ACTA UNIVERSITATIS CAROLINAE

AUC **GEOGRAPHICA**

52
1/2017

CHARLES UNIVERSITY • KAROLINUM PRESS • 2017

ISSN 0300-5402 (Print)
ISSN 2336-1980 (Online)

CONTENTS

MICHAL KUSÁK, KLÁRA KRBCOVÁ
Analysis of the relationship of automatically and manually extracted lineaments from DEM and geologically mapped tectonic faults around the Main Ethiopian Rift and the Ethiopian Highlands, Ethiopia 5–17

FRANTIŠEK KRIŽAN, JOSEF KUNC, KRISTÍNA BILKOVÁ, PETER BARLÍK, ZDENĚK ŠILHAN
Development and classification of shopping centers in Czech and Slovak republics: A comparative analysis. 18–26

VERONIKA ERETOVÁ, VÍT JANČÁK
The past, present and future of diversification of agricultural holdings in Czechia 27–37

TEREZA STEKLÁ, JAN KALVODA, JAKUB KOSTELECKÝ
Landforms and morphogenetic processes in the locality of Geodetic Observatory Pecný, Ondřejovská vrchovina Highland 38–60

MICHAL JENÍČEK, ONDŘEJ HOTOVÝ, ONDŘEJ MATĚJKA
Snow accumulation and ablation in different canopy structures at a plot scale: using degree-day approach and measured shortwave radiation 61–72

ARNOLD KAKAŠ, BRANISLAV BLEHA
Post-communistic Transformation and Population Ageing Versus the Changing Migratory Patterns of Seniors: the Case of the Slovak Republic 73–88

SILESHI TAMENE, TEBAREK LIKA MEGENTO
The effect of rural road transport infrastructure on smallholder farmers' agricultural productivity in Horro Guduru Wollega Zone, Western Ethiopia. 89–99

MARTIN PLEŠIVČÁK
Ideology, cleavages, and voting behaviour in 2009 and 2013 regional elections in Slovakia 100–115

AHMED MUSTEFA ALI, TEBAREK LIKA MEGENTO
The energy–poverty nexus: Vulnerability of the urban and peri-urban households to energy poverty in Arba-Minch town, Southern Ethiopia 116–128

VÍT MACA, JANA SMOLÍKOVÁ
Analysis of significance of environmental factors in landslide susceptibility modeling: Case study Jemma drainage network, Ethiopia 129–136

ANALYSIS OF THE RELATIONSHIP OF AUTOMATICALLY AND MANUALLY EXTRACTED LINEAMENTS FROM DEM AND GEOLOGICALLY MAPPED TECTONIC FAULTS AROUND THE MAIN ETHIOPIAN RIFT AND THE ETHIOPIAN HIGHLANDS, ETHIOPIA

MICHAL KUSÁK[1,2], KLÁRA KRBCOVÁ[1]

[1] Charles University, Faculty of Science, Department of Physical Geography and Geoecology, Czech Republic
[2] Czech Academy of Sciences, Institute of Rock Structure and Mechanics, Department of Engineering Geology, Czech Republic

ABSTRACT

The paper deals with the functions that automatically extract lineaments from the 90 m Shuttle Radar Topographic Mission (SRTM) of Digital Elevation Model (DEM) (Consortium for Spatial Information 2014) in the software ArcGIS 10.1 and PCI Geomatica. They were performed for the Main Ethiopian Rift and the Ethiopian Highlands (transregional scale 1,060,000 km^2), which are one of the tectonically most active areas in the world. The values of input parameters – the RADI (filter radius) value, GTHR (edge gradient threshold), LTHR (curve length), FTHR (line fitting error), ATHR (angular difference), and the DTHR (linked distance threshold) – and their influence on the final shape and number of lineaments are discussed. A map of automated extracted lineaments was created and compared with 1) the tectonic faults on the geological map by Geological Survey of Ethiopia (Mangesha et al. 1996) and 2) the lineaments based on visual interpretation by the author from the same data set. The predominant azimuth of lineaments is similar to the azimuth of the faults on the geological map. The comparison of lineaments by automated visualization in GIS and visual interpretation of lineaments carried out by the authors around the Jemma River Basin (regional scale 16,000 km^2) proved that both sets of lineaments are of the same NE–SW azimuth, which is the orientation of the rift. However, lineaments mapping by automated visualization in GIS identifies a larger number of shorter lineaments than lineaments created by visual interpretation.

Keywords: lineaments, faults, azimuth, morphometry, Main Ethiopian Rift

Received 27 May 2016; Accepted 12 October 2016; Published online 16 February 2017

1. Introduction

1.1 Morphostructural analysis and goals of the paper

Morphostructural analysis includes a set of several methodologies aimed at clarifying the direct and indirect linkage between landforms and the structure of the Earth's crust, whose development and character are currently dependent on the development of the mantle and core (Fairbridge 1968; Demek 1987). On the basis of observed manifestations of active tectonics and the geological structure (as faults and folds) it is then possible to define basic elementary structural units that form a morphologically compact unit. The various methods of morphostructural analysis are based either on field research or they present a set of morphometric techniques and methods of remote sensing. These analysing reference charts, aerial or satellite images and digital elevation models, most commonly in the environment of geographic information systems (GIS) (Casas et al. 2000; Novak & Soulakellis 2000; Kim et al. 2004; Jordan et al. 2005; Jordan & Scott 2005; Ekneligoda & Henkel 2006, 2010; Huggett 200; Arrowsmith & Zielke 2009; Abdullah et al. 2010; Özkaymak & Solzbilir 2012). In order to diversify the knowledge of the tectonic structure of the area, a branch of the morphostructural analysis called morphotectonic analysis, i.e. analysis of fracture systems, fault analysis and analysis of linearly arranged elements of topographic relief – lineaments, is used.

In this paper we aim at understanding the methods of lineaments extraction using automated extensions in ArcGIS 10.1 and in PCI Geomatica (*sensu* Sarp 2005; Kocal et al. 2007; Abdullah et al. 2010; Hubbard et al. 2012; Muhammad & Awdal 2012). We analysed relief and lineament networks at the transregional scale (1,060,000 km^2) using the SRTM DEM – in a much larger area than has been reported in the literature (Hung et al. 2005; Abdullah et al. 2010 and references therein). Automated lineament extraction over such a large area allows quick generation of many lineaments. The development of the DEM usage cause an increase of the number of articles focusing on automated visualization of lineaments. Those authors argue that this is a fully objective method. However, changes in the input parameters directly affect the final shape and number of lineaments. In this paper we discuss the input parameters – the RADI (filter radius) value, GTHR (edge gradient threshold), LTHR (curve length), FTHR (line fitting error), ATHR (angular difference), and the DTHR (linked distance threshold) – and compare the automated extracted lineaments with confirmed faults from the geological map and visual interpretation of lineaments carried out by the authors.

The main objectives of this work are:

https://doi.org/10.14712/23361980.2017.1
Kusák, M. – Krbcová, K. (2017): Analysis of the relationship of automatically and manually extracted lineaments from DEM and geologically mapped tectonic faults around the Main Ethiopian Rift and the Ethiopian Highlands, Ethiopia
AUC Geographica, 52, No. 1, pp. 5–17

(1) to perform automated lineament extraction within the Main Ethiopian Rift and the Ethiopian Highlands;
(2) to define stratigraphic and structural homogenous units using geological maps of Ethiopia (Geology Survey of Ethiopia 1996), extract the layer of geologically proven faults and compare the morphometric characteristics of the faults and lineaments;
(3) to compare the clipped layer of lineaments, which were extracted for the Main Ethiopian Rift and the Ethiopian Highlands using automated visualization in GIS and visual interpretation of lineaments carried out by the author, where the lineaments were drawn on the territory regional scale.

1.2 Lineaments

Linearly arranged elements of relief (lineaments) – for example linear sections of a valley or straight sections of slopes – should be considered as a potential zone of brittle fracture of bedrock with an influence on the geomorphological evolution of the area (Hobbs 1904 in Abdullah et al. 2010). According to Minár & Sládek (2009), lineaments are surface discontinuities probably tectonic in origin and are named as follows according to the method of their construction on the map: 1) photolineaments are linear boundaries identified from aerial or satellite images; 2) topolineaments are linear boundaries identified from topographic maps; 3) morpholineaments are linear boundaries determined solely from the properties of the relief (now mostly using a digital elevation model). Therefore, an analysis of lineaments can give an insight into landscape evolution and the study of lineaments thus allows to obtain information on tectonic activity over large areas, which is useful mainly for areas with limited field access (Ehlen 2004).

Currently, the most common method of extracting lineaments is the use of shaded digital elevation models and topographic maps. The lineaments may be drawn by:

(1) A modern method using automated programs called *automated visualization of lineaments*. According to Abarca (2006), the automated visualization of lineaments involves: A) processing of digital terrain models, i.e. creating shaded relief images; B) setting thresholds, according to which lineaments are automatically plotted; C) automated extraction of lineaments; D) post-processing procedures for lineament conversion from raster to vector and fixing or removing erroneous lineaments. In this paper we present a map of lineaments for the Main Ethiopian Rift and the Ethiopian Highland (a total study area of 1,060,000 km^2; Figure 1) compiled using automated extensions in ArcGIS 10.1 and in PCI Geomatica. The size and remoteness of the study area together with limited availability of detailed topographic information makes this area an ideal location for the utilization of approaches based on a global DEM. For the analysis we used the Shuttle Radar Topography Mission (SRTM), which has dramatically improved the availability of consistent high quality relief information in remote areas of the world. The potential of the SRTM dataset for lineament analysis has been successfully explored by several authors (Sarp 2005; Kocal et al. 2007; Abdullah et al. 2010; Hubbard et al. 2012; Muhammad & Awdal 2012).

(2) An older manual method called *visual interpretation of lineaments by the author*. Lineaments are drawn from different parts of base maps, and then the layers are overlapped (Ehlen 2004). Each author, however, uses individual identification criteria, which are usually based on sensory perception and cannot be quantified, or lineament maps are somewhat subjective and cannot be exactly reproduced by other authors (Wladis 1999). For

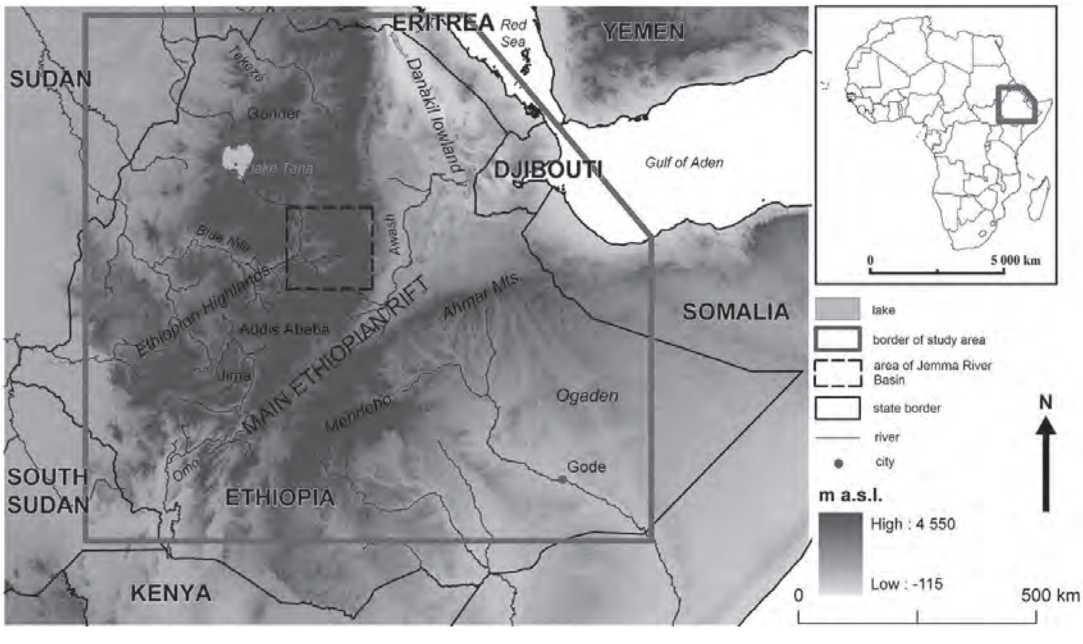

Fig. 1 Study area.

a comparison in this paper we compiled a map of lineaments for the Jemma River Basin using the classic manual method. The Jemma River, the left tributary of the Abay – Blue Nile, cut its valley in the Ethiopian Highlands to the west of the Rift Valley, approximately between 8°–14° north latitude and 36°–40° east latitude, covering the area of 16,000 km^2 (Figure 1).

2. Geological evolution of the study area

The study area is located on the African continent and is composed of the Main Ethiopian Rift and the Ethiopian Highlands. The Ethiopian Highlands are one of the most tectonically active areas in the world and lie in the border zone of three lithospheric plates, i.e. the Eurasian, African and Arabian Plate (Beyene, Abdelsalm 2005). This area has been influenced by sea transgressions (250–65 m.y. ago), episodic volcanism (65 m.y. ago), and the tectonic uplift (in the last 30 m.y.) (Kazmin 1975; Pik et al. 2003; Beyne, Abdelsalam 2005; Gani, Abdelsalam 2006; Gani et al. 2007, 2009; Wolela 2010). The Ethiopian Highlands are a rather complex structural block divided by the Rift Valley (Yunnur, Chorowicz 1998). They are characterized by volcanoes and high altitude plateaux (up to 3,000 m a.s.l.) cut by deep canyons. The flat surface of the structural blocks is the result of tectonic uplift and piling up of lava flows (Pik et al. 2003). The active uplift of the highlands activated fluvial erosion. Three uplift phases with increasing incision rates have been identified for the past 31 m.y.. Furthermore, a significant relationship was found between the uplift rates and the incision rates, which provides evidence of tectonically controlled incision (Gani et al. 2009).

The study area – the Ethiopian highlands experienced distinct geological events, e.g. repeated sea transgression and regression, Tertiary and Quaternary volcanism, uplift of Ethiopian Highlands (in the last 30 m.y.) and opening of Main Ethiopian Rift (in the last 18 m.y.), which caused the formation of faults and fractures (Kazmin 1975; Pik et al. 2003; Beyne, Abdelsalam 2005, 2006; Gani et al. 2007, 2009; Wolela 2010). The geology of the Ethiopian Highlands has been described by many authors who distinguish several differing phases of evolution: for instance Mangesha et al. (1996) recognized 7 phases; Assefa (1980, 1981) 5 phases and Russo et al. (1994) 8 phases of geological evolution. Gani et al. (2007, 2009) and Wolela (2010) distinguished 3 main periods: 1) presedimentation, 2) sedimentation and 3) post-sedimentation. The presedimentation phase (600–250 m.y. ago) is characterized by denudation processes of a Paleozoic crystalline basement, whose rocks dominate in the area. The later phase of sedimentation is dated between 250 and 65 m.y. ago (spans the entire Mesozoic) and recorded repeated sea transgression and regression. The record of this sedimentation time span can be found in the lower parts of the Jemma River network (e.g. sandstones). The third Tertiary post-sedimentation phase began 65 m.y. ago and is responsible for strong volcanic activity. A more in-depth view reveals one volcanic period in the Tertiary (Hofmann et al. 1997) and another in the Quaternary (Gani, Abdelsalam 2006). In general, lava flows dramatically influenced the river network because they covered the paleolandscape with ancient drainage and created a new surface over large areas.

As a result of tectonic activity, the Ethiopian plateau was uplifted (29 m.y.) (Beyene, Abdelsalam 2005; Pik et al. 2003) and the Afar depression emerged (24 m.y. ago) (Gani, Abdelsalam 2006). The southern and central parts of the Main Ethiopian Rift opened 20 m.y. ago (Gani et al. 2007). This opening was associated with the separation of the Danakil blocks (Somalian Plate) from the Nubian Plate, when Kieffer (2004) and Gani, Abdelsalam (2006) dated the emergence of shield volcanoes in the Ethiopian Highlands (10.7 m.y. old). The tectonic uplift rate was fluctuated and the erosion processes also has been changing. Sengor (2001) established the uplift rate of approximately 0.1 mm/year since the Eocene. The rate increased from the Pliocene to the Pleistocene (Wolela 2010). McDougal et al. (1975) assume an average rate between 0.5 and 1 mm/year. Gani et al. (2007) calculated the total uplift for the last 30 m.y. as being 2.2 km minus 300 m for denudation and 150 m for sediment consolidation, which means a total of 1,750 m. As mentioned above, the southern and central openings of the Main Ethiopian Rift are estimated to start 20 m.y. ago (Gani et al. 2009), whereas the northern part of the Rift in the Ethiopian Highlands is 11 m.y. old (Wolfenden et al. 2004). The Afar depression and the Main Ethiopian Rift divided the Ethiopian Highlands into their north-western and south-eastern parts (Kazmin 1975; Coulié et al. 2003).

Uplift of the Ethiopian Highlands, emergence of the Afar depression, separation of the Danakil blocks (Somalian Plate) from the Nubian plate and the opening of the Main Ethiopian Rift (18 m.y. to the Present) caused the formation of faults and fractures in the rock succession of the Ethiopian Highlands: from crystalline rocks (Paleozoic pre-sedimentation stage) to the younger volcanic rocks (Quaternary volcanism) (Gani et al. 2009). The prevailing orientations of the faults and fractures is NE–SW and NW–SE. Uplift of the Ethiopian Highlands caused streams to cut into bedrock and the formation of deep canyons linked to tectonic disturbances (Gani, Abdelsalam 2006; Gani et al. 2007, 2009).

3. Methods and results

The lineaments were automatically extract from the 90 m SRTM in the software ArcGIS 10.1 and PCI Geomatica. They were performed for the Main Ethiopian Rift and the Ethiopian Highlands (transregional scale 1,060,000 km^2). The values of input parameters – the RADI (filter radius) value, GTHR (edge gradient threshold), LTHR (curve length), FTHR (line fitting error), ATHR (angular difference), and the DTHR (linked distance threshold) – and their influence on the final shape and number of lineaments are discussed. Lineaments by automated visualization in GIS were compared with visual interpretation of lineaments carried out by the authors around the Jemma River Basin (regional scale 16,000 km^2).

3.1 Extraction of lineaments

3.1.1 Shuttle Radar Topographic Mission DEM

The *Shuttle Radar Topographic Mission* (SRTM) is an almost globally available digital elevation model (from 60°N to 56°S), which resulted from a single pass interferometric processing of C-band Synthetic Aperture Radar (SAR) data acquired by the Endeavour Shuttle mission in February 2000 (Rabus et al. 2003; Farr et al. 2007). During the mission 95% of the target area was covered by at least two acquisitions corresponding to the ascending and descending paths to avoid data gaps in radar shadow areas in rough terrain. The globally available version of the SRTM in public domain features horizontal resolution 3 arc seconds, which corresponds approximately to 90 m. Its mission specification required a vertical accuracy of below 16 m, which has been achieved (Gorokhovich, Voustianiouk 2006). The original dataset contains a certain amount of gaps mainly due to radar shadows in areas of rugged terrain. Since then several approaches were proposed in order to fill these gaps (Reuter et al. 2007). Tiles of the digital models are available in a mosaic of 5° longitude × 5° latitude. To capture the area of interest, i.e. the Main Ethiopian Rift and the Ethiopian Highlands, four tiles were used, i.e. 44-10, 44-11, 45-10 and 45-11, which were then combined in ArcMap 10.1 (ESRI 2011) into one digital elevation model. Since this is an area around the 10th parallel, the Z-factor value was 0.00000912 m.

Topographic surfaces described as discrete elevation function f (x, y, z) are of high interest for geoscientists. Variables such as slope inclination or slope aspect derived from the elevation data are particularly suitable for investigation of surface shapes and structures since they reflect processes that lead to their formation (Kennelly 2008). The image layer derived from DEM which is highly relevant for morphologic interpretation is hill shading. Variations in brightness in the hill shading image are a function of the illumination direction and the orientation of the surface. The brightness value is calculated as the cosine of the incidence angle of the illumination vector. Subtle changes in shades of grey render the terrain with a three-dimensional appearance. Hill shading conveys much stronger three dimensional impressions than a mere visualization of the elevation model in grey tones. Furthermore, it enhances interpretability of detailed surface structures often completely imperceptible in the DEM visualization.

