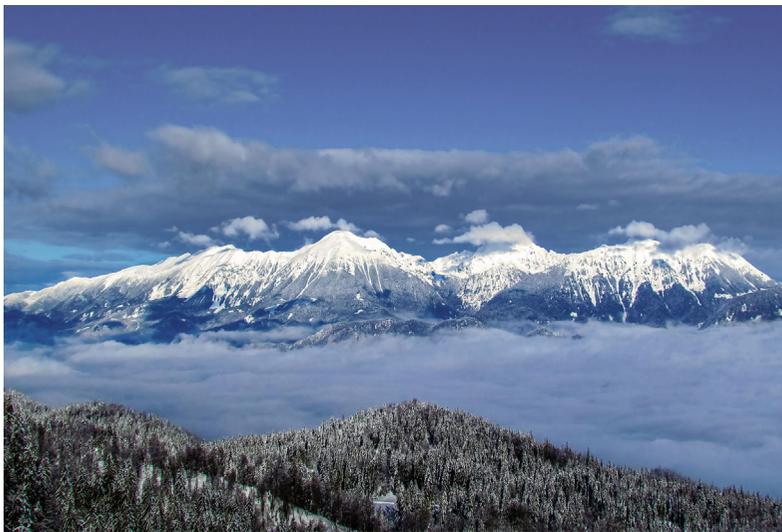
Of the 195 geomorphometric units defined (Perko 2007), the Haloze rough low hills (i.e., the western part of the Haloze region) have the highest relief coefficient (46.9) and the Ravensko and Dolinsko Plain (i.e., the eastern part of the Mura Plain region in northeastern Slovenia) has the lowest relief coefficient (10.0), thus constituting the roughest and the least rough geomorphometric units in Slovenia.

Of the seven geomorphometric types defined (Perko 2007), rough high hills have the highest relief coefficient (37.8), and rough plains have the lowest (23.7).

In terms of the mountainous geomorphometric types alone, the most typical representative of the type *mountains* is the Western Karawanks region (Fig. 4.4), where this type covers 92.8% of the region, and the most typical representative of the type *rough high hills* is the Velenje and Konjice Hills region (Fig. 4.5), where this type covers 43.6% of the region. The most typical example of the geomorphometric type *gentle high hills* is the Big Mountains, Mount Stojna, and Mount Gotenica region, where this type covers 95.0% of the region, followed closely by the Mount Boč and Macelj Ridge region (Fig. 4.6), where this type accounts for 94.1% of the region, even though it already lies outside the mountainous area (Perko 2007).

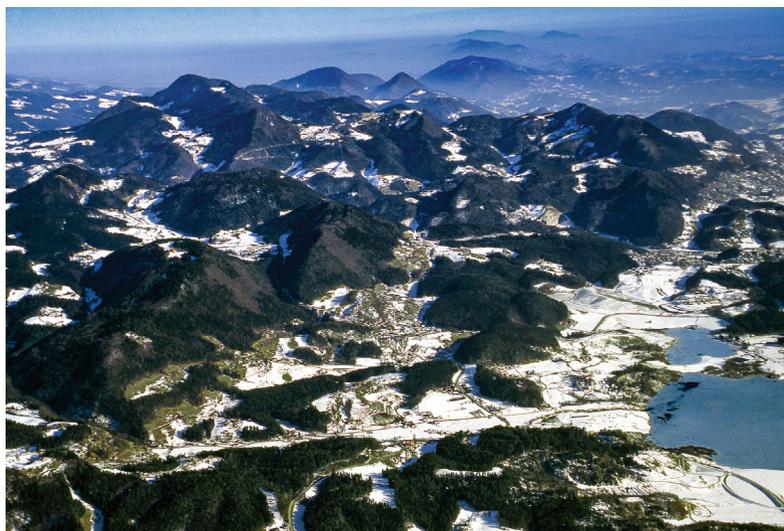


**Fig. 4.3** Perko's geomorphometric landform typology. (Perko et al. 2015)



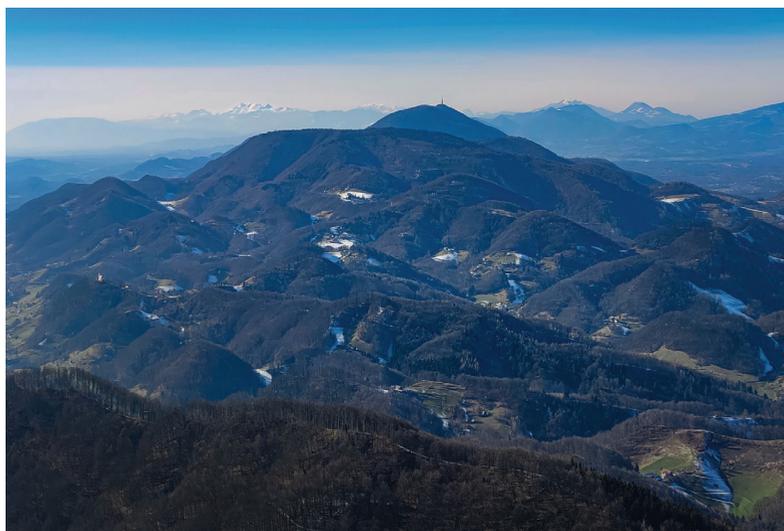
**Fig. 4.4** Western Karawanki region is the most typical representative of the geomorphometric type *mountains*, which covers over 90% of the region, accounting for the largest share in any of the regions defined. The rest of the

region belongs to the type *rough high hills*. The border between Slovenia and Austria runs along the ridges, with Mount Stol (2,236 m) as the highest peak. (Photo by kato08, Adobe Stock)