3.1.2 Data processing

To generate the lineaments from a digital elevation model (DEM) using PCI Geomatica (PCI Geomatics 2010), it is paramount to create shaded relief images, in which a light source is directed from four different directions. Shaded relief images were created in ArcMap 10.1 (ESRI 2011) using the hillshade tool (Spatial Analyst Toolbox → Surface toolset). The first shaded relief image was illuminated from the north, i.e. the solar azimuth (sun angle) was 0° and solar elevation was 30° (Abdullah et al. 2010). Other shaded relief images were created with identical solar elevations and were illuminated from

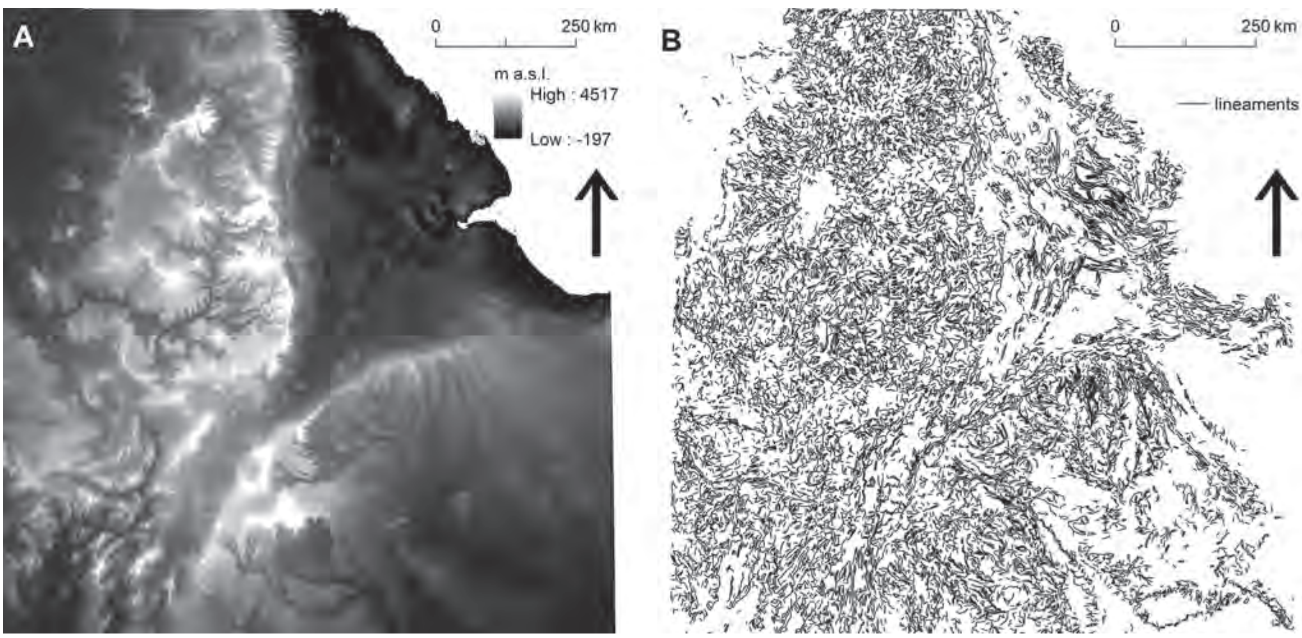

Fig. 2 (*a*) digital elevation model; (*b*) automated lineament extraction.

various directions: 1) from the north-east (solar azimuth of 45°); 2) from the east (solar azimuth of 90°); 3) from the south-east (solar azimuth of 135°).

The next step was to generate a shaded relief image from the previous four shaded relief images (in ArcMap Spatial Analyst toolbox → Local toolset → Combine tool). The combined shaded relief image was created by combining shaded relief images with a solar azimuth of 0°, 45°, 95° and 135°, respectively (*sensu* Abdullah et al. 2010; Muhammad, Awdal 2012). These combined shaded relief images were used for automatic extraction of lineaments in PCI Geomatica (PCI Geomatics 2010) (Figure 2).

3.1.3 Lineament extraction

The tool for automatic lineament extraction in the PCI Geomatica program (PCI Geomatics 2010) is called LINE. The LINE tool consists of six parameters: the RADI (filter radius) value, GTHR (edge gradient threshold), LTHR (curve length), FTHR (line fitting error), ATHR (angular difference), and the DTHR (linked distance threshold) (*sensu* Sarp 2005). The values used in the analysis depend on the data and the size of the study area (*sensu* Kocal et al. 2007; Hubbard et al. 2012). RADI parameter the radius of the edge detection filter in pixels (PCI Geomatics 2010). The larger the RADI (filter radius) value, the less noise and detail appear in the edge detection result. Based on the area, the value of the RADI parameter was 24. GTHR (edge gradient threshold) specifies the threshold for the minimum gradient level for an edge pixel (PCI Geomatics 2010). The suitable output binary image was achieved using GTHR = 94. LTHR (curve length) specifies the minimum length of the curve, which is considered as the lineament (PCI Geomatics 2010). We used a value of 50, which means that the smallest lineament is 50 pixels (4.5 km) long. If the lower value of curved length was chosen, the resulting lineaments would be too short taking into consideration the large study area. On the other hand, if the curved length was chosen higher, the resulting lineaments would link together. FTHR (line fitting error) defines the tolerance for fitting line segments to a curved lineament (PCI Geomatics 2010). A larger value provides less noise and straighter lineaments; for our analysis we used FTHR = 7. ATHR (angular difference) defines the maximum angle between two vectors for them to be linked (PCI Geomatics 2010). The ATHR value used in this analysis was 40, which means that the maximum angle between two linked vectors was 40°. DTHR (linked distance threshold) specifies the maximum distance between two vectors to be linked (PCI Geomatics 2010). The distance between two vectors in our study was 30 pixels (2.7 km).

3.2 Morphometric characteristics of lineaments

The following morphometric characteristics (*sensu* Křížek, Kusák 2014) were used to characterize the lineaments near the Main Ethiopian Rift and the Ethiopian Highlands:

a) the number of lineaments N is determined as the number of all lineaments in the study area;

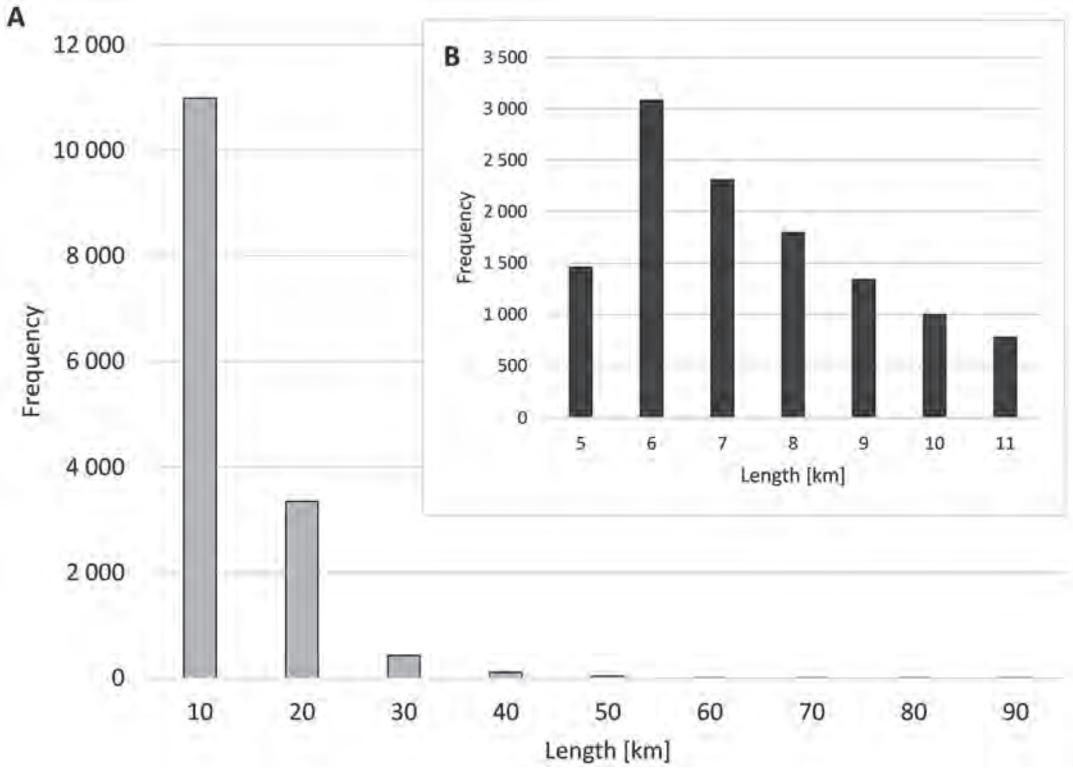

Fig. 3 Frequency of the total lengths of lineaments: (*a*) 10 km frequency; (*b*) 1 km frequency.

b) the total length of lineaments L_t is defined as the sum of lengths of all lineaments in the study area;
c) the morphotectonic network density D is defined by the relation:
$D = L_t / P$ (1),
where P is the study area;
d) the azimuth of lineaments A is determined as the lineament orientation to the geographic coordinate system. The azimuth of lineaments is illustrated by rose diagrams, which are divided into 72 intervals of 5° (in total 360°) moving clockwise. The numbers of lineaments in the rose diagrams are multiplied by their length.

The total length of lineaments L_t and the azimuth of lineaments A were calculated in ArcMap (ESRI 2011) using of the extension Easy Calculate 10 (Ian-ko 2014).

The morphotectonic network of lineaments near the Main Ethiopian Rift and the Ethiopian Highlands consist of 14,940 lineaments. The shortest lineament in the morphotectonic network reach a length of 4.5 km and the longest lineament reach a length of 85 km. In total, 73.6% of the lineaments reach a length of 10 km (Figure 3a), while the number of lineaments in the study area increases with increasing length of lineaments to the length of 6 km, then the number of lineaments decreased with increasing length (Figure 3b). Taking into that the total length of lineaments is 134,151 km and the study area is 1,060,000 km^2, then the morphotectonic network density of lineaments is 0.13 km/km^2. Azimuths of lineaments near the Main Ethiopian Rift and the Ethiopian Highlands were distributed evenly in all directions. On such a surface area, where the different parts of landscape have different geneses and ages, i.e. in history they developed by different tectonic processes, the morphometric characteristic azimuth of the lineaments does not give accurate information. Therefore, the azimuth of lineaments proved to be the most important morphometric characteristic of the morphostructural analysis (Minár, Sládek 2009; Abdullah et al. 2010). Due to this fact and because we considered the azimuth of lineaments to have no dominant direction, the study area need to be divided into seven *subregions*.

3.3 Comparison of extracted lineaments and faults from the geological map of Ethiopia

A detailed analysis of azimuths of faults and lineaments by automated visualization in GIS was performed for the individual *subregions*. The geological map at the scale 1 : 250,000 (Mangesha et al. 1996) was used to divide the area of The Main Ethiopian Rift and the Ethiopian Highlands into 7 geologically homogenous units (Table 1; Figure 4), in order to compare them with the diagrams of the faults and lineaments (see Figure 5; 6). The units are as follows from the youngest one:

a) Afar depression – *subregion 2* is formed by Holocene sediments. Most tectonic faults and lineaments are of the NW–SE azimuth, the same direction as the expansion direction of the Afar depression;
b) Main Ethiopian Rift – *subregion 4* is formed by Pleistocene sediments, the main faults and lineaments are in the same direction as the Main Ethiopian Rift, the NE–SW azimuth;
c) Western part of the Ethiopian Highlands *subregion 1* and *3* and the eastern *subregion 7* consist of Eocene rocks. While the tectonic predisposition of the Main Ethiopian Rift (*subregion 4*) and Afar depression (*subregion 2*) is clear, the strong tectonic uplift in the westernmost part of the Ethiopian Highlands (*subregions 1* and *3*) demonstrates slightly more variability i.e. the tectonic faults and lineaments are predominantly in the N–S azimuth, but there are also many lineaments in a wide range of azimuths. The area of *subregion 7* is too small to perform an analysis of the faults (i.e. on the geological map there are only a few tectonic faults), so this *subregion* was not considered in further analysis;
d) In the south-eastern part of the study area there is a small *subregion 6* which is composed of Cretaceous sediments. There are tectonic faults and lineaments with no dominant azimuth;
e) Eastern part of the Ethiopian Highlands – *subregion 5* is the oldest part of the area and is formed by Late Jurassic rocks. *Subregion 5* was uplifted and inclined to the southeast during the uplift of the Ethiopian Highlands. The tectonic faults and lineaments are predominantly in the NW–SE azimuth, and are supplemented by several faults (NE–SW azimuth) perpendicular to the main direction of the tectonic faults.

The main reason for including the lineament analysis in the determination of the influence of tectonics in the morphostructural analysis is that the lineaments are lithologicallly and/or tectonically controlled. The lineaments are considered as a potential zone of brittle bedrock fracture influencing the geomorphological evolution of the area. (Hobbs 1904 in Abdullah et al. 2010), or more specifically that the lineaments are surface discontinuities of a probable tectonic origin (Minár & Sládek 2009). The predominant azimuth of the lineaments determined by automated visualization in GIS (Figure 6) is similar to the azimuth of the faults on the geological maps of the Geology Survey of Ethiopia (Figure 5; 1996). Because the total number of lineaments (14,940) is much higher than total number of faults (3,004), the lineaments demonstrate slightly more variability of azimuths. However, not every lineament determined by automated visualization in GIS represents a tectonic fault on the landscape and the number of faults on the geological map of the Geological Survey of Ethiopia (Mangesha et al. 1996) is considerably generalized. For a more accurate understanding of the relationship between the lineaments and the landscape, the lineaments determined by automated visualization in GIS were compared with the visual interpretation of

Tab. 1 Seven geologically homogenous units.

Subregions	Area [km²]	Type of rock	Azimuth of faults	Azimuth of lineaments	Azimuths explanation
subregion 1	280,000	Eocene rocks	N–S	N–S	tectonic uplift caused the formation of the lineaments with a N–S direction
subregion 2	183,500	Holocene sediments	NW–SE	NW–SE	the same direction as the expansion of the Afar depression
subregion 3	194,000	Eocene rocks	N–S	N–S	tectonic uplift caused the formation of the lineaments with a N–S direction
subregion 4	100,000	Pleistocene sediments	NE–SW	NE–SW	the same direction as the Main Ethiopian Rift
subregion 5	192,000	Late Jurassic rocks	NW–SE	NW–SE	the same direction as the inclination of its geological unit
subregion 6	65,500	Cretaceous sediments	none dominant	none dominant	more generations of faults were formed at different geological times
subregion 7	45,000	Eocene rocks	–	–	the area is too small to perform an analysis of the faults

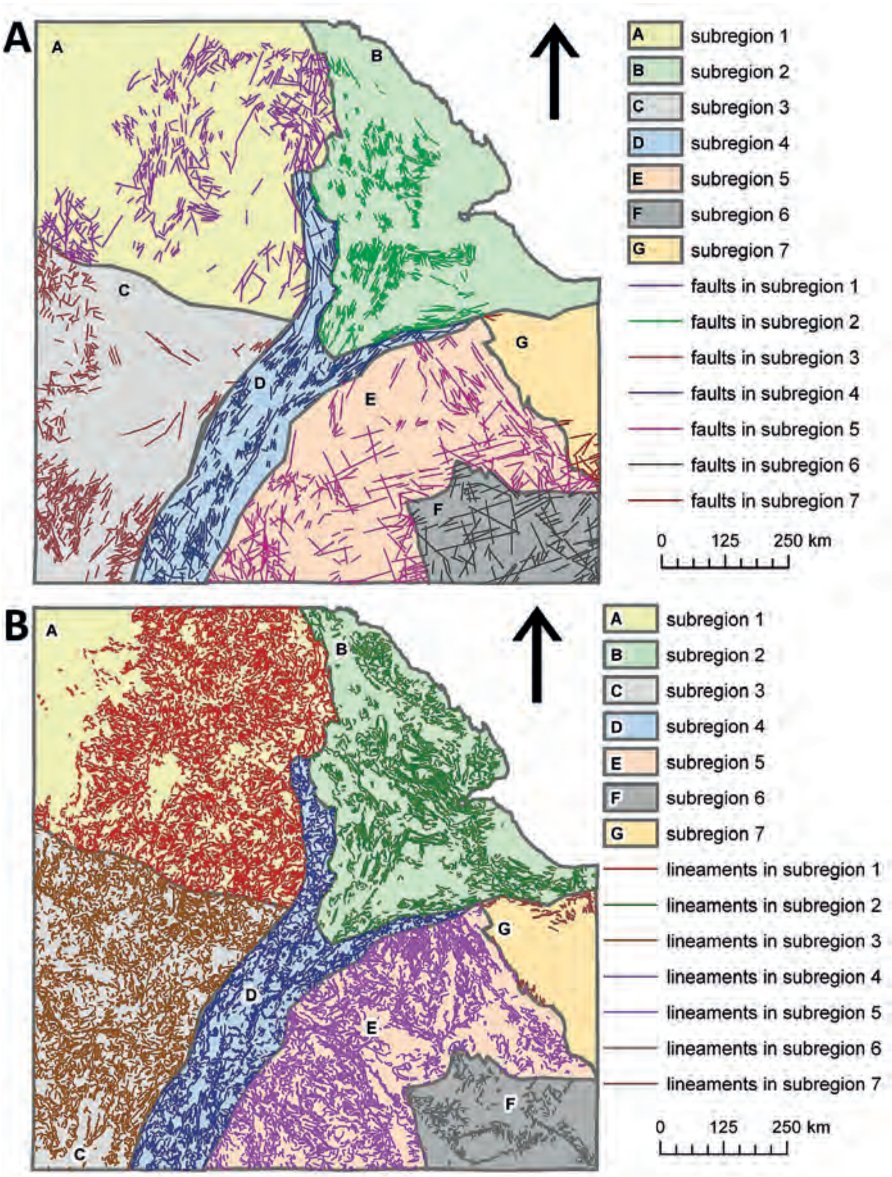

Fig. 4 Geologically homogenous units (Geology Survey of Ethiopia 1996), (*A*) tectonic faults and (*B*) lineaments. Note: (*a*) and (*c*) western part of the Ethiopian Highlands – *subregion 1* and *3* and (*g*) eastern part – *subregion 7* consists of Eocene rocks; (*b*) Afar depression – *subregion 2* is formed by Holocene sediments; (*d*) the Main Ethiopian Rift – *subregion 4* is formed by Pleistocene sediments; (*e*) eastern part of the Ethiopian Highlands – *subregion 5* is formed by Late Jurassic rocks; (*f*) *subregion 6* is formed by Cretaceous sediments.

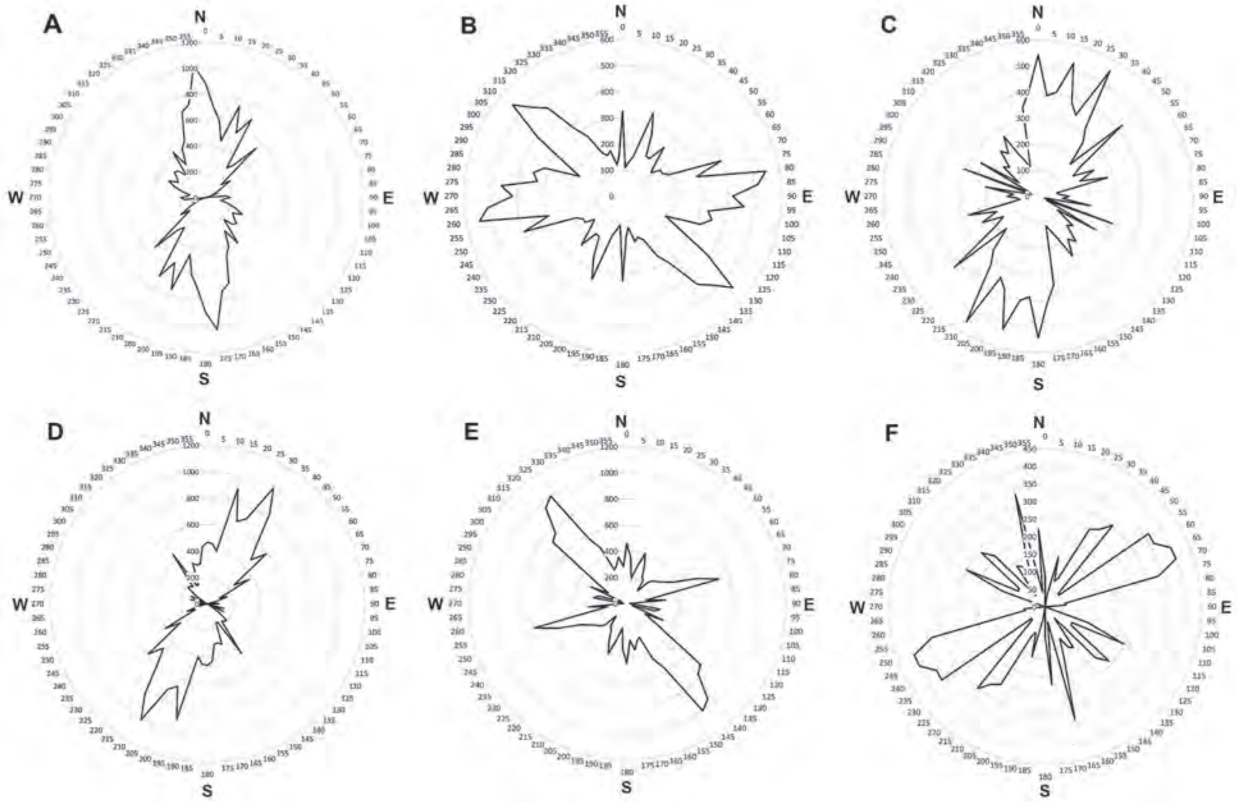

Fig. 5 Azimuth of the faults on the geological map (Geology Survey of Ethiopia 1996). Note: (*a*) N–S azimuth (orientation 175°–355°) of faults in *subregion 1*; (*b*) NW–SE azimuth (orientations 80°–260°; 130°–310°) of faults in *subregion 2*; (*c*) N–S azimuth (oriantations 0°–180°; 25°–205°) of faults in *subregion 3*; (*d*) NE–SW azimuth (orientation 25°–205°) of faults in *subregion 4*; (*e*) NW–SE azimuth (orientations 75°–255°; 145°–325°) of faults in *subregion 5*; (*f*) the faults in *subregion 6* have no dominant azimuth.

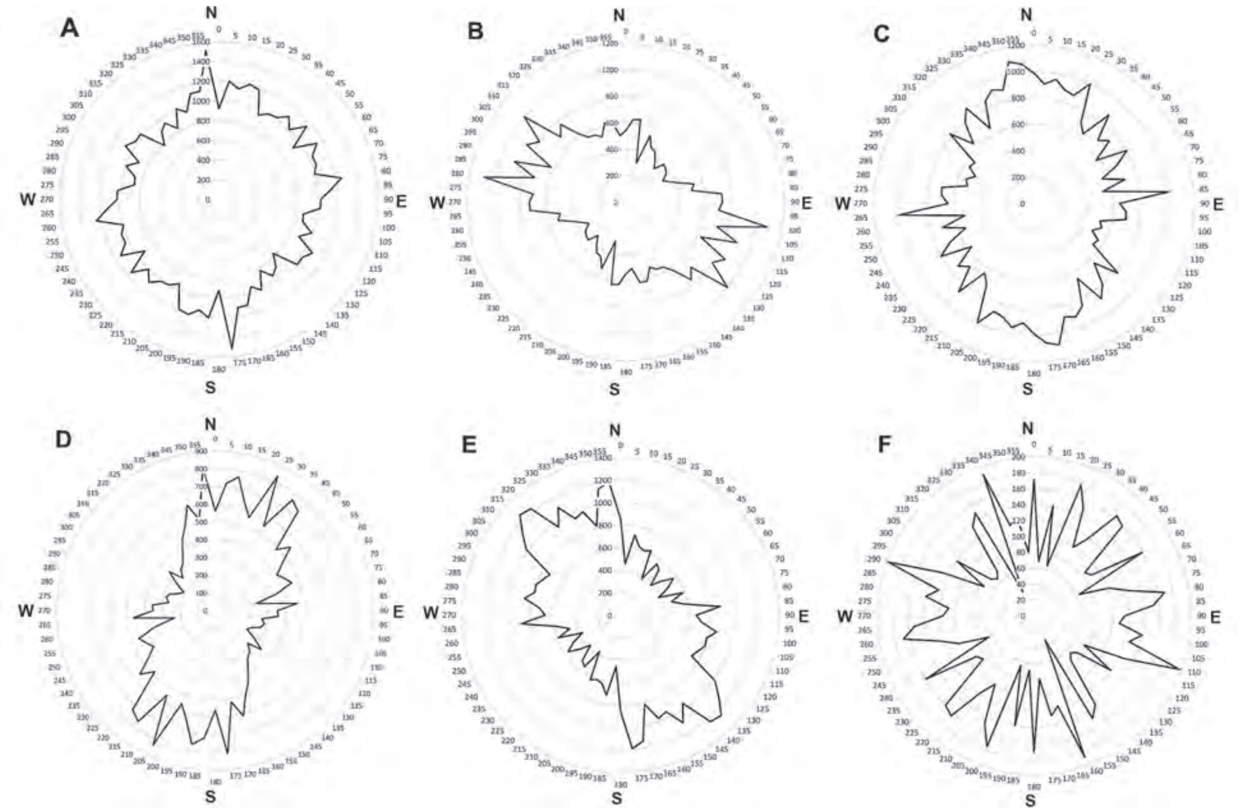

Fig. 6 Azimuth of the lineaments. Note: (*a*) N–S azimuth (orientation 175°–355°) of lineaments in *subregion 1*; (*b*) NW–SE azimuth (orientations 100°–280°; 130°–310°) of lineaments in *subregion 2*; (*c*) N–S azimuth (orientations 0°–180°) of lineaments in *subregion 3*; (*d*) NE–SW azimuth (orientations 0°–180°; 135°–215°) of lineaments in *subregion 4*; (*e*) NW–SE azimuth (orientations 140°–320°; 175°–355°) of lineaments in *subregion 5*; (*f*) the lineaments in the *subregion 6* have no dominant azimuth.

lineaments by the author performed around the Jemma River Basin.

3.4 Comparison of lineaments performed manually and extracted automatically

A total of 408 lineaments were mapped by visual interpretation by the author around the Jemma River Basin and its close surroundings (an area covering 16,000 km²; Figure 7a). The total length of lineament was 5,248 km. This part of the Ethiopian Highlands was influenced by tectonic processes associated with the formation of the Rift Valley. The lineaments have a main NE–SW azimuth (Figure 7b) – the main direction of the azimuth is N25°E and the second direction is N60°E. The NE–SW azimuth of lineaments is consistent with the orientation of the rift.

Lineaments were mapped in the same area by automated visualization in GIS 833 with a total length of 7,553 km (Figure 7c). The main azimuth of these lineaments is also in a NE–SW direction (Figure 7d), with the difference that the main direction of the azimuth is N60°E–N65°E and the second direction is N25°E.

This difference is caused by the different methods of lineaments mapping. During the visual interpretation of the lineaments, the authors identified mainly linear units of thalwegs and ridges in the landscape (Figure 7a). This results in a smaller number of longer lineaments (the most frequently determined total length of lineaments interpreted by the author was between 10 and 15 km). The mapping of lineaments by automated visualization in GIS identifies the lineaments by differences of grayscale of the pixels in the hill shading image – the lineaments

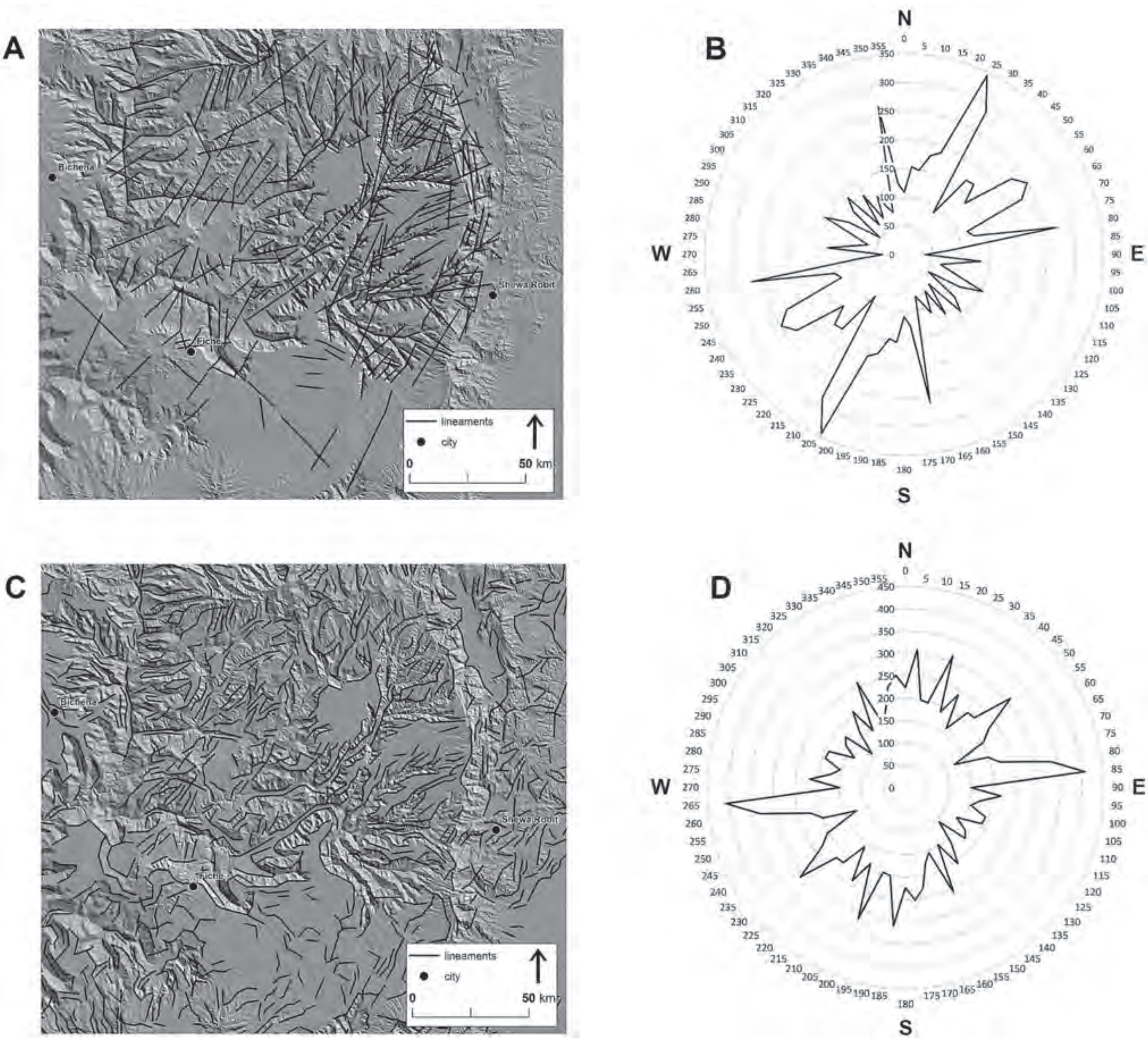

Fig. 7 Lineaments around the Jemma River Basin and its close surroundings. Note: (*a*) visual interpretation of lineaments by the author; (*b*) rose diagram of frequency of lineaments. The dominant NE–SW azimuth (orientations 25°–205°; 180°–260°) of lineaments visually interpretated by the author; (c) lineaments by automated visualization in GIS; (d) rose diagram of frequency of lineaments. The dominant NE–SW azimuth (orientations 45°–225°; 180°–260°) of lineaments by automated visualization.

mainly copied the borders of valleys as opposed to the valley thalwegs (Figure 7c). The result is a larger number of shorter lineaments (the most frequently determined total length of lineaments by automated visualization in GIS was 5 km).

4. Discussion

Automated lineament extraction has been performed by various authors (Kocal et al. 2007; Hung et al. 2005; Abdullah et al. 2010). The authors have also used various different study areas and various input DEM resolutions. Compared with other authors, we used the largest study area (Table 2). Therefore, we needed to use different parameters and thresholds. The resolution also plays the dominant role in the quality of the extracted lineaments. In comparison, we used a lower quality DEM because our input DEM resolution was only 90 m.

The parameters also differ from other authors' parameters (see Table 2). We used larger RADI parameters because the larger the RADI value, the less noise in the result, to the detriment of the amount of detail (Kocal et al. 2007). According to these authors, the value between 5 and 7 gives good results, whereas higher values result in a loss of data. We experimented with the GTHR parameter because its value is difficult to determine at first. We used the highest LTHR value because our study area was very large, so we needed to have long rectilinear lineaments, which were considered to be the lineaments. An interesting difference is also in the FTHR value. The lower the value, the shorter the line segments approximate to the lineaments. The default value is 3 in PCI Geomatica, which corresponds to Kocal et al. (2007), who published, that to obtain shorter line segments the recommended FTHR parameter is between 2 and 3. However, if we considered the size of study area, lower FTHR value produced a shorter segments in the polyline and thus higher amount of noise. The smaller the ATHR parameter, the more disconnected the lineaments appear. We tried several ATHR parameters but the value of 20, which is recommended, showed very short discontinuous lineaments and a value higher than 40 showed polygon shaped lineaments. In comparison with Hung et al. (2005) and Abdullah et al. (2010), we used the highest DTHR parameter value. We wanted to have a higher maximum distance between two vectors. Kocal et al. (2007) and Hung et al. (2005) used very small DTHR values because they had a very small study area. Abdullah et al. (2010) used a DTHR value of 20. Due to the fact that we had a very large study area and we wanted to detect lineaments separately, according to the resolution of the input DEM, a DTHR value of 30 was considered to be the best choice.

This paper demonstrates that the number of lineaments extracted by automatic methods is higher than the number of manually created lineaments. The automatically extracted lineaments are also shorter than man-made lineaments and not every extracted lineament represents a geological feature. This is the main problem of the automated method. Furthermore, the results depend on the previous data resolution. It is assumed that if the resolution of the previous DEM in this large study area would be higher, then the number of extracted lineaments would also be higher. Another error is caused by the border of the input DEM, because the pixel size there can be distorted.

5. Conclusion

The presented study demonstrates that the SRTM DEM with 90 m resolution has enough quality for lineament extraction. For automated lineament extraction from the SRTM DEM, the suitable parameters are necessary. We determined that the size of the study area can be larger than presented by several authors so far (e.g. Hung et al. 2005; Kocal et al. 2007 and Abdullah et al. 2010), i.e. 1,060,000 km^2.

The morphotectonic network consisted of 14,940 lineaments; the most common length of the lineaments was 10 km (73.6%). The predominant azimuth of the lineaments is similar to the azimuth of the faults on the geological map of the scape 1 : 250,000; however, because the total number of lineaments is much higher than the total number of faults (in total 3,004 faults) the lineaments demonstrate slightly more variability of azimuths.

Tab. 2 Parameters used in the automatic extraction of lineament by different authors in comparison with this paper.

Authors	Abdullah et al. (2010)	Hung et al. (2005)	Kocal et al. (2007)	Our work
Study area [km^2]	2,340	284	15	1,060,000
Resolution [m]	30	30	1	90
RADI	12	5	12	24
GTHR	90	10	26–60	94
LTHR	30	7	20–30	50
FTHR	10	3	3	7
ATHR	30	7	20	40
DTHR	20	3	1	30

A detailed analysis of the faults and lineaments azimuths in geologically homogenous units showed a high degree of parallelism. The visual interpretation of lineaments by the author around the Jemma River Basin and the lineaments by automated visualization in GIS at the regional scale have the same NE–SW direction – and in the same orientation like the Rift. Lineaments visually interpreted by the author consist of linear units of thalwegs and ridges in the landscape. This resulted in a smaller number of longer lineaments. In contrast, the mapping of lineaments by automated visualization in GIS identifies the lineaments by differences in the grayscale of the pixels in the hill shading image and the lineaments copied mainly rather border valleys than valley thalwegs, which results in a larger number of shorter lineaments.

In conclusion, the automated lineament extraction is recommanded for larger area (transregional scale). In our opinion, the speed of rendering lineaments leads to a decrease of the accuracy morphostructural analysis results. The method should be still complemented by the author's manual control of lineaments.

Acknowledgements

This study was supported by the Grant Agency of the Czech Republic (P209/12/J068) and the Grant Agency of Charles University in Prague (1436314).

REFERENCES

ABARCA, M. A. A. (2006): Lineament extraction from digital terrain models. International institute for geo-information science and earth observation, Enschede, the Netherlands, 86.

ABDULLAH, A., AKHIR, J. M., ABDULLAH, I. (2010): Automatic Mapping of Lineaments Using Shaded Relief Images Derived from Digital Elevation Model (DEMs) in the Maran – Sungi Lembing Area, Malaysia. EJGE, vol. 15, 949–957.

ASSEFA, G. (1980): Stratigraphy and sedimentation of the type Gohatsion Formation (Lias-Malm) Abay River basin, Ethiopia. Ethiopian Journal of Science (Sinet) 3, 87–110.

ASSEFA, G. (1981): Gohatsion formation: a new Liasmal lithostragraphic unit from the Abby River basin, Ethiopia. Geoscience Journal 2, 63–88.

ARROWSMITH, J. R., ZIELKE, O. (2009): Tectonic geomorphology of the San Andreas zone from high resolution topography: An example from the Cholame segment. Geomorphology 113, 70–81. https://doi.org/10.1016/j.geomorph.2009.01.002

BEYENE, A., ABDELSALAM, M. G. (2005): Tectonics of the Afar Depression: A review and synthesis. Journal of African Earth Sciences 41, 41–59. https://doi.org/10.1016/j.jafrearsci.2005.03.003

CASAS, A. M., CORTÉS, A. L., MAESTRO, A., SORIANO, M. A., RIAGUAS, A. R., BERNAL, J. (2000): LINDENS: A program for lineament length and density analysis. Computers and Geosciences 26, 1011–1022. https://doi.org/10.1016/S0098-3004(00)00017-0

CONSORTIUM FOR SPATIAL INFORMATION [online]. [downloaded 15.1.2014]. WWW: http://www.cgiar-csi.org

COULIÉ, E., QUIDELLEUR, X., GIRLLOT, P. Y., COURTILLOT, V., LEFÉVRE, J. C., CHIESA, S. (2003): Comparative K-Ar and Ar/Ar dating of Ethiopian and Yemenite Oligocene volcanism: implications for Tininy and duration of the Ethiopian traps. Earth and Planetary Science Letters 206, 477–492. https://doi.org/10.1016/S0012-821X(02)01089-0

DEMEK, J. (1987): Obecná geomorfologie. Academia, Praha, 476.

EHLEN, J. (2004): Lineation. In GOUDIE, A. S. (editor) et al.: Encyclopaedia of geomorphology. Routledge, London, 623–624.

EKNELIGODA, T. CH., HENKEL, H. (2006): The spacing calculator software – A Visual Basic program to calculate spatial properties of lineaments. Computers and Geosciences 32, 542–553. https://doi.org/10.1016/j.cageo.2005.08.007

EKNELIGODA, T. CH., HENKEL, H. (2010): Interactive spatial analysis of lineaments. Computers and Geosciences, 36, 1081–1090. https://doi.org/10.1016/j.cageo.2010.01.009

ESRI Inc. ArcMap™. Ver. 10.1. Copyright 2015. [online]. [downloaded 1.1.2014]. WWW: http://www.esri.com.

FAIRBRIDGE, R. W. (1968): The encyclopaedia of geomorphology. Reinhold, New York, 1295.

FARR, T., ROSEN, P., CARO, E., CRIPPEN, R., DUREN, R., HENSLEY, S., KOBRICK, M., PALLER, M., RODRIQUEZ, E., ROTH, L., SEAL, D., SHAFFER, S., SHIMADA, J., UMLAD, J., WERNER, M., OSKIN, M., BURBANK, D., ALSDORF, D. (2007): The Shuttle Radar Topography Mission. Reviews of Geophysics 45, 33. https://doi.org/10.1029/2005RG000183

GANI, N. D., ABDELSALAM, M. G. (2006): Remote sensing analysis of the Gorge of the Nile, Ethiopia with emphasis on Dejen-Gohatsion region. Journal of African Earth Science 44, 145–150. https://doi.org/10.1016/j.jafrearsci.2005.10.007

GANI, N. D., GANI, M. R., ABDELSALAM, M. G. (2007): Blue Nile incision on the Ethiopian Plateau: Pulsed plateau growth, Pliocene uplift, and hominin evolution. GS Today 17, 4–11. https://doi.org/10.1130/GSAT01709A.1

GANI, N. D., ABDELSALAM, M. G., GERA, S., GANI, M. R. (2009): Stratigraphic and structural evolution of the Blue Nile Basin, Northweastern Ethiopian Plateau. Geologic Journal 44, 30–56. https://doi.org/10.1002/gj.1127

GOROKHOVICH, Y., VOSTIANIOUK, A. (2006): Accuracy assessment of the processed SRTM-based elevation data by CGIAR using field data from USA and Thailand and its relation to the terrain characteristics. Remote Sensing of the Environment 104, 409–415. https://doi.org/10.1016/j.rse.2006.05.012

HOFMANN, C., COURTILLOT, V., FERAUD, G., ROCHETTE, P., YIRGU, G., KETEFO, E., PIK, R. (1997): Timing of the Ethiopian flood basalt event and implications of Plume birth and global change. Nature 389, 838–841. https://doi.org/10.1038/39853

HUBBARD, B., MACK, T. J., THOMPSON, A. (2012): Lineament Analysis of Mineral Areas of Interest in Afghanistan. U. S. Geological Survey, Reston VA, 28.

HUGGETT, R. J. (2007): Fundamentals of geomorphology. Routledge, London, 472.

HUNG, L., BATELAAN, O., DE SMEDT, F. (2005): Lineament extraction and analysis, comparison of LANDSAT ETM and ASTER imagery. Case study: Suoimuoi tropical krast catchment. Vietnam. Remote Sensing for Envronmental Monitoring. GIS Aplication and Geology.