**Fig. 4.5** Velenje and Konjice Hills region is the most typical representative of the geomorphometric type *rough high hills*. Second in terms of the share of the area covered in this region is the type *rough low hills*. The ridges of the Paški Kozjak Mountains and the Konjice Mountains

(*Konjiška Gora*) with Mounts Basališče (1,272 m) and Stolpnik (1,012 m) as their highest peaks rise to the east of the Velenje Basin and its subsidence lakes resulting from coal mining operations in the past. (Photo by Marjan Garbajs, GIAM ZRC SAZU archive)



**Fig. 4.6** Mount Boč and Macelj Ridge region along the eastern edges of Slovenia's mountainous region is the second most typical example of the geomorphometric type *gentle high hills*. The types *rough low hills* and *gentle low hills* are also common, but they only account for 6% of the

region. Its highest peak is Mount Boč (978 m), which offers good views of the Slovenian mountains to the west and the non-mountainous areas to the east. (Photo by Matej Lipar, GIAM ZRC SAZU archive)

A comparison of selected indicators for the mountainous and non-mountainous types from the geomorphometric landform typology (Perko 2007), the latest landform typology produced (Perko et al. 2026), and the landscape typology of Slovenia (Perko 1998; Perko et al. 2021) is presented in Tables 4.3, 4.4, and 4.5.

#### 4.5 Geomorphometric Indicators of Slovenia's Landscape Types

Based on Perko's geomorphometric typology, the following seven geomorphometric indicators were selected to present the geomorphometric

**Table 4.3** Some basic characteristics of Slovenian mountainous and non-mountainous geomorphometric types (Perko 1992, 2001; Perko et al. 2015; data sources: 5-m digital elevation model; Gabrovec 1996; Perko et al. 2015, 2017, 2020; Ministry of Agriculture, Forestry, and Food, and Ministry of Natural Resources and Spatial Planning of the Republic of Slovenia)

Variables	Mountainous geomorphometric types (M)	Non-mountainous geomorphometric types (N)	All geomorphometric types	Ratio (M:N)
Area (km <sup>2</sup> )	9,671.1	10,602.3	20,273.4	0.9
Area (%)	47.7	52.3	100.0	0.9
Mean elevation (m)	773.8	358.0	556.4	2.2
Mean inclination (°)	23.0	10.6	16.5	2.2
Insolation (MJ/m <sup>2</sup> )	3,879.5	4,134.6	4,012.8	0.9
Average landscape diversity	0.1686	0.1567	0.1624	1.1
Fields (%)	1.1	16.4	9.1	0.1
Vineyards (%)	0.2	1.8	1.0	0.1
Orchards (%)	0.9	2.1	1.5	0.4
Meadows and pastures (%)	15.3	23.7	19.7	0.6
Forests (%)	76.5	47.0	61.1	1.6
Built-up areas (%)	2.6	7.9	5.4	0.3
Barren areas (%)	3.4	1.0	2.2	3.4
Most frequent landscape type	Alpine hills 35.7%; Alpine mountains 28.8%; Dinaric plateaus 27.9%	Pannonian hills 26.1; Dinaric lowlands 14.8%; Pannonian plains 12.2%; Alpine hills 11.4%; Dinaric plateaus 10.5%	Alpine hills 23.0%; Dinaric plateaus 18.8%; Alpine mountains 15.1%; Pannonian hills 14.8	
Most frequent landform type	High hills 44.2%; high plateaus 38.8%; mountains 16.8%	Low hills 36.7%; plains 29.8%; low plateaus 15.0%	High hills 25.1%; high plateaus 22.3%; low hills 19.3%; plains 15.6%	
Most frequent rock type	Limestone 33.6%; dolomite 18.3%	Clay and silt 22.7%; limestone 20.4%	Limestone 26.7%; clay and silt 13.1%; dolomite 12.4%	
Most frequent vegetation type	Beech 42.0%; beech and fir 17.6%; beech, chestnut, and various oaks 14.0%; beech and hophornbeam 12.3%	Beech, chestnut, and various oaks 34.9%; beech 18.1%; hornbeam 10.9%	Beech 29.5%; beech, chestnut, and various oaks 24.9%; beech and fir 10.5%	

**Table 4.4** Some basic characteristics of Slovenian mountainous and non-mountainous landform types (Hrvatín et al. 2019; data sources: 5 m digital elevation model; Gabrovec 1996; Perko et al. 2015, 2017; Perko and Ciglič 2020; Ministry of Agriculture, Forestry, and Food, and Ministry of Natural Resources and Spatial Planning of the Republic of Slovenia)