IAN-KO – geotools for ArcGis. [online]. [downloaded 15.1.2014]. WWW: http://www.ian-ko.com/

JORDAN, G., SCHOTT, B. (2005): Application of wavelet analysis to the study of spatial pattern of morphotectonic lineaments in digital terrain models. A case study. Remote Sensing of Environment 94, 31–38. https://doi.org/10.1016/j.rse.2004.08.013

JORDAN, G., MEIJNINGER, B. M. L., van HINSBERGEN, D. J. J., MEULENKAMP, J. E., van DIJK, P. M. (2005): Extraction of morphotectonic features from DEMs: Development and applications for study areas in Hungary and NW Greece. International of Applied Earth Observation and Geoinformation 7, 163–182. https://doi.org/10.1016/j.jag.2005.03.003

KAZMIN, V. (1975): Geological Map of Ethiopia. Geological Survey of Ethiopia, Adrie Ababa, Ethiopia.

KENNELLY, P. (2008): Terrain maps displaying hill-shading with curvature. Geomorphology 102, 567–577. https://doi.org/10.1016/j.geomorph.2008.05.046

KIEFFER, B. (2004): Flood and Shield Basalt from Ethiopia: Magmas from the African Superswell. Journal of Petrology, 45, 793–834. https://doi.org/10.1093/petrology/egg112

KIM, G. B., LEE, J. Y., LEE, K. K. (2004): Construction of lineament maps related to groundwater occurrence with ArcView and AvenueTM scripts. Computers and Geosciences 30, 1117–1126. https://doi.org/10.1016/j.cageo.2004.09.002

KOCAL, A., DUZGUN, H. S., KARPUZ, C. (2007): An Accuracy assessment methodology for the remotely sensed discontinuities: a case study in Andesite Quarry area, Turkey. International Journal of Remote Sensing 17, 3915–3936. https://doi.org/10.1080/01431160601086001

KŘÍŽEK, M., KUSÁK, M. (2014): Variability of the morphometric characteristics of valley networks caused by variations in a scale. Acta Universitatis Carolinae – Geographica 48(1), 33–42. https://doi.org/10.14712/23361980.2014.4

MANGESHA, T., CHERNET, T., HARO, W. (1996): Geological Map of Ethiopia (1 : 250,000). Geological Survey of Ethiopia: Addis Ababa, Ethiopia.

McDOUGALL, I., MORTON, W. H., WILLIAM, M. A. J. (1975): Ages and rates of denudation of trap series basalts at the Blue Nile Gorge, Ethiopia. Nature 254, 207–209. https://doi.org/10.1038/254207a0

MINÁR, J., SLÁDEK, J. (2009): Morphological network as an indicator of a morphotectonic field in the central Western Carpathians (Slovakia). Z. Geomorph. N.F. 53, 215–221. https://doi.org/10.1127/0372-8854/2009/0053s3-0023

MUHAMMAD, M. M., AWDAL, A. H. (2012): Automatic Mapping of Lineaments Using Shaded Relief Images Derived from Digital Elevation Model (DEM) in Kurdistan, northeast Iraq. ANAS 6(2), 138–146.

NOVAK, I. D., SOULAKELLIS, N. (2000): Identifying geomorphic features using LANDSAT-5/TM data processing techniques on Lesvos, Greece. Geomorphology 34, 101–109. https://doi.org/10.1016/S0169-555X(00)00003-9

ÖZKAYMAK, C., SÖZBILIR, H. (2012): Tectonic geomorphology of the Spildagi High Ranges, western Anatolia. Geomorphology 173–174, 128–140. https://doi.org/10.1016/j.geomorph.2012.06.003

PCI GEOMATICS ENTERPRISES INC (2010): PCI Geomatica-10, version 10.3.1. Richmond Hill, Ontario, Canada.

PIK, R., MARTY, B., CARIGNAN, J., LAVÉ, J. (2003): Stability of the Upper Nile drainage network (Ethiopia) deduces from (U/Th)/He thermochronometry: implications for uplift and erosion of the Afar plume dome and Planetary Science Letters, 215, 73–88.

RABUS, B., EINEDER, M., ROTH, R., BAMLER, R. (2003): The shuttle radar topography mission – a new class of digital elevation models acquired by spaceborne radar. ISPRS Journal of Photogrammetry and Remote Sensing 57(4), 241–262. https://doi.org/10.1016/S0924-2716(02)00124-7

REUTER, H. I. A., NELSON, A. J. (2007): An evaluation of void filling interpolation methods for SRTM data, International Journal of Geographic Information Science 21(9), 983-1008. https://doi.org/10.1080/13658810601169899

RUSSO, A., ASSEFA, G., ATNAFU, B. (1994): Sedimentary evolution of the Abby River (Blue Nile) Basin, Ethiopia. Neues Jahrbuch fur Geologie und Palaeontologie Monatshefte 5, 291–308.

SARP, G. (2005): Lineament Analysis From Satellite Images, North-West Of Ankara, Msc thesis, Middle East Technical University, 76.

SENGOR, A. M. C. (2001): Elevation as indicator of mantle-plume activity. Geological Society of America 352, 183–225.

WLADIS, D. (1999): Automatic Lineament Detection Using Digital Elevation Models with Second Derivate Filters. Photogrammetric Engineering and Repote Sensing 4, 453– 458.

WOLELA, A. (2010): Diagenetic evolution of the Ansian-Pliensbachian Adigrat Sandstone, Blue Nile Basin, Ethiopia. Journal of African Earth Science 56, 29–42. https://doi.org/10.1016/j.jafrearsci.2009.05.005

WOLFENDEN, E., YIRGU, G., EBINGER, C., DEINO, A., AYALEW, D. (2004): Evolution of the northern Main Ethiopian Rift: birth of a triple junction. Earth and Planetary Science Letters 24, 213–228. https://doi.org/10.1016/j.epsl.2004.04.022

YUNNUR, M. T., CHOROWICZ, J. (1998): Recent volcanism, tectonics and plate kinematics near the junction of the African, Arabian and Anatolian plates in the eastern Mediterranean. J. Volcanol. Geoth. Res. 85, 1–15. https://doi.org/10.1016/S0377-0273(98)00046-8

RESUMÉ

Analýza vztahu automaticky a ručně vykreslených lineamentů z DEM a tektonických poruch kolem Etiopského riftu a Etiopské vysočiny, Etiopie

Článek se zabývá metodami automatického vykreslení lineamentů pomocí programů ArcGIS 10.1 a PCI Geomatica s použitím dat SRTM DEM s velikostí pixelu 90 m (CGIAR-CSI 2014). V článku jsou diskutovány hodnoty vstupních parametrů a jejich vliv na konečný tvar a počet vykreslených lineamentů v okolí Etiopského riftu a Etiopské vysočiny (nadregionální měřítko), které patří mezi tektonicky nejvíce ovlivněné části světa. Na základě automatických metod GIS programů byla vytvořena mapa lineamentů, která byla následně porovnána 1) s reálnými tektonickými poruchami zaznamenanými v geologické mapě v měřítku 1 : 250 000 (Mangesha et al. 1996) a 2) s lineamenty vykreslenými na základě autorské vizuální interpretace digitálních modelu reliéfu v okolí povodí řeky Jemmy (regionální měřítko).

Převládající azimuty lineamentů se ukázaly být shodné s azimuty tektonických poruch na geologických mapách. Z porovnání automaticky vykreslených lineamentů v prostředí GIS a lineamentů vzniklých autorským vykreslením vyplývá, že u obou skupin lineamentů převažuje SV–JZ orientace, tedy stejný směr jakým je orientovaný i Etiopský rift. Z tohoto srovnání dále vyplývá, že mapování lineamentů pomocí automatizovaných metod v prostředí GIS identifikuje větší počet lineamentů, ale jejich délka je – oproti ručnímu vykreslení – kratší.

Závěrem lze říci, že automatizované metody vykreslení lineamentů jsou vhodné pro analýzy rozsáhlých území (transregionální měřítko). Podle našeho názoru, rychlost vykreslení lineamentů vede k poklesu přesnosti výsledků morfostrukturní analýzy a metody by stále měla být doplněna o autorovu manuální kontrolu vykreslených lineamentů.

Michal Kusák
Charles University, Fakulty of Science
Department of Physical Geography and Geoecology
Czech Republic
Albertov 6, 128 43 Prague 2
E-mail: kusak.michal@centrum.cz
Tel.: +420604892482

Klára Krbcová
Charles University, Fakulty of Science
Department of Physical Geography and Geoecology
Czech Republic
Albertov 6, 128 43 Prague 2
E-mail: Klara.Krbcova@seznam.cz
Tel.: +420604892086

DEVELOPMENT AND CLASSIFICATION OF SHOPPING CENTERS IN CZECH AND SLOVAK REPUBLICS: A COMPARATIVE ANALYSIS

FRANTIŠEK KRIŽAN[1], JOSEF KUNC[2], KRISTÍNA BILKOVÁ[1], PETER BARLÍK[1], ZDENĚK ŠILHAN[2]

[1] Comenius University in Bratislava, Faculty of Natural Science, Department of Regional Geography, Protection and Planning of the Landscape, Slovak Republic
[2] Masaryk University in Brno, Faculty of Economics and Administration, Department of Regional Economics and Administration, Czech Republic

ABSTRACT

Modern shopping centers of the "West-European" type have existed in the Czech and Slovak republics since 1997 and 2000, respectively, i.e. for less than two decades. Despite this rather short period they have become synonymous with the most significant transformations both in shopping behaviour and in the more generally understood patterns of social and cultural behavior of all population groups (entertainment and leisure time utilization). This article compares similarities and differences in the temporal, spatial and functional structures of shopping centers in two countries that had, until 1993, developed for seventy years as a single state, and which have demonstrated significant similarities in their economies, cultures and societies even after the separation.

Keywords: shopping centers, classification, similarities and differences, Czech Republic, Slovak Republic

Received 29 June 2016; Accepted 1 November 2016; Published online 16 February 2017

1. Introduction

The shopping-center phenomenon is probably the most significant manifestation of contemporary retail business activity in both the Czech and Slovak republics. Here we do not refer only to the physical appearance of shopping centers, but more importantly to their social and cultural impacts, one of which is the modification of long-established patterns of shopping behavior and shopping customs for most population groups (Kunc et al. 2013; Spilková 2012a; Timothy 2005).

The central role of retailing, i.e. the selling of goods and the provision of services to consumers, has been evolving into the contemporary format for several decades. Continually accelerating globalization and internationalization trends have manifested themselves in hasty and hectic ways of life, where we all seem to lack time (Giddens 2002). Large chain stores and shopping centers have not only drawn the attention of shoppers away from traditional forms of retail shopping (Szczyrba 2005); shopping centers have, to a large extent, replaced traditional public spaces and everything that belongs to them (Cooper 2007; Jackson et al. 2011; van Leeuwen and Rietveld 2011; Voyce 2006). Many commercial and non-commercial functions of individual municipal districts (catering, post offices, banks, medical offices, etc.) have been transferred gradually to shopping centers, as described by Spilková and Hocheľ (2009) and Pospěch (2010). Shopping centers in post-socialist countries have become one of the key signifiers of the modification of society's consumer behavior (cf. Pospěch 2017; Spilková 2003; Spilková and Radová 2011).

The possibility to shop, enjoy services, entertainment and relaxation "under a single roof" has offered a solution to the lack of time people currently experience. The shopping-center solution has its negative sides, though, which, over time, have become increasingly apparent. By this we mean the establishment of consumers society (Mansvelt 2005), where certain consumers spend entire days in shopping centers; the creation of an artificial social status dependent on being seen "out and about" in a shopping center – especially among members of the younger generation, the so-called *mall junkies* (Spilková 2012b; Underhill 2004); the frequently non-regulated construction of buildings in inappropriate locations due to political pressure from some public administration bodies and the developers themselves, etc. (England 2000; Spilková 2010). A visit to a shopping center has become an attraction, entertainment, a form of leisure and even a specific form of social event not only for young people but also, for example, for senior citizens. It is possible to assess shopping centers by their attractiveness in this context, depending on multiple factors, and express their ability to attract consumers (Kunc et al. 2016).

The aim of this paper is to present similarities and differences between shopping centers in the Czech and Slovak republics according to their temporal and spatial structures. We shall focus on the conditions preceding and accompanying their entry and establishment in both markets with the aim of describing the evolution and expansion of shopping centers in the Czech and Slovak republics from 1997 to 2015. Furthermore, we shall compare shopping centers from the perspective of space and location in relation firstly to genesis, and secondly to shopping area.

https://doi.org/10.14712/23361980.2017.2
Križan, F. – Kunc, J. – Bilková, K. – Barlík, P. – Šilhan, Z. (2017): Development and classification of shopping centers in Czech and Slovak republics: A comparative analysis
AUC Geographica, 52, No. 1, pp. 18–26

2. Background

The term 'shopping center' has been evolving since the early 1950s. A range of definitions has been developed for shopping centers, often tending to reflect changes in the industry. In simple terms, a shopping center can be defined as a building that contains many shop units but is managed as a single property. Shopping centers today are increasingly complex in terms of size, type and characteristics, which has contributed to the confusion as to shopping centers' identities (Pitt and Musa 2009). A shopping center is a spatial pattern of homogeneous or heterogeneous retailers agglomerating in the same place. On the one hand, it is a highly organized commercial complex in a building or area that consists of a variety of retailers who together provide a comprehensive service to consumers. On the other hand, the shopping center is also a kind of commercial real estate that serves to integrate businesses and is usually a blend of retail, services, catering, leisure, entertainment and other composite forms (Shi et al. 2015). A general shopping center definition according to the International Council for Shopping Centers (ICSC) states that a shopping center is a set of retail and other business facilities, which has been planned, built, owned and managed as one entity, usually with proprietary parking available. The most common combination is a shopping gallery and an anchor tenant (magnet) in the form of a hypermarket or a larger supermarket (ICSC 2005).

Since it is still difficult to find uniform criteria for shopping center classification (cf. Guy 1998), we shall use the European ICSC definition with the limiting value of 5,000 square meters of gross leasable area (Table 1). In the Czech Republic we will therefore work with a database of 83 shopping centers and in Slovak Republic with 47 (Kunc et al. 2016).

Globalization trends within the retail environment have been some of the most visible features of socio-economic transformation in both the Czech and Slovak republics since 1989. The shopping needs of Czech and Slovak consumers had been neglected during the period in which there was a centrally planned economy (Drtina 1995; Szczyrba 2005) and consequently there was a strong impetus to change this situation in the subsequent democratization period. Although the fastest establishment of the private retail sector was not recorded in the Czech-Slovak environment but in Hungary (Douglas 1995), the transformation in the Czech Republic's retail field was amongst the most decisive of the Central European post-socialist countries (cf. Kok 2007; Kunc et al. 2013). Slovak Republic went through the transformation of its retailing structures later and more slowly (Križan et al. 2016).

Two of the most important aspects to consider when planning shopping center building projects are spatial localization and accessibility within the municipal and suburban environments. The issue of localization is frequently discussed in the course of urban planning and must (should) be subject to regulations and comply with the requirements of environmental protection (England 2000; Koželouh 2010). It is, in principle, possible to distinguish three options for shopping center localization (Guy 1998): i) *edge-of-center*, ii) *out-of-center* and iii) *out-of-town*. All impacts of a building project on the surrounding territory must be taken into account during the building of a new shopping center. The greatest conflict for a newly built-up area is the replacement of the previous differently used land resources (Spilková and Šefrna 2010). It is also necessary to take into account interference with the municipal or suburban cultural landscape, which could cause negative attitudes in the affected population (Kok 2007; Kunc et al. 2012a).

The construction and subsequent expansion of shopping centers within inner city structures is always limited by the cultural-historical value of the original built-up territory. Inner-city shopping centers are typically multi-story buildings with smaller total leasable areas, where it is frequently impossible to locate a large-scale shop, such as a hypermarket, as a magnet. A multiplex cinema, for

Tab. 1 International standard for individual types of European shopping centers.

Format	Type of the Scheme		Gross Leasable Area (GLA)
Traditional	Very Large		80,000 m^2 and above
	Large		40,000–79,999 m^2
	Medium		20,000–39,999 m^2
	Small	Comparison-based	5,000–19,999 m^2
		Convenience-based	5,000–19,999 m^2
Specialized	Retail Park	Large	20,000 m^2 and above
		Medium	10,000–19,999 m^2
		Small	5,000–19,999 m^2
	Factory Outlet Center		5,000 m^2 and above
	Theme-oriented Center	Leisure-based	5,000 m^2 and above
		Non-leisure-based	5,000 m^2 and above

Source: ICSC (2005).

example, could become a magnet, which would, along with retailing and service units, contribute to the resurgence of a historic city core. Walking is the most common means of transport in city centers due to the limitations of other means of transport. A lack of parking spaces at the back of a shopping center – understandable within pedestrian zones in historical cores – could be considered a problem, but could be compensated for by the center's localization and walking distance to public transportation services or park & ride parking lots (Kunc et al. 2012a). In specific cases (Ostrava in the Czech Republic and Prešov in Slovak Republic, for example) cities can have sufficient surface area available for building in the city center or in its vicinity, to be able to construct large shopping centers in the so-called "*in-town*" or "*inner-city*" locations. Westquay Shopping Centre (75,000 m^2) in Southampton, England, is an example of such a location. The construction of the shopping center was an important part of the regeneration strategy of the city, which was, due to the decisive role of the shopping center, called a "retail-led urban regeneration" (Lowe 2005).

Revitalizing old industrial buildings (mostly on city edges or within the wider inner city) using the original, sometimes architecturally valuable, buildings is another means of building shopping centers that is becoming more common. These developments are not always in shopping or commercial areas, but, as noted by Kok (2007), retailing is a reliable source of income and therefore is often a key factor influencing the feasibility of the project. The scope of these construction projects is frequently constrained by the surrounding buildings or communication facilities and parking will most often be underground or rooftop.

There are more options for spatial expansion for shopping center developments situated beyond the city centers and their close surroundings. Here shopping centers can be reconstructed from former communal facility buildings, newly built in empty spaces within housing development complexes or as redevelopments of manufacturing premises. These shopping centers usually include a hypermarket, a hobby market, restaurants and service facilities. Building shopping centers within large housing-development complexes is to be assessed positively since these complexes have customarily been underdeveloped from the retailing point of view (Mulíček 2007; Szczyrba 2005). Shopping arcades, service and entertainment facilities, promenades and spaces available for leisure tend to become new natural places for people to meet; these can become the new centers of municipal districts or of heavily urbanized territories (Kunc et al. 2012a, 2012b).

Large projects with large-surface-area buildings and open-air single-level parking lots for thousands of vehicles are found in the suburbs, beyond the city itself. The magnet could be a hypermarket with groceries and related goods or some other kind of large store with a non-grocery assortment of goods. Inside these shopping centers you can find multiplex cinemas, restaurants, fast-food restaurants, various sports facilities, leisure time facilities and other facilities; these are frequently accompanied by hobby markets and the so-called 'DIY' (do it yourself) shops.

It is necessary to note, however, that the construction of a large shopping center in the vicinity of a historic city core could be a serious threat to existing commercial and service functions in the city core and entail a decrease in the number of city core visitors (Crosby et al. 2005).

3. Methods and Data

The methodology used for this article can be divided into two groups. The first group focusses on the description of temporal and spatial aspects of the shopping centers development in both countries. This is a comparative analysis of the analyzed shopping format time series within a spatial context (Erkip and Ozuduru 2015; Fertaľová 2005; Graff 2006; Kunc et al. 2013; Mitríková 2008; Szczyrba 2010; Trembošová 2012).

The second group focusses on the classification of shopping centers in Czech and Slovak cities. The classifications, based on the typical methods of shopping center assessment, are according to the following criteria: (i) genesis, (ii) location, (iii) size of the gross leasable area (Coleman 2012; Guy 1998; Križan et al. 2015; Kunc et al. 2013).

The data can be divided into four groups. The first group includes data from the authors' internal databases i.e. data relating to retail field development and transformation collected within the Czech and Slovak republics. The second group includes data from the internal databases of individual shopping centers, and focusses on their internal structures and retailing facilities. The third group includes data from the internal databases of the INCOMA and GfK survey agencies. The fourth data group is based on field research. This data is the foundation for an empirical approach to this issue.

4. Shopping centers in the Czech and Slovak republics: Development

The origins and the development of the shopping centers have been well discussed (Coleman 2012). In post-communist countries, such as the Czech and Slovak republics, retailing developed after WWII in a relatively isolated way, without the influence of retailing globalization trends (Earle et al. 1994; Krásný 1992; Maryáš et al. 2014; Očovský 1974). The political transformation in December 1989 had a great impact on retail development (Kok 2007). The beginning of the 1990s saw a process of atomization in retailing, followed by a process of internationalization (Fertaľová 2005; Kita 2008; Pulpitlová 2003; Simová 2010; Szczyrba 2005). Central European markets became prime targets for expanding retail corporations

(Kok 2007). It was at this stage that the shopping center phenomenon occurred. It is possible to distinguish three stages in the development of the shopping centers in the Czech Republic and in Slovak Republic. The first stage (1997–2003) saw the appearance of the first shopping centers. The first shopping center opened in the Czech Republic in 1997, and in Slovak Republic three years later (Fig. 1). The first stage of shopping centers building was more profound for the Czech Republic since 36.1% of current shopping centers within the country were built before 2003, while in Slovak Republic, just 14.9% were built.

The second stage of shopping centers development (2003–2009) witnessed a peak in new shopping centers building before 2008 and then a gradual decline to 2009. 49.4% of the current shopping centers were built in the Czech Republic during this stage. The development in Slovak Republic was more intense, as approximately 28 shopping centers were opened there between 2004 and 2009: 59.6% of all shopping centers in Slovak Republic.

New shopping centers development in the third stage (2009–present) shows further differences between the Czech Republic and in Slovak Republic. The Czech Republic saw gradual decline in new shopping centers building before 2010 with an increase in development starting again in 2012. In Slovak Republic, a decline in new shopping centers construction can be observed (probably due to a delayed response to the global economic crisis, only seen in 2011). Several projects were suspended, owners were changed, or changes were made to the size or character of the builds. Not one shopping center was built in Slovak Republic in 2013. There was a recovery in 2014, and by 2015 Slovak Republic and the Czech Republic switched their positions with Slovak Republic building more than the Czech Republic. 13.1% of the current shopping centers in the Czech Republic were opened during the last 5 years, while Slovak Republic witnessed no such decline (almost one fifth of the current shopping centers were opened in this last stage of development).

In general, you can observe similar trends in shopping centers development in the Czech Republic and in Slovak Republic with a delay of 2 to 4 years in the latter country. This time-space shift in the West-East direction, called wave diffusion, is visible in retailing in both countries (Szczyrba 2005; Križan and Lauko 2014).

5. Shopping centers in the Czech and Slovak republics: Classification

It is possible to classify shopping centers according to various criteria (Križan et al. 2014; Kunc et al. 2012). Three criteria have been used in this article: (i) genesis, (ii) location, (iii) gross leasable area.

In terms of their genesis, shopping centers can be divided between those built on greenfield and those built on brownfield sites (previously developed area; for the purpose of this article we are going to use more common term "brownfield"). Shopping centers built on brownfield sites slightly prevail in the Czech Republic (50.6%). Conversely, shopping centers built on greenfield sites prevail in Slovak Republic (54.3%). Even larger differences can be observed when comparing the graph (Fig. 2). The construction of greenfield shopping centers prevailed in the Czech Republic during the period of analysis (1997–2015) for a total of 9 years. Conversely, the construction of brownfield shopping centers prevailed for 8 years. The situation is similar in the territory of the Slovak Republic. The ratio between the numbers of years with the prevalence of greenfield shopping centers building to brownfield is 6 : 6 (Fig. 2). In contrast to Slovak Republic, not a single shopping center was built on a greenfield site in the Czech Republic after 2009, which is a positive development.

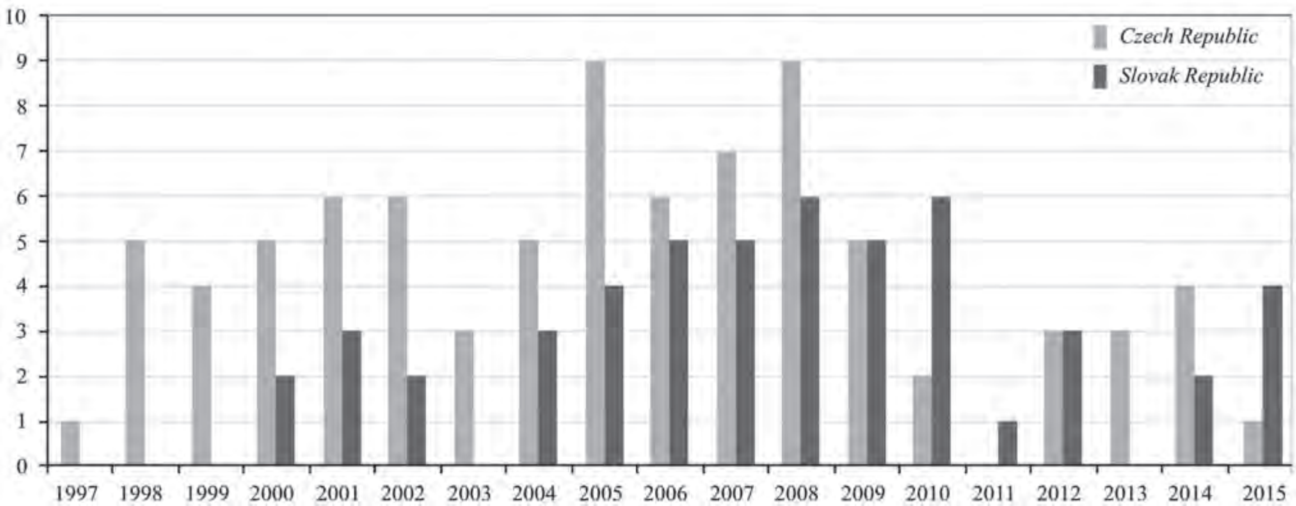

Fig. 1 Newly opened shopping centers in the Czech Republic and Slovak Republic between 1997 and 2015.
Source: Our own survey

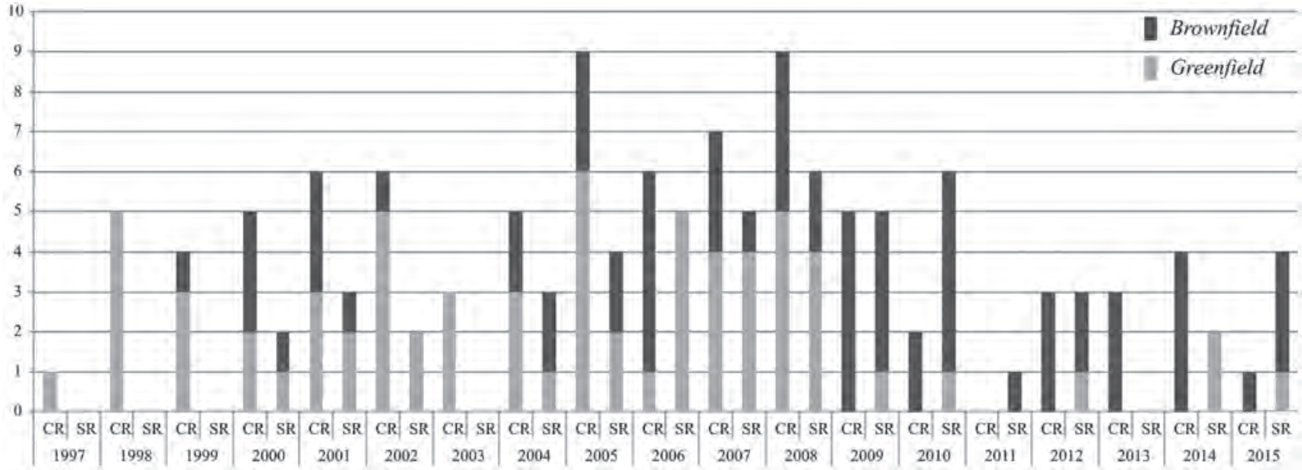

Fig. 2 Newly opened shopping centers in the Czech Republic (CR) and Slovak Republic (SR) according to their division into greenfield and brownfield sites.
Source: Our own survey

Shopping center localization within basic morphogenetic city zones is the second assessment criterion (Guy 1998; Križan et al. 2014). Shopping centers in the "out of center" group are the most frequent in the Czech Republic (44.0%), while shopping centers in the "edge of center" group are the least frequent (16.7%). The "out of town" group includes over half of all shopping centers in Slovak Republic (54.9%) while the "edge of center" group is also the least frequent (15.7%). When analyzing shopping center building according to locality in the period between 1997 and 2015 (Fig. 3), you can see a general trend from a prevalence of out of town shopping center building in the first stage (1997–2003) to an increasing frequency of out of center and edge of center building in the second and third stages (2003–present). This trend is more overt in the case of the Czech Republic. The "out of town" type of shopping center building period has still prevailed both in the Czech and Slovak republics (6 years).

The size of the Gross Leasable Area (GLA) is the third criterion of shopping center classification (ICSC 2005) in both countries. The fact that in the period between 1997 and 2015 small shopping centers were built most frequently in both countries, while large and very large shopping centers were built only rarely is a common characteristic of shopping center development in both countries (Fig. 4). A decrease in the GLA of newly opened shopping centers is a trend in both countries. Over one half of

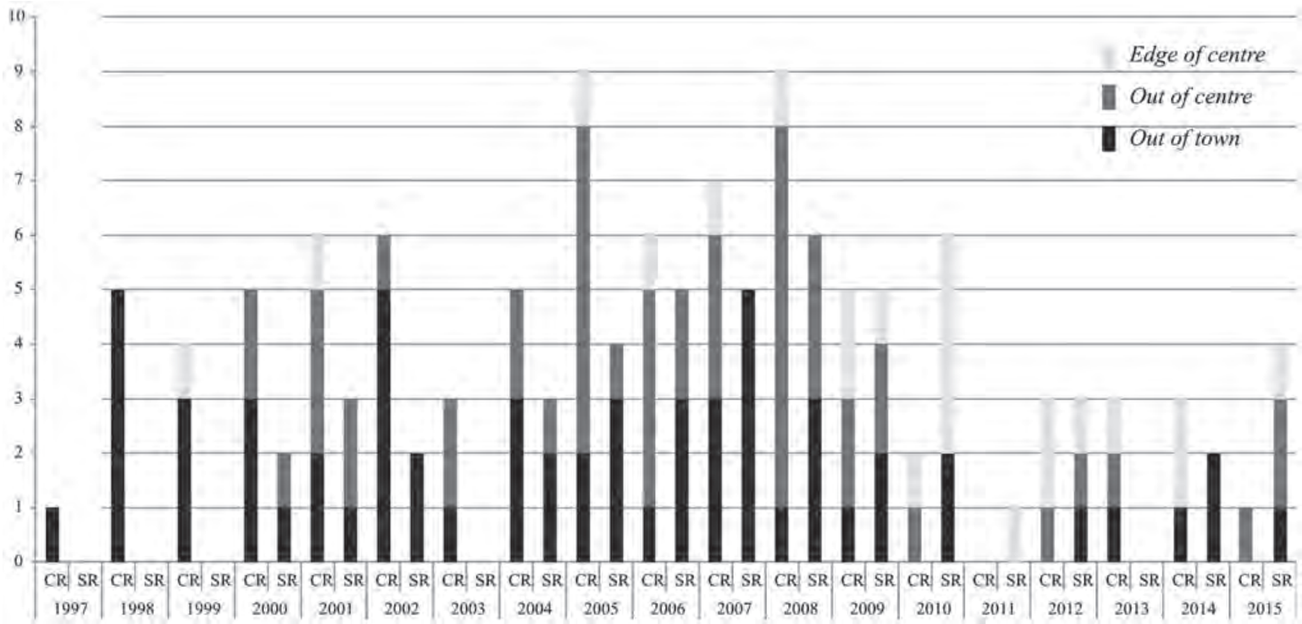

Fig. 3 Newly opened shopping centers in the Czech Republic (CR) and Slovak Republic (SR) according to their localization within basic morphogenetic city zones.
Source: Our own survey

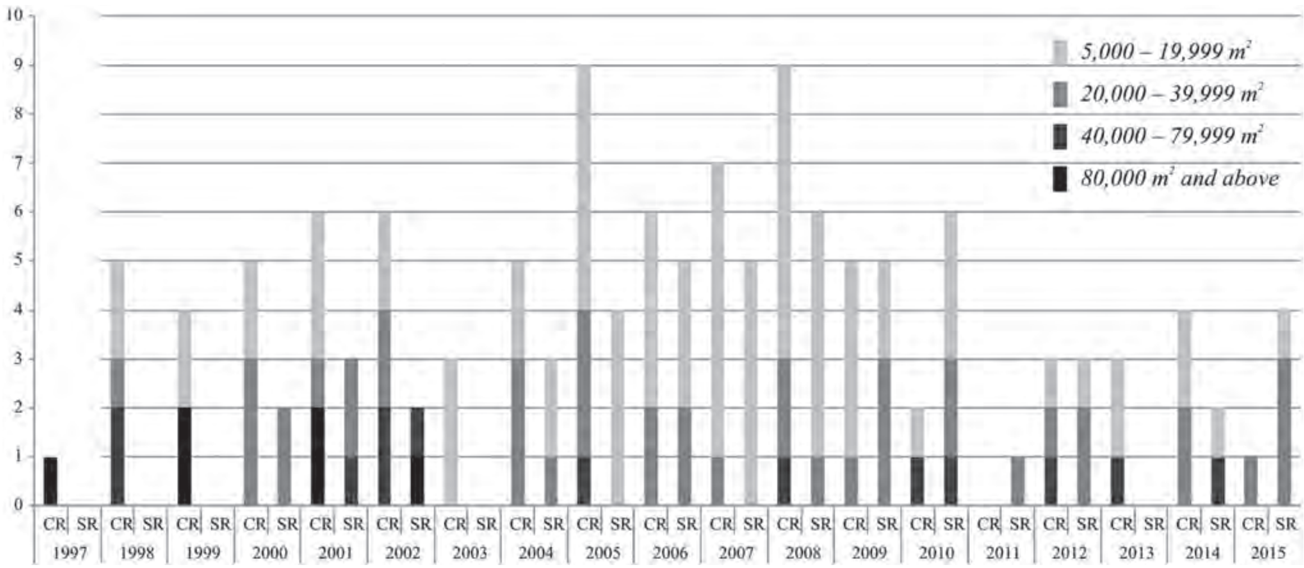

Fig. 4. Newly opened shopping centers in the Czech Republic (CR) and Slovak Republic (SR) according to the size of the gross leasable area
Source: Our own survey

all shopping centers in the Czech Republic (56.0%) and in Slovak Republic (52.9%) are small shopping centers. Shopping centers with a GLA smaller than 40,000 m^2 represent a share of over 80% and in Slovak Republic this share exceeds 90%. While only one shopping center in Slovak Republic belongs among the very large shopping centers, there are five such shopping centers in the Czech Republic. You can also see a decline in shopping center numbers correlated with the growth of their GLA. The average GLA for a Czech shopping center is 26,800 m^2, while in Slovak Republic it is 22,100 m^2.

6. Discussion and Conclusions

The main aim of this paper is to introduce, compare, and interpret similarities and differences between shopping centers in the Czech and Slovak republics. The criteria used for analysis are development (temporal shift), genesis (building on brownfield or greenfield sites), localization in urban and suburban environments and the size of the gross leasable area. These criteria have been chosen for their simplicity and availability in both countries. The results of the analysis can be summarized as follows:

(i) Shopping centers development in Slovak Republic is two to four years behind the Czech Republic. This delay is caused by the long-term economic underdevelopment of Slovak Republic in comparison to the Czech Republic, which began long before the creation of a common state – this is known as an east-west gradient (the west is more developed than the east). After the decline of the planned economies at the end of the 1980s, socioeconomic regional differences have occurred in how far the innovations, and patterns of behavior of citizens of developed market economies – well linked to shopping centers and shopping in general – have been accepted (this can be considered a form of wave diffusion). Generally, the trend in post-communistic countries is a delay in the commercialization or decentralization of retail when compared to more developed European countries.

(ii) Brownfield sites have been the prevailing choice for the construction of new shopping centers for 8 years in the Czech Republic and for 6 years in Slovak Republic. Although the same cannot be said for Slovak Republic, not a single greenfield shopping center has been built in the Czech Republic since 2009. The move away from building shopping centers on greenfield sites is perceived mainly positively by both the professional and non-professional public. Property development agencies have realised the importance of historical areas and the inner centers of cities as places where there is a traditional concentration of customers. The earlier preference for building huge shopping centers on peripheries has declined and there has been a clear shift towards the development of brownfield sites rather than greenfield sites. There are two types of post-socialist countries (Maksić 2016). The first type is similar to developed European countries, where there have been attempts made to include large-scale retail building regulations into their legislation (Hungary and Poland). The second group includes countries that have still not adopted regulations in this area (Albania). Even though there has been no retail impact assessment regarding the building of shopping centers in the Czech Republic, or in Slovak Republic, in recent years the Czech Republic can be perceived as an example (building of shopping centers on brownfields). In the context of a lasting building boom, Slovak Republic still hasn't reduced its greenfield building, despite the fact that the existing trend leans toward building on brownfield sites.

(iii) In the period between 1997 and 2015, you can see a general trend from a prevalence of out of town shopping center building in the first stage (1997–2003) to an increasing frequency of out of center and edge of center building in the second and third stages (2003–present). This trend is more overt in the case of the Czech Republic and it is closely correlated to the preferred development of previously used areas, i.e. brownfields sites. However, peripheries are still attractive for shopping center localization (Nagy 2001).

(iv) Small shopping centers are the most frequent type in both countries. Shopping centers with a GLA smaller than 40,000 m^2 represent a share of over 80% in the Czech Republic while this share exceeds 90% in Slovak Republic. The creation of very large shopping centers (80,000 m^2 and more) is a phenomenon of the beginning of this century and is likely not to be repeated. The market is saturated to a certain extent and trends in recent years show the consolidation of already established (trans)regional centers, their remodelling, modernization or expansion, or alternatively the filling of those gaps that do exist in the market with smaller centers. In line with the comparative economic development of both countries during the last decade, we can expect the differences to equalise in the near future. The area of the GLA may become more highly regulated by local municipalities, which could deter retailers and developers. On the other hand, the area of shopping centers is a fundamental element determining attractiveness (Kunc et al. 2016).

In the context of planning it is necessary to define and adopt measures for the development of shopping centers in both countries. There is no unifying classification involving planning in either of these countries, nor is there any definition of the standards or regulations of their construction (Koželouh 2010). Nevertheless, the building of shopping centers is not just about seizing quality land (Spilková and Šefrna 2010) but about the impact on local retailers. It is this aspect of the regulations coming from local administrations that should be part of city planning and development.

Erkip and Ozuduru (2015) have noted the impacts of shopping center development within an urban policy perspective. The impacts of shopping centers on (1) public spaces, (2) urban sprawl, (3) sustainability and (4) traffic-induced environmental problems are among the major issues we need to consider. These ideas show the possible course of shopping centers research in post-communistic countries. We presume that the development of shopping centers is not finished. Another point to consider is that alternative retail is typical for both countries, as we can see, for example, in the case of farmer's markets (Spilková et al. 2013).

It is possible to extrapolate, from the outcomes of this comparative study, shopping centers development for some of the other post-socialist countries in central and eastern Europe. The Polish market is still dynamic in central Europe and along with the Turkish and Russian markets has become the European leader in building new shopping centers. The rest of the former Eastern Bloc has gradually stabilized (in particular Romania and Bulgaria in recent years), whereas the countries of former Yugoslavia (e.g. Serbia, Croatia) have their building boom yet to come (European Shopping Centre Development Report; April 2016). However, in a non-regulated market we have to take into consideration a certain number of exceptions and the idiosyncratic tendencies of developers that can always be found in every region.

Acknowledgements

This contribution is supported by the VEGA project "Specifics of time-space human behaviour under the impact of socio-economic changes" (No. 1/0082/15); and by the VEGA project "Social, economic and environmental determinants of regional development and transformation: a regional geographic approach" (No. 1/0540/16); and by the internal grant "Shopping centers and shopping habits of teenagers: Brno case study" of the Faculty of Economics and Administration, Masaryk University (MUNI/A/0943/2015).

REFERENCES

COLEMAN, P. (2012): Shopping Environments. London, Routledge.

COOPER, D. (2007): Being in Public: The Threat and Promise of Stranger Contact. Law & Social Inquiry 32, 203–232. https://doi.org/10.1111/j.1747-4469.2007.00056.x

CROSBY, N., HUGHES, C., LIZIERI, C., OUGHTON, M. A. (2005): A message from the oracle: The Land use impact of a major in-town shopping center on local retailing. Journal of Property Research 22, 245–265. https://doi.org/10.1080/09599910500453848

CUSHMAN & WAKEFIELD (2016): European Shopping Centre Development Report. April 2016. Available from: http://www.cushmanwakefield.com/en/research-and-insight/2016/european-shopping-centre-development-report-april-2016/

DOUGLAS, M. J. (1995): Privatisation, Growth and Sustainability of the Retail Sector in Budapest. Moravian Geographical Reports 3, 44–52.

DRTINA, T. (1995): The Internationalisation of Retailing in the Czech and Slovak Republics. The Service Industries Journal 15, 191–203. https://doi.org/10.1080/02642069500000057

EARLE, J. S., FRYDMAN, R., RAPACZYNSKI, A., TURKEWITZ, J. (1994): Small privatization: the transformation of retail trade and consumer services in the Czech Republic, Hungary, and Poland. Budapest, Central European University Press Book.

ENGLAND, J. R. (2000): Retail Impact Assessment: A Guide to Best Practice. London, Routledge.