Variables	Mountainous landform types (M)	Non-mountainous landform types (N)	All landform types	Ratio (M:N)
Area (km <sup>2</sup> )	11,280.9	8,992.5	20,273.4	1.3
Area (%)	55.6	44.4	100.0	1.3
Mean elevation (m)	753.2	309.5	556.4	2.4
Mean inclination (°)	22.1	9.5	16.5	2.3
Insolation (MJ/m <sup>2</sup> )	3,897.4	4,157.8	4,012.8	0.9
Average landscape diversity	0.1702	0.1525	0.1624	1.1
Fields (%)	1.2	19.1	9.1	0.1
Vineyards (%)	0.2	2.1	1.0	0.1
Orchards (%)	1.0	2.2	1.5	0.5
Meadows and pastures (%)	17.3	22.7	19.7	0.8
Forests (%)	74.8	43.8	61.1	1.7
Built-up areas (%)	2.5	9.0	5.4	0.3
Barren areas (%)	3.0	1.1	2.2	2.7
Most frequent landscape type	Alpine hills 37.0%; Dinaric plateaus 27.6%; Alpine mountains 26.6%	Pannonian hills 30.5; Dinaric lowlands 15.4%; Pannonian plains 14.4%; Mediterranean hills 10.5%	Alpine hills 23.0%; Dinaric plateaus 18.8%; Alpine mountains 15.1%; Pannonian hills 14.8	
Most frequent geomorphometric type	High gentle hills 59.1%; mountains 17.3%	Low gentle hills 47.7%; level plains 21.3%; low rugged hills 17.5%; rugged plains 13.3%	High gentle hills 33.0%; low gentle hills 23.9%; low rugged hills 13.0%	
Most frequent rock type	Limestone 32.0%; dolomite 18.5%	Clay and silt 25.7%; limestone 20.0%; sandstone and marl (flysch) 10.6%;	Limestone 26.7%; clay and silt 13.1%; dolomite 12.4%	
Most frequent vegetation type	Beech 41.0%; beech and fir 18.1%; beech, chestnut, and various oaks 14.8%; beech and hophornbeam 11.7%	Beech, chestnut, and various oaks 36.8%; beech 15.1%; hornbeam 12.7%; hornbeam and pedunculate oak 11.0%	Beech 29.5%; beech, chestnut, and various oaks 37.7%; beech and fir 10.5%	

characteristics of Slovenia's mountainous and non-mountainous landscape types and regions (Tables 4.6 and 4.7): surface height, surface slope, surface aspect, height coefficient to indicate surface height diversity, slope coefficient to indicate surface slope diversity, aspect coefficient to indicate surface aspect diversity, and relief coefficient to indicate the overall surface diversity.

All landscape types and many regions extend to Slovenia's border, which in places distinctly

cuts off only certain surface aspects. Therefore, surface aspect is an appropriate indicator only for comparing landscape units that lie entirely inside Slovenia, whereas it can be misleading in other cases and is therefore omitted in general comparisons. A good example is the Karawanks on the Slovenian–Austrian border, which extend from the west toward the east, and so the northern surface aspects predominate on the Austrian side and the southern aspects predominate on the Slovenian side.

**Table 4.5** Some basic characteristics of Slovenian mountainous and non-mountainous landscape types (Perko 1998; Perko et al. 2021; data sources: 5-m digital elevation model; Gabrovec 1996; Perko et al. 2015, 2017; Perko and Ciglič 2020; Ministry of Agriculture, Forestry, and Food, and Ministry of Natural Resources and Spatial Planning of the Republic of Slovenia)

Variables	Mountainous landscape types (M)	Non-mountainous landscape types (N)	All landscape types	Ratio (M:N)
Area (km <sup>2</sup> )	11,531.4	8,742.0	20,273.4	1.3
Area (%)	56.9	43.1	100.0	1.3
Mean elevation (m)	735.5	320.0	556.4	2.3
Mean inclination (°)	21.8	9.5	16.5	2.3
Insolation (MJ/m <sup>2</sup> )	3,885.9	4,180.3	4,012.8	0.9
Average landscape diversity	0.1701	0.1522	0.1624	1.1
Fields (%)	1.6	19.0	9.1	0.1
Vineyards (%)	0.2	2.2	1.0	0.1
Orchards (%)	1.1	2.1	1.5	0.5
Meadows and pastures (%)	16.9	23.4	19.7	0.7
Forests (%)	74.3	43.6	61.1	1.7
Built-up areas (%)	3.0	8.6	5.4	0.3
Barren areas (%)	3.0	1.0	2.2	3.0
Most frequent geomorphometric type	High gentle hills 51.8%; low rugged hills 12.8%	Low gentle hills 46.4%; level plains 20.7%; low rugged hills 13.4%; rugged plains 11.1%	High gentle hills 33.0%; low gentle hills 23.9%; low rugged hills 13.0%	
Most frequent landform type	High hills 41.2%; high plateaus 33.5%; mountains 14.4%	Low hills 40.1%; plains 31.9%; low plateaus 12.7%	High hills 25.1%; high plateaus 22.3%; low hills 19.3%; plains 15.6%	
Most frequent rock type	Limestone 32.2%; dolomite 17.4%	Clay and silt 25.0%; limestone 19.4%; sandstone and marl (flysch) 11.3%; marl 10.4%	Limestone 26.7%; clay and silt 13.1%; dolomite 12.4%	
Most frequent vegetation type	Beech 42.9%; beech and fir 16.5%; beech, chestnut, and various oaks 16.0%; beech and hophornbeam 11.3%	Beech, chestnut, and various oaks 36.8%; hornbeam 13.1%; beech 11.9%; hornbeam and pedunculate oak 11.2%	Beech 29.5%; beech, chestnut, and various oaks 24.9%; beech and fir 10.5%	

Among the remaining six geomorphometric indicators selected, Alpine mountains show the highest average values for all indicators except the aspect and relief coefficients, and the Pannonian plains show the lowest average values for all indicators except the aspect coefficient.

Among mountainous landscape types, Alpine hills have the highest aspect coefficient (40.4) because they are more dissected by river valleys than the more uniform Alpine mountains

(33.5). Among non-mountainous landscape types, Pannonian plains have the highest aspect coefficient (56.0) because the finely terraced fluvial deposits change the surface aspect quickly, even though that may not be so obvious due to the small height differences. Because the finely dissected karst surface also contributes to a rapid alternation of aspect, Dinaric plateaus, Dinaric lowlands, and Mediterranean plateaus also have a higher average aspect coefficient than Alpine mountains.

**Table 4.6** Some basic morphometric indicators of Slovenian mountainous (in bold) and non-mountainous (in italic) landscape types (Perko 1998; Perko et al. 2021; data sources: 5-m digital elevation model and Ministry of Natural Resources and Spatial Planning of the Republic of Slovenia; Perko 2007)

Landscape types	Area in km <sup>2</sup>	Surface height average	Surface slope average	Surface aspect average	Surface height coefficient	Surface slope coefficient	Surface aspect coefficient	Surface relief coefficient
<b>Alpine mountains</b>	3,062	1053.79	28.24	84.12	6.74	45.61	33.51	37.49
<b>Alpine hills</b>	4,660	582.02	21.10	87.30	4.23	39.94	40.42	38.88
<i>Alpine plains</i>	819	373.14	5.69	66.88	0.98	16.90	44.98	23.09
<i>Pannonian hills</i>	2,995	288.47	12.01	83.65	2.10	28.16	44.03	33.33
<i>Pannonian plains</i>	1,297	195.79	1.65	70.19	0.21	4.62	55.98	13.01
<b>Dinaric plateaus</b>	3,809	667.34	17.49	90.37	3.44	34.70	38.05	34.90
<i>Dinaric lowlands</i>	1,897	402.67	9.59	85.61	1.59	23.28	46.39	30.25
<i>Mediterranean hills</i>	1,061	305.22	14.40	84.41	2.71	31.45	42.36	34.61
<i>Mediterranean plateaus</i>	673	425.73	10.58	91.18	1.90	24.83	42.59	30.57
Slovenia	20,273	556.43	16.52	84.76	3.35	32.38	41.38	33.50

Alpine hills have the highest average relief coefficient (37.5, compared to 33.5 for all of Slovenia, 37.2 for mountainous areas, and 28.6 for non-mountainous areas) among all landscape types, which means they constitute the roughest parts of Slovenia in terms of geomorphometry; the opposite applies to Pannonian plains (13.0; Table 4.6).

#### 4.6 Geomorphometric Indicators of Slovenia's Regions

Among the twenty mountainous regions defined, the Western Karawanks (Fig. 4.7; for the locations of individual regions, see Fig. 3.8. and Table 3.2 in Chap. 3 of this book) have the highest average surface height (1,186.0 m, compared to 556.4 m for all of Slovenia) and the highest average surface slope (29.4°, compared to 16.5° for all of Slovenia), and the Julian Alps (Fig. 4.8) have the highest surface height coefficient (7.2,

compared to 3.4 for all of Slovenia) and the highest surface slope coefficient (48.1, compared to 32.4 for all of Slovenia), which means that the surface height and slope change the most rapidly in this region. The Ložnica and Hudinja Hills have the highest surface aspect coefficient (46.0), whereas among the non-mountainous regions the Mura Plain has an even higher one (57.7). The Idrija Hills (Fig. 4.9) have the highest relief coefficient (40.7, compared to 33.5 for all of Slovenia), which means that, in terms of geomorphometry, they constitute the roughest mountainous region in Slovenia. The highest relief coefficient overall (45.8) has, however, been established for the non-mountainous region of Haloze (Fig. 4.10), which makes it morphometrically the roughest region in Slovenia (Table 4.7); among other things, this is also reflected in higher landslide hazard (Zorn and Komac 2008).