ERKIP, F., OZUDURU, B. H. (2015): Retail development in Turkey: An account after two decades of shopping malls in the urban scene. Progress in Planning 102, 1–33. https://doi.org/10.1016/j.progress.2014.07.001

FERTAĽOVÁ, J. (2005): Some methodological issues in classification of retail stores (with examples from European countires). Folia Geographica 8, 13–19.

GIDDENS, A. (2002): Runway World. How Globalization is Reshaping Our Lives. London, Profile Books.
GRAFF, T. O. (2006): Unequal competition among chains of supercenters: Kmart, Target, and Wal-Mart. The Professional Geographer 58, 54–64. https://doi.org/10.1111/j.1467-9272.2006.00511.x
GUY, C. (1998): Classifications of retail stores and shopping centres: some methodological issues. GeoJournal 45, 255–264. https://doi.org/10.1023/A:1006960414161
HIRT, S. (2006): Post-socialist urban forms: Notes from Sofia. Urban Geography 27, 464–488. https://doi.org/10.2747/0272-3638.27.5.464
ICSC Research (2005): Towards a Pan-European Shopping Centre Standard-A Framework for International Comparison. New York, International Council of Shopping Centers.
JACKSON, V., STOEL, L., BRANTLEY, A. (2011): Mall Attributes and Shopping Value: Differences by Gender and Generation Cohort. Journal of Retailing and Consumer Services 18, 1–9. https://doi.org/10.1016/j.jretconser.2010.08.002
KITA, P. (2008): K niektorým aspektom koncentrácie a konkurencie v oblasti distribúcie v kontexte globalizácie. Ekonomický časopis 56, 912–924.
KOK, H. J. (2007): Restructuring retail property markets in Central Europe: Impacts on urban space. Journal of Housing and the Built Environment 22, 107–126. https://doi.org/10.1007/s10901-006-9068-z
KOŽELOUH, J. (2010): Environmentální dopady prostorové expanze velkoplošného maloobchodu v České republice 2003–2009. Brno, Nesehnutí. Dostupné na: <http://www.nesehnuti.cz/publikace/vyzkum_2003-2009.pdf>.
KRIŽAN, F., BILKOVÁ, K., KITA, P. (2014): Urban retail market in Bratislava (Slovakia): Consumers perception and classification of shopping centres. Management & Marketing 9, 483–500.
KRIŽAN, F., BILKOVÁ, K., KITA, P., KUNC, J., BARLÍK, P. (2015): Nákupné centrá v Bratislave a atribúty ovplyvňujúce preferencie spotrebiteľov. Geografický časopis 67, 341–357.
KRIŽAN, F., BILKOVÁ, K., KITA, P., SIVIČEK, T. (2016): Transformation of Retailing in Post-Communist Slovakia in the Context of Globalization. E+M Ekonomie a management 19, 148–164. https://doi.org/10.15240/tul/001/2016-1-011
KRIŽAN, F., LAUKO, V. (2014): Geografia maloobchodu. Úvod do problematiky. Bratislava, Univerzita Komenského v Bratislave.
KUNC, J. et al. (2013): Časoprostorové modely nákupního chování české populace. Brno, Masarykova univerzita.
KUNC, J., TONEV, P., SZCZYRBA, Z., GREPLOVÁ, Z. (2012a): Perspektivy nákupních center v České republice s důrazem na lokalizaci v urbánním prostředí: příklad města Brna. Urbanismus a územní rozvoj 15, 14–20.
KUNC, J., FRANTÁL, B., TONEV, P., SZCZYRBA, Z. (2012b): Spatial Patterns of Daily and Non-daily Commuting for Retail Shopping: Case of the Brno City, Czech Republic. Moravian Geographical Reports 20, 39–54.
LOWE, M. (2005): The regional shopping centre in the inner city: A study of retail-led urban regeneration. Urban Studies 42, 449–470. https://doi.org/10.1080/00420980500035139
MANSVELT, J. (2005): Geographies of Consumption. London, Sage.
MARYÁŠ, J., KUNC, J., TONEV, P., SZCZYRBA, Z. (2014): Shopping and services related travel in the hinterland of Brno: changes from the socialist period to present. Moravian Geographical Reports 22, 18–28. https://doi.org/10.2478/mgr-2014-0015
MAKSIĆ, M. (2016). Institutional obstacles in large-scale retail developments in the post-socialist period – A case study of Niš, Serbia. Cities 55, 113–121. https://doi.org/10.1016/j.cities.2016.04.005
MITRÍKOVÁ, J. (2008): Geografické aspekty transformácie maloobchodu a nákupného správania sa na Slovensku (prípadové **štúdie** z miest Prešov a Košice). Prešov, Prešovská univerzita v Prešove.
MULÍČEK, O. (2007): Prostorové aspekty současného vývoje maloobchodní sítě. Urbanismus a územní rozvoj 10, 14–20.
NAGY, E. (2001): Winners and losers of the transition of city centre retailing in east Central Europe. European Urban and Regional Studies 8, 340–349. https://doi.org/10.1177/096977640100800406
OČOVSKÝ, Š. (1974): Priestorové črty tovarovej výmeny. In: Plesník, P. a kol. (eds.): Slovensko – Ľud (211–242). Bratislava, Obzor.
PITT, M., MUSA, Z. N. (2009): Towards defining shopping centres and their management systems. Journal of Retail & Leisure Property 8, 39–55. https://doi.org/10.1057/rlp.2008.25
POSPĚCH, P. (2010): Význam a normalita ve veřejném prostoru a v nákupním centru. In: Vacková, B., Ferenčuhová, S., Galčanová, L. (eds.): Československé město včera a dnes: Každodennost – reprezentace – výzkum (113–136). Brno, Pavel Mervart, Masarykova univerzita.
POSPĚCH, P. (2017): Urban or Family-Friendly? The Presentation of Czech Shopping Centers as Family-Friendly Spaces. Space and Culture 20, 68–80. https://doi.org/10.1177/1206331216646059
PULPITLOVÁ, M. (2003): Transformácia maloobchodnej siete v SR. In: Novák, S. (ed.): Geografie IV: Geografické aspekty středoevropského prostoru (133–137). Brno, Masarykova univerzita.
SHI, Y. S., WU, J., WANG, S. Y. (2015): Spatio-temporal features and the dynamic mechanism of shopping center expansion in Shanghai. Applied Geography 65, 93–108. https://doi.org/10.1016/j.apgeog.2015.11.004
SIMOVÁ, J. (2010): Internationalization in the process of the Czech retail development. E+M Ekonomie a Management 13, 78–91. https://doi.org/10.1080/09654313.2010.492583
SPILKOVÁ, J. (2003): Nový fenomén: nákupní centrum a utváření nákupního chování spotřebitelů v transformačním období. Geografie 108, 277–288.
SPILKOVÁ, J. (2010): Retail development and impact assessment in Czech Republic: Which tools to use? European Planning Studies 18, 1469–1484.
SPILKOVÁ, J. (2012a): Geografie maloobchodu a spotřeby. Praha, Karolinum.
SPILKOVÁ, J. (2012b): The Birth of the Czech Mall Enthusiast: The Transition of Shopping Habbits from Utilitarian to Leisure Shopping. Geografie 117, 21–32.
SPILKOVÁ, J., HOCHEĽ, M. (2009): Toward the Economy of Pedestrian Movement in Czech and Slovak Shopping Malls. Environment and Behavior 41, 443–455. https://doi.org/10.1177/0013916508325003
SPILKOVÁ, J., RADOVÁ, L. (2011): The formation of identity in teenage mall microculture: A case study of teenagers in Czech malls. Czech Sociological Review 47, 565–586.
SPILKOVÁ, J., ŠEFRNA, L. (2010): Uncoordinated New Retail Development and Its on Land Use and Soils: A Pilot Study on the Urban Fringe of Prague, Czech Republic. Lanscape and Urban Planning 94, 141–148. https://doi.org/10.1016/j.landurbplan.2009.09.001
SPILKOVÁ, J., FENDRYCHOVÁ, L., SYROVÁTKOVÁ, M. (2013): Farmers' markets in Prague: a new challenge within the urban shoppingscape. Agriculture and Human Values 30, 179–191.

SZCZYRBA, Z. (2005): Maloobchod v ČR po roce 1989 – vývoj a trendy se zaměřením na geografickou organizaci. Olomouc, Univerzita Palackého.

SZCZYRBA, Z. (2010): Development of retail geographical structure in the Czech Republic: a contribution to the study of urban environment changes. Acta Universitatis Palackianae Olomucensis – Geographica 41, 5–20.

TIMOTHY, D. J. (2005): Shopping Tourism, Retailing, and Leisure. New York, Channel View Publications.

TREMBOŠOVÁ, M. (2012): Geografické aspekty maloobchodnej siete mesta Nitra. Nitra, UKF.

UNDERHILL, P. (2004): Call of the Mall. The Geography of Shopping by the Author and Why We Buy. New York, Simon & Schuster.

VAN LEEUWEN, E. S., RIETVELD, P. (2011): Spatial Consumer Behaviour in Small and Medium-sized Towns. Regional Studies 45, 1107–1119. https://doi.org/10.1080/00343401003713407

RESUMÉ

Vývoj a klasifikace nákupních center v České a Slovenské republice: komparativní analýza

Příspěvek se zaměřuje na analýzu, komparaci a interpretaci podobností a rozdílů mezi nákupními centry v České a Slovenské republice v časové, prostorové a funkční struktuře, na podmínky jejich vstupu a etablování se na obou trzích. Na základě dat za nákupní centra v období let 1997–2015 bylo provedeno jednak hodnocení vývoje výstavby nákupních center s ohledem na typické etapy a dále klasifikace center podle tří základních kritérií: i) geneze, ii) lokalizace a iii) velikost pronajímatelné plochy. Komparace a interpretace přinesly následující základní zjištění: (i) S ohledem na výstavbu nákupních center je možné pozorovat obdobné trendy ve vývoji nákupních center v České a Slovenské republice s určitým fázovým zpožděním Slovenské republiky v rozmezí dvou až čtyř let (vlnová difúze Z–V). (ii) Výstavba nákupních center na dříve využívaných územích (brownfields) převládá v obou zemích již osm let. Na rozdíl od Slovenské republiky však v České republice nevzniklo od roku 2009 jediné nákupní centrum na zelené louce, což je možné akceptovat pozitivně. (iii) V období let 1997–2015 je možné prokázat všeobecný trend ve smyslu iniciační výstavby nákupních center na předměstích a následný přesun na okraj centra města (vnitřní město), resp. k centru města. Této skutečnosti pomohl nejen tlak ze strany politiků a veřejnosti nezabírat další kvalitní zemědělskou půdu, ale developeři si také uvědomili přirozenou zákaznickou sílu městských center a nejbližšího okolí. Tento trend opět je zřetelnější v případě České republiky. (iv) Ve sledovaném období se nejčasteji stavěla malá nákupní centra, zřídka velká nebo velmi velká nákupní centra. Trendem v obou zemích je snižování velikosti pronajímatelné plochy pro nově otevřená centra, zřejmý je také pokles počtu nově otevíraných nákupních center související s nárůstem průměrné prodejní prodejní/pronajímatelné plochy. Převládá spíše remodelace, modernizace či výstavba menších center, které vyplňují případné mezery na již poměrně nasyceném trhu. Se srovnáváním ekonomické vyspělosti v posledním desetiletí lze do blízké budoucnosti očekávat i vyrovnávání uvedených rozdílů v obou zemích, jež patří v prostoru postsocialistické střední a východní Evropy k maloobchodně nejstabilnějším.

František Križan
Comenius University in Bratislava,
Faculty of Natural Science
Department of Regional Geography, Protection and Planning of the Landscape
Mlynská dolina, 842 15 Bratislava
Slovak Republic
E-mail: krizan@fns.uniba.sk

Josef Kunc
Masaryk University in Brno,
Faculty of Economics and Administration
Department of Regional Economics and Administration
Lipová 507/41a, 602 00 Brno
Czech Republic
E-mail: kunc@econ.muni.cz

Kristína Bilková
Comenius University in Bratislava,
Faculty of Natural Science
Department of Regional Geography, Protection and Planning of the Landscape
Mlynská dolina, 842 15 Bratislava
Slovak Republic
E-mail: bilkova@fns.uniba.sk

Peter Barlík
Comenius University in Bratislava,
Faculty of Natural Science
Department of Regional Geography, Protection and Planning of the Landscape
Mlynská dolina, 842 15 Bratislava
Slovak Republic
E-mail: barlik@fns.uniba.sk

Zdeněk Šilhan
Masaryk University in Brno,
Faculty of Economics and Administration
Department of Regional Economics and Administration
Lipová 507/41a, 602 00 Brno
Czech Republic
E-mail: z.silhan@mail.muni.cz

THE PAST, PRESENT AND FUTURE OF DIVERSIFICATION OF AGRICULTURAL HOLDINGS IN CZECHIA

VERONIKA ERETOVÁ, VÍT JANČÁK

Charles University, Faculty of Science, Department of Social Geography and Regional Development, Czechia

ABSTRACT

The article deals with diversification of the activities of agricultural holdings in Czechia. The purpose of diversification is to create and also keep new jobs in the rural areas, keep or even increase the farm income and to contribute to the recovery of the villages. It may lead to stabilization of the rural population, increase the quality of their lives and the competitiveness of agricultural holdings. The main aim of the article is to describe the extent and importance of diversification in the specific environment of Czechia before and after 1989 and also to outline its likely future development. The article offers analysis of the development of non-agricultural activities before 1989 in the conditions of the centrally planned economy. Then it deals with diversification of activities of agricultural holdings after 1989 – during the period of transition of the Czech agriculture, which led to the application of the market economy. The article also outlines the possible future development of diversification of activities of agricultural holdings in Czechia.

Keywords: Czech agriculture, post-productivism, rural development, non-agricultural activities, diversification

Received 5 February 2016; Accepted 10 October 2016; Published online 16 February 2017

1. Introduction

Agriculture, as an important sector in the national economy, focuses on the cultivation of strategic materials, foodstuff production and sustenance of people. The essential significance of agriculture is emphasised by its irreplaceable character, indispensability of foodstuff and pervasive nature of production. The role of agriculture has undergone significant changes in the past years. Besides the production function, "out-production" functions of agriculture are stressed as well as its profound influence on shaping the character of the landscape, on the environment and on the rural space (Hrabák 2014; Bičík, Jančák 2005). The farmer has become an active actor shaping the landscape.

When it comes to its concept the article is based on the notion of post-productive agriculture and multifunctionality, which are closely connected with the new perspective given to the rural areas, with a new rural paradigm (OECD 2006).

The changing character of the countryside, including changes in agriculture, is explained as a postproductivist transition – from productivist to post-productivist agriculture (Almsted 2013; Konečný 2012; Ilbery, Bowler 1998). One of the features of this is the transition from specialization to diversification of the agriculture.

Transition to post-productivism should be seen as a continuum, as agricultural holdings may have some signs of post-productivist behaviour, while remaining focused on primary agricultural production (i.e. on productivist agriculture).

Evans et al. (2002, p. 317) summarizes the characteristic features of post-productivism into 5 categories. The categories include a shift from quantity to quality in food production, growing diversification through both on-farm and off-farm activities, extensification and support to sustainable farming based on agro-environmental policy, dispersal of the production structure, environmental regulation and change in governmental support to the agriculture.

The criticism of the concept of post-productivism has resulted in forming an alternative concept of multifunctional agriculture, which admits a coexistence of productivist agriculture with post-productivist activities (Almsted 2013; Konečný 2012). It can be argued that the concept of multifunctionality is a characteristic feature of all agricultural holdings. Each of them realizes, to a certain extent, some non-agricultural activities, e.g. landscape maintenance.

The term diversification means differentiation, dispersal of economic activities into more fields. Diversification in agriculture is related to a change in the economic function of the countryside and agriculture and can be seen as a part of a wider process of rural diversification (Robinson 2004).

It is difficult to find one definition for diversification of agricultural holdings. Most experts tend to think that the term includes business activities implemented in the holding or activities that are dependent on agricultural land and on capital assets of holdings (Ilbery 2009; European Commision 2008; Ilbery et al. 2006). Diversification can be also defined as the use of economies of scope. It

https://doi.org/10.14712/23361980.2017.3
Eretová, V. – Jančák, V. (2017): The past, present and future of diversification of agricultural holdings in Czechia
AUC Geographica, 52, No. 1, pp. 27–37

can be described as a portfolio of activities which leads to a spread of risks and incomes and where a loss in one or even more activities does not cause a crisis or decline of the enterprise (Špička 2006). There are even more perspectives on diversification. The final conclusion whether the given case is an example of diversification or not has to be done in each individual situation, in a given time and on a given place.

The purpose of diversification is to create and also maintain jobs in the rural space, maintain or even increase income and contribute to recovery of villages. Diversification can help to stabilize rural population, raise the quality of its life and increase competitiveness of agricultural holdings.

Czechia has undergone a specific development of the agricultural sector. Agriculture was influenced by a more than forty years of the socialistic economy. Under the centrally planned economy agriculture underwent deep structural changes including dramatic changes in land ownership and operation of agriculture. Large agricultural enterprises such as cooperative farms (cooperative sector) and state farms (state sector) were established and started to play the dominant role in the Czech agriculture. Even before 1989 the both types of farms also conducted some non-agricultural activities. After 1989 the centrally planned economy was transformed into the market economy resulting in profound changes in the production structure of agriculture. The number of employees decreased significantly, the amount of livestock was reduced, and many legislative changes were undertaken. Non-agricultural activities of agricultural holdings were reduced; some of them disappeared, some were divided into the secondary sector (industry) and tertiary sector (services).

The objective of this article is to outline the extent and significance of diversification of activities of agricultural holdings in Czechia, both before and after 1989, on the basis of the available statistical data and to sketch a potential future of these activities in Czechia. This will be done on the basis of a literature review, own experience from field research and interviews with representatives of agricultural holdings, private farmers and people who have worked in the primary sector for a long time.

In particular the article aims to answer the following research questions: which activities represent most often the target of diversification? Do these activities change over time? Are these activities regionally differentiated? Are there better preconditions for diversification in some regions than in others? How did the year 1989 and the related socioeconomic transition influence the diversification of activities of agricultural holdings?

1.1 Methodology

The article is based on a historical, evolutionary approach, which is often used within the geography of agriculture. It enables to identify the main drivers as well as the main evolutionary trajectories and also the changing spatial distribution of the key phenomena.

As the main source of information, statistics concerning agriculture were used. The analysis of development of non-agricultural activities before and after 1989 in Czechia is based on the data of the Czech Statistical Office (ČSÚ) and Eurostat. The data in section 2.1 come from the materials of ČSÚ – "The development of non-agricultural activities of state farms and cooperative farms in Czechia" (ČSÚ 1990) and "The development of non-agricultural activities in cooperative farms and state farms 1985–1989" (ČSÚ 1990). In section 2.2 the data come predominantly from the Agrocensus surveys which were performed in Czechia for the first time in 1995. The year 2000 is considered as the reference year for Agrocensus; in that year a global census of agricultural holdings was held under FAO. The Czech Statistical Office organizes the Agrocensus surveys regularly every ten years, thus the latest was held in 2010. The surveys of Agrocensus are followed by Farm structure surveys in agriculture that were undertaken in 2003, 2005, 2007 and 2013. The next one is planned for 2016.

The section 2.3 is based on the author's own experience from field research and interviews.

Diversification plays a significant role in the agriculture and life in the countryside, nevertheless, research on the micro-regional level has been very limited in Czechia. The article is intended as acontribution to the topic of diversification and its purpose is to reflect special conditions of development of agriculture in Czechia and their influence on diversification of activities of agricultural holdings.

2. Diversification of agricultural holdings in Czechia

2.1 Non-agricultural activities before 1989 – the past

Non-agricultural activities of agricultural holdings played an important role in the development of rural areas and agriculture. They contributed to the scientific and technical progress, a higher level of employment, a better use of production sources and helped solve the seasonal periodicity of agricultural production (Eretová 2013; Bičík, Jančák 2005). Non-agricultural activities also improved the quality of services in the countryside as they enriched the market with industrial and other products. Non-agricultural activities also introduced features of competition between individual branches of the national economy. Moreover, they contributed to better economic results of the individual holdings. Higher revenues helped to improve the living conditions in the rural areas and social and economic conditions of agricultural workers. All arguments mentioned above were the reasons why non-agricultural activities were implemented by cooperative farms as well as state farms in all region of the former Czechoslovakia.

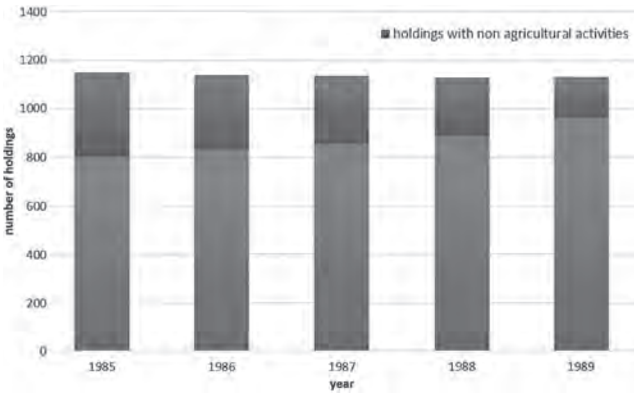

Fig. 1 Number of holdings with non-agricultural activities 1985–1989. Source: Czech statistical office, 1990.