The Mura Plain (Fig. 4.11) has the lowest relief coefficient in Slovenia (11.1), which makes it the least rough region of all in terms of geomorphometry. The lowest relief coefficient among

**Table 4.7** Some basic morphometric indicators of Slovenian mountainous (in bold) and non-mountainous (in italic) regions (Perko 1998; Perko et al. 2021; data sources: 5-m digital elevation model and Ministry of Natural Resources and Spatial Planning of the Republic of Slovenia; Perko 2007)

Regions	Area in km <sup>2</sup>	Surface height average	Surface slope average	Surface aspect average	Surface height coefficient	Surface slope coefficient	Surface aspect coefficient	Surface relief coefficient
<b>Julian Alps</b>	1,542	1107.24	28.91	87.11	7.21	48.05	32.67	37.76
<b>Kamnik–Savinja Alps</b>	889	957.26	27.06	84.48	6.26	43.18	34.11	36.91
<b>Western Karawanks</b>	331	1186.01	29.35	65.13	6.74	43.20	33.05	36.77
<b>Eastern Karawanks</b>	300	918.82	27.02	88.70	5.78	42.89	36.59	38.65
<b>Cerkno, Škofja Loka, Polhov Gradec, and Rovte Hills</b>	979	646.50	23.60	88.01	4.74	42.24	40.71	40.35
<b>Sava Hills</b>	1,909	483.02	20.72	87.96	4.11	40.55	41.18	39.52
<b>Ložnica and Hudinja Hills</b>	244	363.35	15.26	81.32	2.61	35.72	45.97	39.16
<b>Velenje and Konjice Hills</b>	241	625.38	22.22	82.46	4.55	42.51	41.06	40.41
<b>Pohorje, Strojna, and Kozjak</b>	1,287	713.28	20.67	87.81	4.26	37.62	37.90	36.49
<i>Sava Plain</i>	676	393.32	6.12	65.11	1.07	18.29	43.72	23.97
<i>Savinja Plain</i>	143	277.98	3.66	75.22	0.55	10.33	50.94	18.95
<i>Goričko</i>	492	274.87	7.29	78.47	1.36	18.15	39.19	25.41
<i>Lendava Hills</i>	17	225.53	11.18	83.65	2.09	27.82	36.75	30.94
<i>Slovenian Hills</i>	1,034	268.16	9.58	83.83	1.66	24.26	45.07	31.05
<i>Dravinja Hills</i>	281	317.62	9.32	82.39	1.59	22.56	43.80	29.26
<i>Haloze</i>	241	316.59	22.48	94.99	3.38	44.55	48.82	45.76
<i>Mount Boč and the Macelj Ridge</i>	73	461.97	25.07	84.09	4.80	45.06	40.48	41.66
<i>Vogljajna and Upper Sotla Hills</i>	293	307.05	13.94	84.58	2.40	33.01	46.47	38.06
<i>Central Sotla Hills</i>	101	304.62	14.19	94.70	2.73	33.32	42.55	35.78
<i>Krško, Senovo, and Bizeljsko Hills</i>	461	275.37	14.88	80.51	2.73	35.52	44.11	38.10
<i>Mura Plain</i>	602	183.92	1.28	65.48	0.14	3.00	57.67	11.06
<i>Drava Plain</i>	425	234.81	1.59	69.60	0.20	4.82	56.17	13.54
<i>Krka Plain</i>	270	160.81	2.58	81.61	0.41	7.93	51.92	16.52
<b>Kambreško and Banjšice Plateaus</b>	272	549.47	22.30	91.13	4.70	39.96	37.06	37.27
<b>Idrija Hills</b>	239	647.59	28.14	90.82	5.96	46.19	37.80	40.70
<b>Trnovo Forest Plateau, Mount Nanos, and Hrušica Plateau</b>	508	830.70	20.66	87.99	4.02	39.78	37.63	37.32
<b>Javornik Hills and Snežnik Plateau</b>	458	967.61	16.62	90.47	3.37	35.02	38.23	35.56

(continued)

**Table 4.7** (continued)

Regions	Area in km <sup>2</sup>	Surface height average	Surface slope average	Surface aspect average	Surface height coefficient	Surface slope coefficient	Surface aspect coefficient	Surface relief coefficient
<b>Krim Hills and Menišija Plateau</b>	300	633.20	17.38	96.53	3.48	36.35	37.48	35.41
<b>Bloke Plateau</b>	144	743.37	14.35	88.60	2.68	31.70	42.58	35.09
<b>Big Mountains, Mount Stojna, and Mount Gotenica</b>	553	735.80	17.31	86.28	3.41	34.77	37.07	34.42
<b>Little Mountains, Kočevje Rog Plateau, and Mount Poljane</b>	584	611.62	14.52	86.76	2.68	28.40	35.82	30.68
<b>Dry Carniola and Dobropolje</b>	424	399.06	11.43	90.16	2.09	25.76	39.45	30.34
<b>Radulja Hills</b>	116	373.06	16.67	88.71	3.11	36.83	45.57	39.93
<b>Gorjanci Hills</b>	212	469.21	17.07	108.88	3.32	35.69	39.71	36.51
<i>Pivka Lowland and Mount Vremščica</i>	297	607.09	9.90	86.52	1.81	24.65	43.71	31.36
<i>Inner Carniola Lowland</i>	270	571.38	10.28	81.36	1.56	24.40	46.33	30.84
<i>Ribnica–Kočevje Lowland</i>	113	489.24	6.83	83.44	0.84	14.90	49.72	24.65
<i>Velike Lašče Region</i>	71	591.08	15.76	90.84	2.82	35.43	45.53	39.09
<i>Ljubljana Marsh</i>	180	296.78	3.25	78.25	0.55	10.76	56.30	18.55
<i>Lower Carniola Lowland</i>	318	363.43	10.05	86.69	1.88	26.32	43.35	32.16
<i>Novo Mesto Region</i>	259	280.58	11.12	94.99	1.98	26.42	43.25	32.22
<i>White Carniola</i>	388	231.66	10.09	83.82	1.44	22.89	47.67	31.54
<i>Gorizia Hills</i>	83	232.20	19.31	81.32	3.79	37.84	42.42	38.97
<i>Vipava Hills</i>	310	215.07	12.54	80.41	2.34	26.84	41.47	31.15
<i>Brkini Hills and Reka Valley</i>	342	525.36	15.87	87.45	2.75	34.37	45.03	38.13
<i>Koper Hills</i>	327	179.12	13.38	85.83	2.76	31.16	40.40	33.11
<i>Karst Plateau</i>	429	333.64	9.66	90.54	1.72	23.10	43.31	29.65
<i>Podgorje Karst Plateau, Čičarija Plateau, and Podgrad Lowland</i>	245	587.25	12.20	92.30	2.22	27.88	41.33	32.18
Slovenia	20,273	556.43	16.52	84.76	3.35	32.38	41.38	33.50