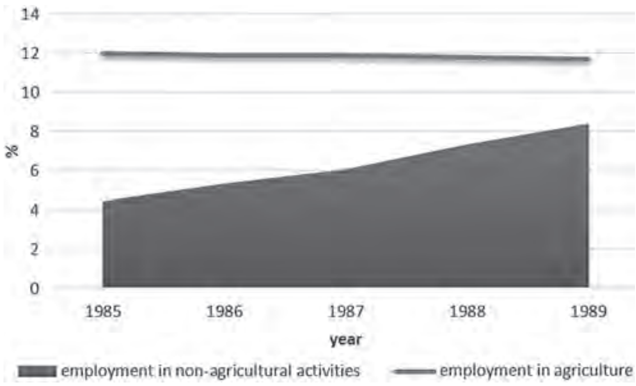

Fig. 2 Employment in non-agricultural production 1985–1989. Source: Czech statistical office 1990.

At the beginning of their origin, non-agricultural activities were only of a marginal significance (Eretová 2013). They were meant as a simple production, provision of services and valorisation of local resources. The origin of non-agricultural production was motivated by the aim to ensure employment for the people working mainly in the crop production offseason.

The dynamic development of the non-agricultural activities started in the 1970s (ČSÚ 1990). Holdings were looking for new resources for development and intensification of agricultural production and the local production resources were used for that purpose. Non-agricultural activities were also extended during the 1980s. In the case of state farms, non-agricultural activities were watched from 1983 when a dynamic growth lasting until 1989 was registered. In 1989, the total number of agricultural holdings (both cooperative and state farms) amounted to 1130 and as can be seen in Figure 1, non-agricultural activities were run in more than 85% (962 holdings in absolute terms) of them (ČSÚ 1990). Non-agricultural activities became a significant source for operation and development of agricultural holdings.

Differentiation of non-agricultural activities can be analysed within the individual territorial units. Holdings located in conditions less favourable for agricultural production often performed better in non-agricultural production in the former Czechoslovakia just as did holdings located in the average or worse conditions where the agricultural production was unprofitable. In the regions unfavourable for agriculture, the profit from non-agricultural production helped to cover the financial loss stemming from the agricultural production. According to the share of revenues of agricultural holdings from non-agricultural activities the leading regions in Czechia were the North Moravian Region and the South Moravian Region. On the other hand, the North Bohemian Region showed the lowest part of non-agricultural production in cooperative farms (ČSÚ 1990).

The structure of non-agricultural production was influenced mainly by local conditions – the suitability of particular types of non-agricultural production in the given area, material and raw material resources, the level of cooperation with governmental organizations, the distance from industrial centres and the abilities of both managers (leaders) and employees of the individual agricultural holdings. The wide range of activities covered by the term non-agricultural production was divided into several categories (ČSÚ 1990) – processing of agricultural products, mining, earthwork, wood processing, metal processing, plastic manufacturing, textile manufacturing, goods production, construction work, reparation works, transport, electrical engineering and other.

Among non-agricultural production metal processing, wood processing and construction work were originally the most common activities (in the 1970s and early 1980s). Later, these branches were overridden by activities with a higher profit and productivity – electrical engineering, processing of agricultural products and earthwork. These trends can be observed both in cooperative and state farms. In terms of profitability, reparation works and goods production were the most successful fields in state farms while reparation works and plastic manufacturing were the most profitable categories in cooperative farms. However some of the activities of non-agricultural production were loss-making (e.g. wood processing in the case of state farms, ČSÚ 1990).

The launch of non-agricultural production in the manufacturing led towards more job opportunities, even during the off-season. After the dynamic development of non-agricultural activities of agricultural holdings during 1970s, the structure of the individual categories of agricultural work activities changed significantly, too. The number of employees in the livestock and crop production decreased and the number of "technical-economical" workers increased. The growth in the significance of non-agricultural production was largely proportional to the number of employees, as shown in Figure 2.

Overall, the non-agricultural production made up a significant part of the manufacturing activities of holdings and provided additional profits. The share of non-agricultural production in the output of cooperative farms amounted to almost 22% and made more than 43% of

Fig. 3 Farm profit from non- agricultural production. Source: Czech Statistical Office, 1990.

their profits in 1989 as follows from Figure 3 (ČSÚ 1990). The share of non-agricultural production in the output of state farms amounted to 6% but accounted for more than 18% of the profit in 1989. The profit of the non-agricultural productions was an addition to own resources of the holdings and improved their economic results considerably. Importantly, its significance is closely related to unfavourable natural conditions for agricultural production.

An extreme example showing the importance of non-agricultural production was the corporate farm Slušovice, later called "Agrokombinát Slušovice", where the outputs of nonagricultural production reached 95% in 1989 (Hait 2009; Bičík, Jančák 2005). Thus, in this farm primary agricultural production played only a marginal role. Non-agricultural activities were originally focused on improvement of primary production results (biochemical and chemical production, agricultural machinery, metal processing). Over the time, the farm extended its activities to construction work and even to microelectronics. Non-agricultural production became the main source of revenues for the implementation of long-term investments and strategic goals. In that time, Slušovice became a very attractive address and its population increased significantly thanks to the high personal evaluation and well-developedamenities.

2.2 Non-agricultural activities since transition (after 1989) – the present

After 1989 the centrally planned economy gave way to the market economy. Since 1991 the transformation process has been ongoing in agriculture. Its goal is to solve relations to land and property. Original large holdings such as cooperative and state farms were changed into a number of smaller businesses of varied legal forms – companies (joint-stock, limited liabilities, newly transformed cooperative and state farms, private farms; Eretová 2011). As a part of the transformation process the land expropriated in 1948 was given back (Bičík, Jančák 2005). The land restitution meant restoration of private farming, which was suppressed before 1989. However, only a small part of the people who gained back their farmland started to run an enterprise on their own. The forty year period of collective farming is represented by two generations of descendants who have never farmed independently and often live in the places very distant from the returned land and property. Moreover, they have lost the bonds which were shared by their ancestors. The lease farmland to large holdings of legal persons or private farmers has become a typical phenomenon in Czechia.

Czechia is distinguished by the specific size and ownership structure of its agricultural holdings which is partly a heritage of the former regime. In absolute numbers, private farms dominate, since their number increased considerably after 1990, but they operate only less than 30% of the agricultural land. Most of the agricultural land in Czechia is operated by large size holdings, companies and cooperatives (70%), but they comprise less than 8% of businesses in agriculture (Zelená zpráva 2014). The holdings of legal entities, holdings that are seen as large, that concentrate production factors; show more diversification of their activities (Eretová 2013). This is the case of almost 40% of all legal persons, but only of 11% of physical persons (Agrocensus 2010).

Private farms in Czechia are more specialized. These holdings distinguish themselves with higher flexibility and ability to react to changes. The low level of diversification can be caused by insufficient technical, technological and human capacity. Smaller holdings are limited in extraneous capital, the share of own capital is considerably higher and they show a higher dependence on operation subsidies. Thanks to their character and individual approach to the customer, private farms are suitable for non-agricultural activities such as various forms of rural tourism and handcraft. They are able to use local markets or on-farm sale for their production. On the other hand, big holdings can reach the extraneous capital more easily but they are not very flexible and generally make business decisions more slowly. Production factors are concentrated there and these holdings have available capacities for nonagricultural activities available (Špička 2008).

The rural areas create a limited number of new job opportunities. Agricultural holdings, despite the weakening role of agriculture, are still among the significant employers in small villages (Eretová 2013). As the mechanization of production and the reduction of animal production are growing, the demand for new employees in holdings focusing on conventional agricultural production is quite small. Non-agricultural activities operated by agricultural holdings are therefore new opportunities for job creation. These activities have employed especially local people and those from the surrounding of a holding (Doucha et al. 2003) and contribute to a higher level of employment of the village inhabitants.

Extent of diversification

After 1989 non-agricultural activities of agricultural holdings have been reduced. Some of the activities disappeared; other became a part of the secondary and tertiary sectors where they have been run till now. Agriculture was the only field where also the property shares of people who worked in the collective farms were calculated ("Transformation Act" 42/1992 Sb., Chloupková 2002). Workers of non-agricultural production were registered as workers in agriculture. But it was not possible to register these workers as workers in agriculture after the separation of the production to other sectors of the economy. This transfer contributed to the decrease of the total number of workers in agriculture by one half during the following five years (Doucha et al. 2012; Věžník et al. 2004; Chaplin 2001).

Figure 4 shows the increase of agricultural holdings that diversified their activities towards non-agricultural activities as early as between 1990 and 1995. After 1989, activities of non-agricultural production disappeared or were integrated into the secondary and tertiary sectors. Only a very limited number of holdings have kept the same extent of non-agricultural activities as before 1989. In the early 1990s, a lot of segments of the market stayed unused and it was easy to start running the business and therefore to implement diversification of agricultural activities. Both the habits of the population, the demand for products and services which were offered by agricultural holdings during the previous era and rather weak competition played a certain role in the repeated implementation of non-agricultural activities in many holdings. The growth of holdings with non-agricultural activities slowed down between 1995–2000, mainly because of the lack of experience of managers (leaders) of the holdings and their inability to cope with the new conditions. Moreover, the demand for these activities decreased during the time, competition increased and consumption habits of population changed.

Because of different thresholds and methodology used for the individual surveys of Agrocensus the data cannot be directly compared. In 2013, almost 19% of holdings occupied themselves with the diversification which means an increase if we compare the number with older studies. If compared with other EU countries, the value is close to the level of diversification in West-European and North-European countries, as shown in Figure 5.

The structure of non-agricultural activities changed from year to year. According to the Agrocensus 1995 and

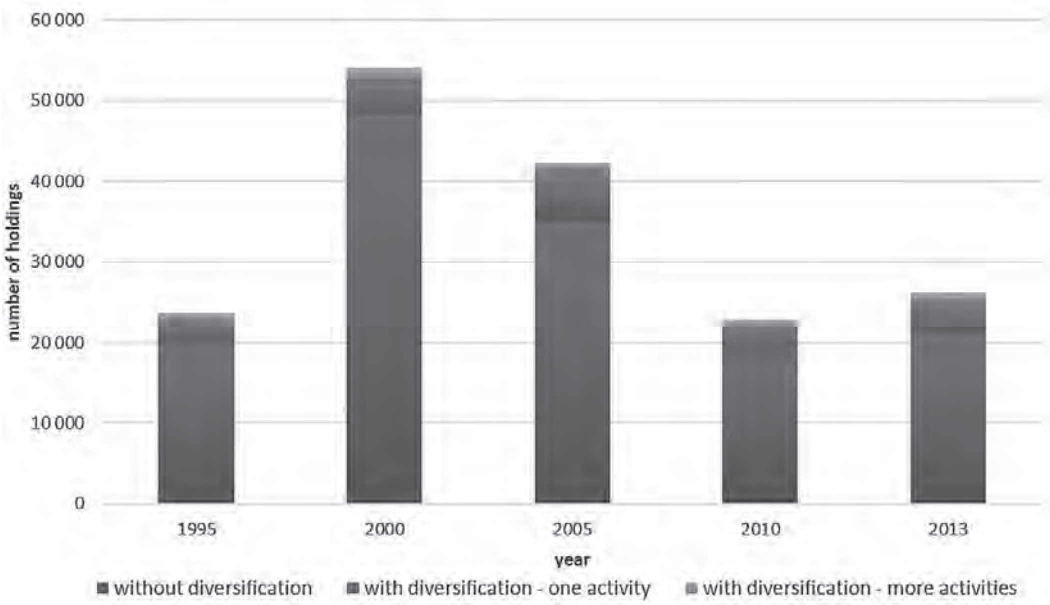

Fig. 4 Holdings with/without diversification in Czechia. Sources: Agrocensus 2000, 2010, Farm structure survey 1995, 2005, 2013.

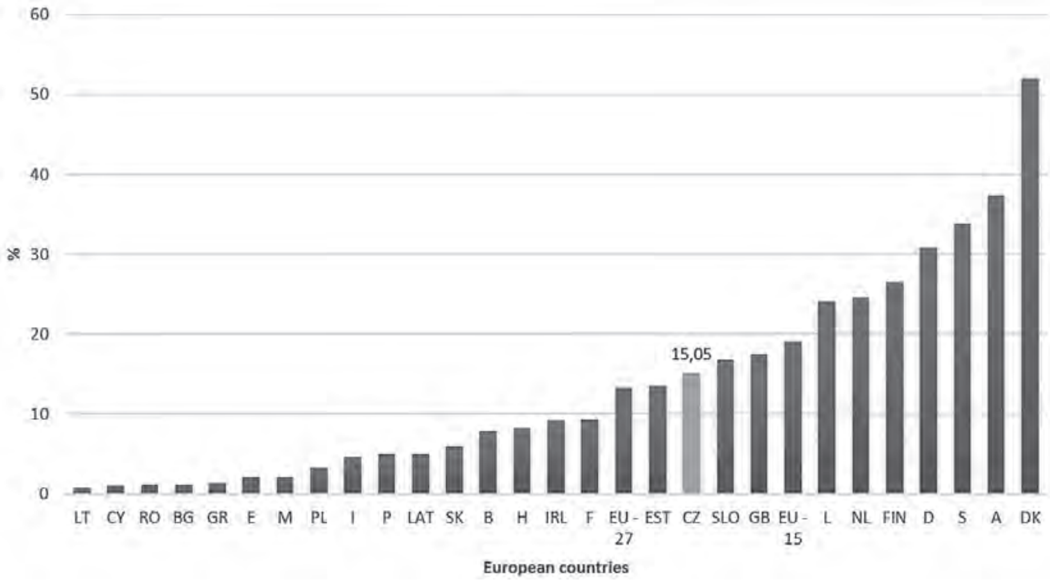

Fig. 5 Percentage (share) of holdings by non-agricultural activities in EU in 2010. Source: Agricultural census 2010 by country, Eurostat.

2000, the most common categories of non-agricultural activities were services for agriculture, commercial activities, transport and other.

Since 2010 the definition of non-agricultural activities directly related to holdings has been based on the Commission Regulation (EC) No 1200/2009 which specifies these activities: tourism; handcraft; processing of farm products; renewable energy production; wood processing; aquaculture; contractual work; forestry work; other gainful activities.

As Figure 6 shows the most common non-agricultural activities in Czechia are contractual works for another enterprise, both of agricultural and non-agricultural character. The popularity of tourism and related activities and forestry work has been also growing. The share of tourism in non-agricultural activities was 2.6% according to Agrocensus 2000; then it increased to 13.2% in 2010; and by 2013, the share relatively decreased to almost 10% (Agrocensus 2000, 2010, Farm structure survey 2013), but in terms of total numbers more and more holdings are occupied with it. The relative decrease is caused by the growth of total number of holdings with diversification. Rural tourism in Czechia has not fully developed yet; farms do not use fully their potential for its varied forms (Moudrý 2006). This is due to the low level of connected services, tourist infrastructure and a missing tradition. On the other hand, there is not a high enough demand for rural tourism.

Figure 6 shows that the importance of processing of farm products even among holdings in Czechia begins to take on. Nearly 19% of holdings engaged in this category of non-agricultural activities operated in 2013.

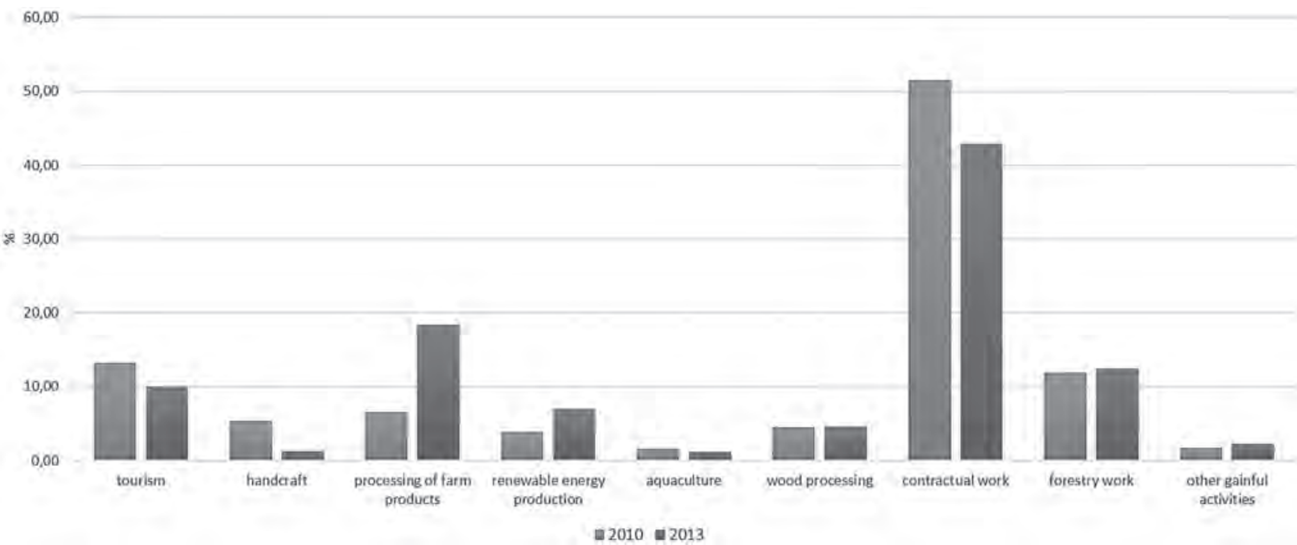

Fig. 6 Diversification by activity in Czechia in 2010 and 2013. Sources: Agrocensus 2010, Farm structure survey 2013.

Regional differentiation of non-agricultural activities

In Czechia, a territorial differentiation of spread of holdings with diversification of their activities can be noticed. The variation is not only in the number of holdings, which diversify their activities, but also in actual activities implemented by the individual holdings.

As already mentioned in this chapter, the number of holdings diversifying their activities has been growing in Czechia. Diversification on the level of regions became the focus of Agrocensus 2010. The highest absolute proportion of diversifying holdings in the mentioned year can be noticed in the Central Bohemia Region. An above-average proportion can be seen in the South Bohemia Region, the Hradec Králové Region, the Vysočina Region and the South Moravia Region. At the same time these regions display the highest number of agricultural holdings and also the largest amount of available agricultural land.

The evaluation of the proportion of holdings operating non-agricultural activities in the total number of holdings operating in the individual regions is of a higher reflective value. In this case, regions with the lowest number of operating agricultural businesses have the highest share; that is the capital of Prague and the Karlovy Vary Region where non-agricultural activities were run by almost 20% of businesses in 2010. The lowest share was observed in the Pilsen Region and the South Moravia Region.

A difference can also be seen in the activities in which holdings most often apply diversification of their activities in individual regions (see Figure 7). The regional differentiation depends on the character of natural conditions, location of the given region and tradition of some of the activities. Holdings situated out of centres can benefit from their location, unique environment as well as historical and cultural heritage.

As the Figure 7 shows, contractual services, both of the agricultural and non-agricultural character, are the most important form of diversification in all regions. The capital of Prague is an exception in the comparison of the regions because its holdings occupy themselves with only a limited range of activities and the important categories for it are contractual services and tourism. Thanks to the character of agricultural primary production, processing of farm products plays an important role in the South Moravia Region. Forestry and tourism are both significantly represented in the total comparison. Activities related to tourism are important for the Karlovy Vary Region, the Ústí Region and the Liberec Region. The significance of forestry and processing of farm products has been growing in the Zlín Region. The intensity of this field is also related to wood processing. Aquaculture plays the most important role in the South Bohemia Region as it is the region with a long tradition of fish farming and some agricultural holdings are occupied with it.