the mountainous regions (30.3) is typical of Dry Carniola and Dobropolje (Fig. 4.12, Table 4.7).

**Fig. 4.7** Western Karawanks have the highest average surface height and slope among all Slovenian regions. The Košuta Ridge, the longest Slovenian mountain ridge, is also part of this region. Left: the highest peak of the Košuta Ridge, Mount Košutnikov Turn (2,133 m), right: Mount Veliki Vrh (2,088 m). (Photo by Bor Rojnik / Wirestock Creators, Adobe Stock)



**Fig. 4.8** Due to significant surface height differences, the Julian Alps have the highest average height and slope coefficients among all Slovenian regions. The photograph shows a view of the Soča Valley and Kobarid toward Big Mount Kanin (*Visoki Kanin*, 2,587 m) on the Slovenian–Italian border, at the southern edges of the Julian Alps. (Photo by Mny-Jhee, Adobe Stock)



#### 4.7 Geomorphometric Indicators of Slovenia's Mountainous and Non-Mountainous Areas

The main geomorphometric differences between Slovenia's mountainous and non-mountainous areas (Table 4.8) show that, despite its smallness, Slovenia is a diverse country not only in terms of landscapes (Ciglič and Perko 2013) but also geomorphometry. Moreover, its landscape diversity is largely the result of geomorphometric diversity (Perko et al. 2015, 2017, 2024).

The average **surface height** of all of Slovenia is 556.4 m, of its non-mountainous areas is 320.0 m, which is 42% less, and that of its mountainous areas is 735.5 m, which is 32% more than the average surface height of all of Slovenia and 130% more than that of its non-mountainous areas. The Western Karawanks have the highest average surface height (1,186.0 m) among the mountainous regions, and the Ložnica and Hudinja Hills have the lowest (363.4 m), and so the ratio between the two is slightly more than 3:1.

Slovenia's average surface height is nearly 300 m lower than the average land surface height

**Fig. 4.9** Idrija Hills have the highest average relief coefficient among Slovenian mountainous regions. Its significant surface roughness is primarily the result of numerous creeks, the Idrija Fault, and rapid rock alternation. The photograph shows Spodnja Idrija at the confluence of the Idrija and Kanomljica rivers. (Photo by Taljat, Adobe Stock)



**Fig. 4.10** Haloze has the highest average relief coefficient among all Slovenian regions and thus forms the roughest part of Slovenia. Its wooded western section is the roughest geomorphometric unit. The region lies southwest of the Drava River along the Slovenian–Croatian border. (Photo by Marjan Garbajs, GIAM ZRC SAZU archive)



of the Earth, which is 841 m (Perko 2001). With an average surface height of 830.7 m, the Trnovo Forest Plateau, Mount Nanos, and Hrušica Plateau region most closely approaches this average in Slovenia.

Among the 100-m elevation zones, the largest share of Slovenia's total surface (18.2%) lies in the zone between 200 and 300 m, the largest share of mountainous areas (13.5%) lies in the 500–600-m zone, and the largest share of non-mountainous areas (36.3%) lies in the 200–300-m zone. A total of 6.5% of all of Slovenia lies above an elevation of 1,200 m, which is roughly the upper

settlement limit in Slovenia (Perko 2001), along with 11.4% of mountainous areas. There are no non-mountainous areas above that line. Among the regions, the Western Karawanks account for the largest share in that zone (45.7%; Figs. 4.13 and 4.14).

There are also great differences among the landscape types. Alpine mountains extend across all 100-m elevation zones above an elevation of 100 m, and the Pannonian plains lie almost entirely within the 200–300-m elevation zone. Alpine mountains account for over 80% of Slovenia's areas above an elevation of 1,200 m and Mediterranean hills



**Fig. 4.11** Mura Plain has the lowest average relief coefficient, which makes it the least rough part of Slovenia and its breadbasket. The eastern part of the region between the meandering Mura River and its tributary Ledava from

the Austrian to the Croatian border is the least rough geomorphometric unit in Slovenia. (Photo by Jože Pobjič, GIAM ZRC SAZU archive)



**Fig. 4.12** Dry Carniola and Dobrepolje is the Slovenian mountainous region with the lowest average relief coefficient. Dry Carniola is a plateau-like area cut through by the

Krka Valley, and Dobrepolje is an oblong dry karst polje to its west. The photograph shows Žužemberk, the largest town in the region. (Photo by Stepo, Adobe Stock)

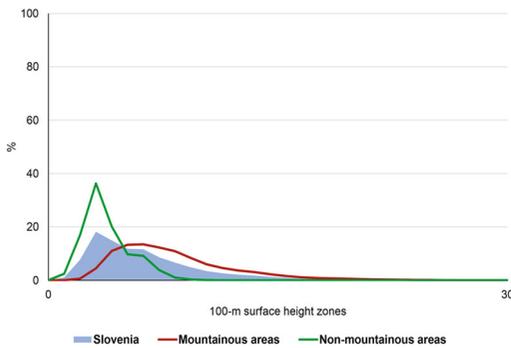
cover over 90% of all of Slovenia's areas below an elevation of 100 m.

The average **surface slope** of Slovenia is 16.5°, of its non-mountainous areas is 9.5°, which is 42% less, and of its mountainous areas is 21.8°, or 32% more than Slovenia's total

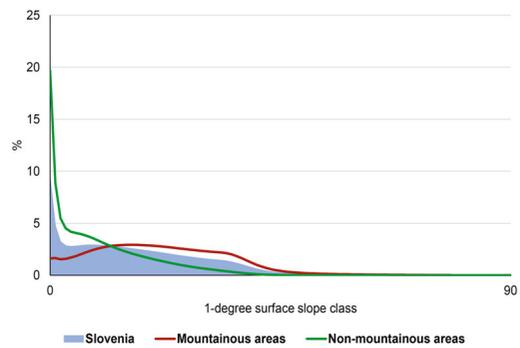
surface average and 129% more than the average of its non-mountainous areas. The Western Karawanks have the highest average surface slope (29.4°) among Slovenian regions, and the Bloke Plateau has the lowest (14.4°). The ratio between the two is 2:1, which is lower than the ratio

**Table 4.8** Some basic morphometric indicators of Slovenian mountainous (in bold) and non-mountainous (in italic) areas (Perko 1998; Perko et al. 2021; data sources: 5-m digital elevation model and Ministry of Natural Resources and Spatial Planning of the Republic of Slovenia; Perko 2007)

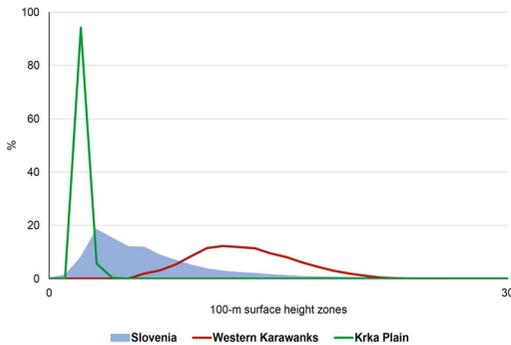
Areas	Area in km <sup>2</sup>	Surface height average	Surface slope average	Surface aspect average	Surface height coefficient	Surface slope coefficient	Surface aspect coefficient	Surface relief coefficient
<b>Mountainous areas</b>	11,531	735.47	21.80	87.47	4.64	39.71	37.80	37.20
<i>Non-mountainous areas</i>	8742	320.04	9.53	81.18	1.66	22.70	46.09	28.63
Slovenia	20,273	556.43	16.52	84.76	3.35	32.38	41.38	33.50



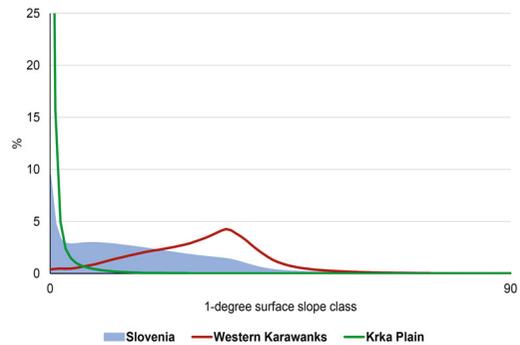
**Fig. 4.13** Surface height frequency distribution across thirty 100-m elevation zones for all of Slovenia and its mountainous (red) and non-mountainous areas (green)



**Fig. 4.15** Surface slope frequency distribution across ninety one-degree categories for all of Slovenia and its mountainous (red) and non-mountainous areas (green)



**Fig. 4.14** Surface height frequency distribution across thirty 100-m elevation zones for all of Slovenia, the highest region on average (red), and the lowest region on average (green)



**Fig. 4.16** Surface slope frequency distribution across ninety one-degree categories for all of Slovenia, the steepest region on average (red), and the flattest region on average (green)

between the highest and lowest average surface heights.

Among the one-degree slope categories, the largest share of Slovenia's total surface lies in

the 0°–1° category (9.4%), the largest share of its mountainous areas lies in the 15°–16° category (2.9%), and the largest share of its non-mountainous areas lies in the 0°–1° category

(19.7%). A total of 56.8% of all of Slovenia lies in areas with slopes over  $12^\circ$ , where modern agriculture is no longer possible; the share of mountainous surface in that category is 75.5% and that of non-mountainous surface is 32.3%. Among the regions, the Western Karawanks account for the largest share (92.0%; Figs. 4.15 and 4.16).

There are also great differences between individual landscape types in terms of surface slope. The surface slope of over 80% of the Pannonian plains is below  $2^\circ$ , which accounts for over a third of all of Slovenia. The corresponding share of Alpine mountains is below 3%, which means that the ratio between the two landscape types is as high as 32:1.

The average **surface aspect** of all of Slovenia is  $84.8^\circ$ , of its non-mountainous areas is  $81.2^\circ$  or 4% less, and of its mountainous areas is  $87.5^\circ$  or 3% more than the average surface aspect of all of Slovenia and 8% more than that of its non-mountainous areas. The differences are thus small. Taking account of only those regions that lie entirely within Slovenia and are not cut off by the border in certain parts (e.g., the northern aspects of the Western Karawanks or the southern aspects of the Gorjanci Hills), the Krim Hills and Menišija Plateau region has the highest average surface aspect ( $96.5^\circ$ ), or the most northern aspects, among all the mountainous regions. The predominance of northern aspects over southern ones is mainly due to the region's extensive northern slopes, which descend from the mountainous areas in the north toward the flat Ljubljana Marsh, which then gently transitions into the Bloke Plateau to the south. The Ložnica and Hudinja Hills region, whose numerous ridges descend toward the Savinja Plain in the south, has the lowest average surface aspect ( $81.3^\circ$ ). The ratio between the two is only slightly higher than 1.

The average **surface height coefficient** is 3.4 for all of Slovenia, 1.7 for its non-mountainous areas (50% lower), and 4.6 for its mountainous areas (39% higher than the average coefficient for all of Slovenia and 180% higher than that for its non-mountainous areas). The Julian Alps, where the surface heights change the most rapidly, have the highest average surface height coefficient (7.2) among the mountainous regions, and the Dry

Carniola and Dobropolje region has the lowest (2.1), making the ratio between the two higher than 3:1.

The average **surface slope coefficient** is 32.4 for all of Slovenia, 22.7 for its non-mountainous areas (30% lower), and 39.7 for its mountainous areas (23% higher than the average coefficient for all of Slovenia and 75% higher than that for its non-mountainous areas). The Julian Alps have the highest average surface slope coefficient (48.1) among the mountainous regions, and the Dry Carniola and Dobropolje region has the lowest (25.8), making the ratio between the two slightly less than 2:1.

The average **surface aspect coefficient** is 41.4 for all of Slovenia, 46.1 for its non-mountainous areas (11% higher), and 37.8 for its mountainous areas (9% lower than the average coefficient for all of Slovenia and 18% lower than that for its non-mountainous areas). The Ložnica and Hudinja Hills region has the highest average surface aspect coefficient (46.0) among the mountainous regions, and the Little Mountains, Kočevje Rog Plateau, and Mount Poljane region has the lowest (35.8), making the ratio between the two barely higher than 1.

A comparison between the surface slope and aspect coefficients shows that the surface aspect coefficient for Slovenia and all its landscape types except the Alpine mountains is higher than the slope coefficient. This means that in most of Slovenia the surface aspects change more rapidly than the surface slopes, or that Slovenia's surface aspect variability is greater than its surface slope variability. This is largely contributed to by the dense river system on non-karst terrain and the corroded character of karst terrain. In non-mountainous areas, the aspect coefficient is twice as much as the slope coefficient, whereas in mountainous areas the difference is almost negligible, with the aspect coefficient only 5% lower than the slope coefficient.

The **surface relief coefficient** combines the surface slope and aspect coefficients. It is the most synthetic of all the geomorphometric indicators used, combining the surface slope and aspect variability, and showing the total surface roughness. The average surface relief coefficient

is 33.5 for all of Slovenia, 28.6 for its non-mountainous areas (or 15% lower), and 37.2 for its mountainous areas (or 11% higher than the average coefficient for all of Slovenia and 30% higher than that for its non-mountainous areas).

The Idrija Hills have the highest average surface relief coefficient (40.7) among the mountainous regions, and the Dry Carniola and Dobropolje region has the lowest (30.3), making the ratio between the two slightly higher than 1. Haloze has the highest average surface relief coefficient (45.8) among the non-mountainous regions, and the Mura Plain has the lowest (11.1), and so the ratio between the two is just slightly over 4:1.

The ratios between the mountainous regions with the highest and lowest indicators thus range from 3:1 for surface height to nearly 1:1 for surface slope and aspect. Taking account of mountainous and non-mountainous regions together, the ratios between the highest and lowest indicators are significantly higher, such as, for example, higher than 7:1 for surface height, where the highest average surface height among the mountainous regions is 1,186.0 m recorded for the Western Karawanks, and the lowest among the non-mountainous regions is 160.8 m recorded for the Krka Plain.

Comparing all geomorphometric units, regions, landscape types, and geomorphometric types, the highest average surface relief coefficients were recorded for the western Haloze geomorphometric unit (45.9), the Haloze region (45.8), the Alpine hills landscape type (38.9), and the rough high hills geomorphometric type (37.8). These are thus areas at various scales with the roughest surface in Slovenia.

**Acknowledgements** This study was conducted as part of the research program The Geography of Slovenia (P6-0101), financed by the Slovenian Research and Innovation Agency.

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