There is not only one conclusion for the differentiation of agricultural holdings. Those that operate in worse natural conditions show a higher level of diversification of their activities because they cannot rival fully other regions in agricultural primary production (e.g. the

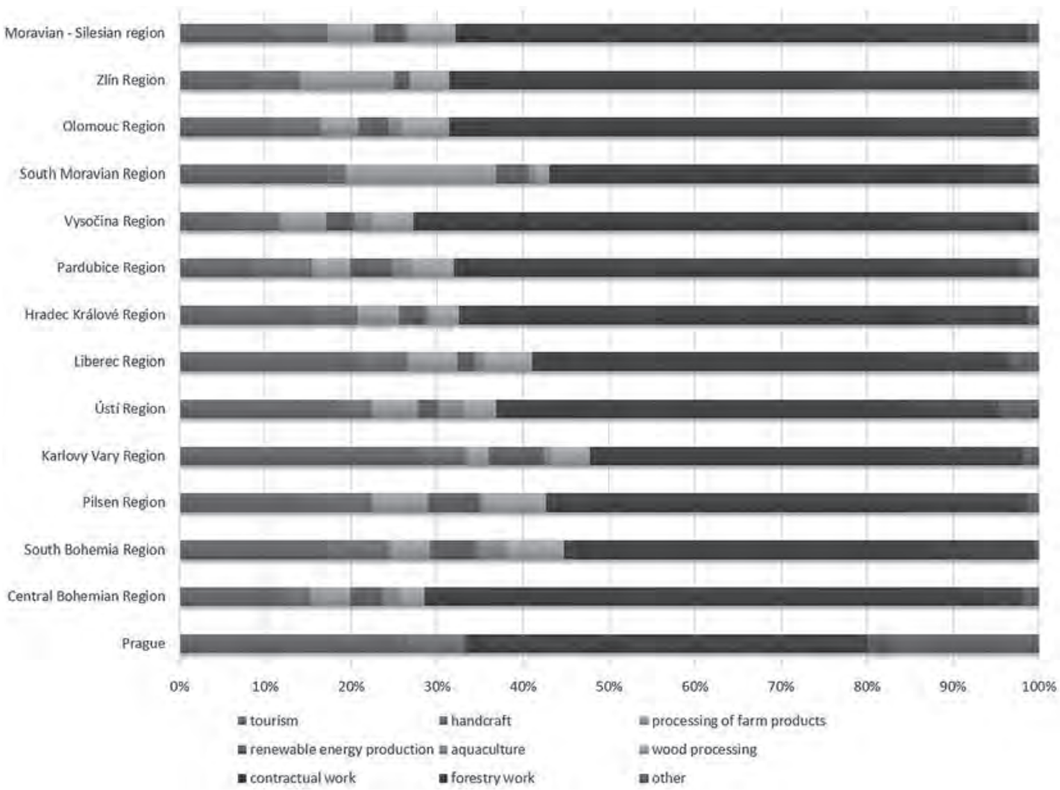

Fig. 7 Regional differentiation of diversification in Czechia in 2010. Source: Agrocensus 2010.

Karlovy Vary Region versus the South Moravia Region). On the other hand, regions where agriculture is strongly developed and represents a traditional field of economy (e.g. the Central Bohemia Region) show also a high percentage of holdings operating non-agricultural activities. This can be caused by the effort to find new ways with which to maximize the profit and accommodate the current demand. The location of a holding plays a significant role as it is connected to the differing demand for non-agricultural activities of agricultural holdings. The situation is different in the Central Bohemia Region which is very near to Prague than in border regions of Czechia where the structure of demand would be quite different.

2.3 The future of diversification

The rural areas will be dead areas without job opportunities and basic services. Due to this, diversification means one of the successful strategies of development of rural areas and villages. The main goal of this strategy should be the job creation in the rural areas. Non-agricultural activities of agricultural holdings can be a tool of stabilization of rural population, have an impact on local economy and can contribute to maintain the natural environment and cultural heritage (Eretová 2013; Doucha, Ratinger 2007).

Diversification of economic activities in rural areas with the goal to create new jobs and increase economic development is also one of the focus fields of the European Union (EU) in the Rural Development Programme for the period 2014–2020. The support should be used mainly in the processing industry, retail and building industry. In addition to these fields, activities related to rural tourism and investments in the equipment for bio fuel production or construction of biogas plants should be supported (Rural Development Programme 2014–2020). Projects creating new jobs or/and environment-friendly projects should be preferred. If agricultural primary production is not attended by the growth of non-agricultural activities of holdings or new measures of Common Agricultural Policy, its share in employment in rural areas will decrease further (Doucha et al. 2012; Věžník et al. 2004). It is important to increase farmers' awareness of calls, advisory and instructional activities. The process of drawing funds is for some farmers extremely demanding when it comes to its bureaucracy (Věžník et al. 2013). The possible running drawing or advance drawing of funds would be also helpful.

It is necessary to bear in mind that diversification and instruments for its support were created within the context of the EU 15 and later transferred in the new member countries including Czechia. But Czechia is distinguished by a specific development and therefore by different characteristics of agricultural sector than in original member countries. Preconditions on which instruments supporting diversification were based often conflict with the reality of Central and Eastern European countries (Chaplin et al. 2004). The unit for policy intervention in West European countries is the farm household. Similarly, agricultural diversification has taken the farm household as a unit of analysis. In contrast, as already mentioned above, Czechia is distinguished by the specific size and ownership structure of agricultural holdings. In addition, holdings in former Czechoslovakia were encouraged to develop non-agricultural activities and the returns from this type of activities were significantly higher than from primary agricultural production. Chaplin et al. (2004) also mentions that farmers in Central and Eastern Europe have less physical, financial and landed capital for conversion into new business activities than EU15 countries.

Cooperation projects and those focused on knowledge transfer are also emphasised in the current Rural Development Programme. Ageing of workers in agriculture is one of the main problems of the sector. One half of the people working in agriculture are between 45 and 59 years, including the leaders (managers) of the holdings (Doucha et al. 2012). It is necessary to attract young people in the agricultural sector both in terms of salaries and in terms of prestige of the job. The younger educated farmer is distinguished by a higher level of diversification than the older, less educated farmer or the part-time farmer (Eretová 2013).

Surrounding countries can be a source of inspiration, too. Germany and Austria are countries with a high share of holdings diversifying their activities (European Commission 2008; Weiss, Briglauer 2002). On the basis of statistics we can define their traditional fields- forestry work, tourism and renewable energy production (Eurostat 2010).

A potential is also hidden in product processing. Nowadays, only 4.5% of all enterprises are occupied with it (ČSÚ 2013). Primary production is exported to other EU countries and subsequently imported back in the form of products intended for consumption. On-farm product processing and direct sale to customers (sale from the yard, on local markets) who are still quite willing to pay a higher sum for foodstuffs with an added value, is a welcome opportunity. This is related to local marketing and promotion of agricultural production. The farmer and his family or the employees play an important role in this and they should be included in the business and innovation activities. These actors help to build a relationship between farmers/enterprises and customers (consumers of foodstuff). The change of concept of agricultural production is important especially in the cases where the relationship producer – product is established, where production processes and product quality are known. A shift towards regional production can open a space for cooperation under clusters (Marsden 2006). The purpose of the formation of the clusters can be the common (collective) purchase, marketing and a stronger negotiating position.

Potential for support of quality of life, social integration or development of not only rural communities offers a view of diversification as a social help. It is related to the "social agriculture", an approach on the border between multifunctional agriculture and social services (Ministry of Agriculture 2015). According to this approach, activities of agricultural holdings are intended for persons with temporal or constant specific needs. Farmers can provide organizations caring for the target groups with free spaces, can integrate individuals in common on-farm activities (e.g. maintenance of the farm and its surrounding, livestock care) or/and operate sheltered workshops. The result consists in more effective social help, social responsibility or rehabilitation of disadvantaged and integration of disabled persons (Ministry of Agriculture 2015).

The key for the implementation of non-agricultural activities should be an interconnection of all functions of rural areas, cooperation, synergy of the agents and their activities on the local and regional level (Van der Ploeg et al. 2000).

3. Conclusion

Agriculture is one of the most significant users of rural areas. However, its function has changed significantly over the past years. The emphasis is put on non-agricultural activities of agricultural holdings which are related to transition of agriculture, to transition from specialization to diversification of agriculture. Diversification can be considered a significant opportunity for stabilization of farmers' incomes and overall rural development.

The goal of this article was to outline the extent and significance of diversification of activities of agricultural holdings in Czechia before transition as well as after it and to sketch the potential future of diversification.

In the introduction, several research questions were formulated: which activities represent most often the target of diversification? Do these activities change over time? Are these activities regionally differentiated? Are there better preconditions for diversification in some regions than in others? How did the year 1989 and the related socioeconomic changes influence diversification of activities of agricultural holdings?

Which activities represent most often the target of diversification? Do these activities change over time? The most common activity in Czechia is contractual work for another subject. The popularity of tourism and forestry work has been also growing since tranformation. Before 1989, activities such as metal processing, wood processing and construction works dominated; later electrical engineering, processing of agricultural products and earthwork became the most important ones.

How did the year 1989 and the related socioeconomic changes influence diversification of activities of agricultural holdings? Before transition more than 80% of holdings were engaged with non-agricultural production. After 1989, these activities were separated into the independent businesses and reclassified into secondary and tertiary sectors. Separation of the part of the activities out of agriculture resulted in a significant statistical decrease in the number of workers in the primary sector. A lot of holdings continued and expanded in non-agricultural production by implementation of new activities after 1989. Only a small part of holdings have kept the same activities as they performed before 1989.

The number of enterprises that performed a non-agricultural activity varies slightly in the given years. In 2013 a non-agricultural activity was implemented by almost 19% of holdings (both private farmers and legal entities). If compared to 2010, a little growth can be observed. Therefore, Czech agriculture has been approaching North European and West European countries in the share of diversifying enterprises.

Are these activities regionally differentiated? Are there better preconditions for diversification in some regions than in others? Generally, in Czechia holdings of legal entities are more active in diversification while holdings of physical persons tend to be more specialised. Czechia is also distinguished by the extent and ownership structure of agricultural businesses. Physical persons (private farmers) clearly dominate in the number. On the other hand, legal persons dominate in the area of farmed land. These large holdings concentrate sufficient production factors important for implementation of non-agricultural activities. There is a discernible territorial differentiation in location of holdings and types of non-agricultural activities. The differentiation depends primarily on the character of natural conditions, location of the region and tradition of the given activity. Diversification is more common in holdings which are located in unfavourable natural conditions, mainly (in addition to contractual work) in activities related to tourism where holdings benefit from their location and quality of the environment. On the other hand, processing of agricultural products is typical for regions focusing more on agricultural primary production such as South Moravia Region.

The main limitation of the article is the availability of the data and their comparability. Moreover, the use of aggregate data and regional averages can cover up individual transitions of the holdings and farms. It is not enough to rely on the statistical data while studying diversification of activities of agriculture holdings. Diversification plays a significant role in the agriculture and life in the countryside, nevertheless, research on the micro-regional level has been very limited in Czechia. Therefore the future research should be focused exactly on the micro-regional level, on the particular physical (farmers) as well as legal persons.

To conclude, it is necessary to acknowledge that diversification cannot be seen as a panacea. It can help to solve various problems but in the case of unsuccessful farmers (businesspeople) there is a low chance that diversification would be a successful strategy (Eretová 2013; Hron 2007; Turner et al. 2006).

Acknowledgements

The work on the article was supported by the Charles University Grant Agency, project No. 369915 "Diversification of activities of agricultural holdings" (V. Eretová) and by the Czech Science Foundation, project No. P410/12/G113 "Historical Geography Research Centre" (V. Jančák).

REFERENCES

ALMSTED, A. (2013): Post-productivism in rural areas: A contested concept. In: Lundmark, L., Sandström, C. (eds.): Natural resources and regional development theory. Umea, 8–22.
BIČÍK, I., JANČÁK, V. (2002): České zemědělství po roce 1990. Geografie 106, 4, 209–222.
BIČÍK, I., JANČÁK, V. (2005): Transformační procesy v českém zemědělství po roce 1990. Univerzita Karlova v Praze, Praha.
ČSÚ (1990): Vývoj nezemědělské činnosti státních statků a zemědělských družstev v ČR. Český statistický úřad (Czech Statistical Office), Praha.
ČSÚ (1990): Vývoj přidružené výroby v zemědělských družstvech a státních statcích v letech 1985–1989. Český statistický úřad (Czech Statistical Office), Praha.
ČSÚ: Agrocenzus (Agrocensus) 1995, 2000, 2010. Český statistický úřad (Czech Statistical Office), Praha. http://czso.cz/ (19.11. 2014)
ČSÚ: Strukturální výsledky za zemědělství v roce 2003, 2005, 2007, 2013 (Farm structure survey 2003, 2005, 2007, 2013). Český statistický úřad (Czech Statistical Office), Praha. http://www.czso .cz/ (19.11.2014)
DOUCHA, T., JELÍNEK, L., MEDONOS, T., RATINGER, T. (2003): The state of farm and rural income diversification in Czech Republic. In: Proceedings of FAO Workshop: Farm Commercialisation and Income Diversification on the Road to EU Accesion. FAO, Rome, 139–151.
DOUCHA, T., RATINGER, T. (2007): The role of agriculture in rural development during the transition, the case of the Czech Republic. In: Sustainability of the Farming Systems: Global Issues, Modelling Approaches and Policy Implications. European Commission. Luxemburg, 197–215.
DOUCHA, T., DRLÍK, J., SPĚŠNÁ, D., RATINGER, T. (2012): Zaměstnanost v zemědělství ve vztahu k rozvoji venkova. Presentation. ÚZEI, Praha.
ERETOVÁ, V. (2011): Proměny forem hospodaření v transformačním období, modelové území ORP Kralovice. Bachelor thesis. Praha, KSGRR PřF UK.
ERETOVÁ, V. (2013): Diverzifikace činností zemědělských podniků v Česku v postindustriálním období. Master thesis. Praha, KSGRR PřF UK.
EUROPEAN COMMISSION (2008): Other gainful activities: pluriactivity and farm diversification in EU 27. Brussels.
EUROSTAT (2010): Agricultural census 2010 by country. Brussels.
EVANS, N., MORRIS, C., WINTER, M. (2002): Conceptualizing agriculture: a critique of post-productivism as the new orthodoxy. Progress in Human Geography 26, 3, 313–332. https://doi .org/10.1191/0309132502ph372ra
EVROPSKÁ KOMISE (2009): Nařízení Komise (ES) č. 1200/2009, ze dne 30. listopadu 2009, kterým se provádí nařízení Evropského parlamentu a Rady (ES) č. 1166/2008 o statistických zjišťováních o struktuře zemědělských podniků a o statistickém zjišťování o metodách zemědělské výroby, pokud jde o koeficienty pro velké dobytčí jednotky a definice ukazatelů. Brussels.
HAIT, P. (2009): JZD AK Slušovice – hospodářský zázrak za socialismu. Bachelor thesis. Praha, Institut ekonomických studií FSV.
HRABÁK, J. (2014): Multifunkcionalita českého zemědělství a rozvoj venkova: aktuální situace. Geografické infomácie 18(1), 54–68. https://doi.org/10.17846/GI.2014.18.1.54-68
HRON, J., ŠTUSEK, J., ARNOŠT, M., HUML, J., PLATILOVÁ VORLÍČKOVÁ, L. (2007): Diversification – strategy of building the competitive advantage in agribusiness. Agriculture Economics – Czech 53(12), 580–584.
CHAPLIN, H. (2001): Czech republic: review of policies and information affecting diversification. Idara Working Paper 2/5. London.
CHAPLIN, H., DAVIDOVA, S., GORTON, M. (2004): Agricultural adjustment and the diversification of farm households and corporate farms in Central Europe. Journal of Rural Studies 20, 61–77. https://doi.org/10.1016/S0743-0167(03)00043-3
CHLOUPKOVÁ, J. (2002): Czech Agricultural Sector: Organisational Structure and its Transformation. Unit of Economics Working Papers. Royal Veterinary and Agricultural University, Frederiksberg.
CHOVANEC, T., HUDCOVÁ, E., MOUDRÝ, J. (2015): Sociální zemědělství – představení konceptu. Ministry of Agriculture of Czech Republic, Praha.
ILBERY, B., HOLLOWAY, L., MAYE, D., WATTS, D. (2006): Final Report of the Research into the Potencial Impacts of CAP Reform on the Diversification Activities of Tenant Farmers in England. University of Hull, Hull. University of Coventry, Coventry.
ILBERY, B., MAYE, D., WATTS, D. (2009): Farm diversification, tenancy and CAP reform: Results from a survey of tenant farmers in England. Journal of Rural Studies 25, 333–342. https:// doi.org/10.1016/j.jrurstud.2008.08.001
JANČÁK, V., GÖTZ, A. (1997): Územní diferenciace českého zemědělství a její vývoj. Praha, katedra sociální geografie a regionálního rozvoje, Přírodovědecká fakulta, Univerzita Karlova.
KONEČNÝ O. (2012): Multifunkcionalita: geografie, venkov, zemědělství. In: SVOBODOVÁ, H. (ed.): Nové výzvy pro geografii, výroční konference České geografické společnosti. Brno, 182–189.
MARSDEN, T. (2006): The road towards sustainable rural development: Issues of theory, policy and practice in a European context. In: Cloke, P., Marsden, T., Mooney, P. (eds.): Handbook of rural studies. SAGE Publications, London, 201–212. https:// doi.org/10.4135/9781848608016.n14
MOUDRÝ, J. (2006): Multifunkční zemědělství. Multimediální texty. České Budějovice, Katedra agroekologie, Zemědělská fakulta, Jihočeská univerzita v Českých Budějovicích.
MINISTRY OF AGRICULTURE OF THE CZECH REPUBLIC (2015): Zpráva o stavu zemědělství ČR – Zelená zpráva 2014 (Report on the situation of agriculture in the Czechia – Green report 2014), Praha. htttp://eagri.cz/ (2.10.2015)
MINISTRY OF AGRICULTURE OF THE CZECH REPUBLIC (2015): Program rozvoje venkova na období 2014–2020 (Rural Development Programme 2014–2020). http://www.eagri.cz (30.10.2015)
OECD (2006): The New Rural Paradigm: Policies and Governance. OECD Publishing. Paris.
ROBINSON, G. (2004): Geographies of agriculture. Kingston University, School of Geography, London.
ŠPIČKA, J. (2006): Řízení podnikatelských rizik v zemědělství. Research institute of agricultural economics (VÚZE), Praha.

ŠPIČKA, J. (2008): Porovnání ekonomické výkonnosti malých a velkých zemědělských podniků v ČR. Presentation. VÚZE, Praha.

TURNER, M., WHITEHEAD, I., MILLARD, N., BARR, D., HOWE, K. (2006): The effects of public funding on farmers' attitudes to farm diversification. University of Exeter, Centre for Rural Research, Exeter.

VAN DER PLOEG, J. D., RENTING, H., BRUNORI, G., KNICKEL, K., MANNION, J., MARSDEN, T., DE ROEST, K., SEVILLA-GUZMÁN, E., VENTURA, F. (2000): Rural Development: from Practices and Policies towards Theory. Sociologia Ruralis 40(4), 391–408. https://doi.org/10.1111/1467-9523.00156

VĚŽNÍK, A., BARTOŠOVÁ, L. (2004): Selected regional geographical differences of the Czech Republic agriculture, after the transformation processes. Agricultural Economics 50(5), 207–216.

VĚŽNÍK, A., KRÁL, M., SVOBODOVÁ, H. (2013): Agriculture of the Czech Republic in the 21st century: From productivism to post-productivism. Quastiones Geographicae 32(4), 7–14. https://doi.org/10.2478/quageo-2013-0029

WEISS, CH., BRIGLAUER, W. (2002): Determinants and Dynamics of Farm Diversification. University of Kiel, Department of Food Economics and Consumption Studies, Kiel.

WILSON, G. A. (2008): From "weak" to "strong" multifunctionality: Conceptualising farm – level multifunctional transitional pathways. Journal of Rural Studies 24, 367–383. https://doi.org/10.1016/j.jrurstud.2007.12.010

Zákon č. 42/1992 Sb., o úpravě majetkových vztahů a vypořádání majetkových nároků v družstvech („Transformation Act").

RESUMÉ

Minulost, současnost a budoucnost diverzifikace zemědělských podniků v Česku

Hlavním tématem článku je diverzifikace činností zemědělských podniků v Česku, a to před rokem 1989 a po něm. Cílem článku je přiblížit rozsah a význam diverzifikace činností zemědělských podniků v rámci Česka jak v období centrálně plánovaného hospodářství před rokem 1989, tak po něm, tedy v období přechodu k tržní ekonomice.

České zemědělství prošlo složitým vývojem a mnoha změnami ovlivněnými politickou situací a ekonomickým vývojem země až do současného stavu. Ten mnozí autoři nazývají přechodem od produkčního k postprodukčnímu zemědělství, který je mimo jiné charakterizován přechodem od specializace k diverzifikaci zemědělství (Ilbery, Bowler 1998).

Účelem diverzifikace je vytvořit a také udržet pracovní místa na venkově, zvýšit příjem hospodářství a přispět k oživení venkovských obcí.

Cílem článku je přiblížit rozsah a význam diverzifikace činností zemědělských podniků v rámci Česka v období před rokem 1989 a po něm, jakož i možnostmi budoucností diverzifikace.

V úvodu článku je formulováno několik výzkumných otázek: do jakých činností zemědělci nejčastěji diverzifikují svoji činnost? Mění se tyto činnosti v čase? Jsou tyto činnosti regionálně diferencovány? Jsou v některých regionech lepší předpoklady pro diverzifikaci než v jiných? Jaký vliv měl na diverzifikaci rok 1989 a s ním spojené společenské změny?

Nezemědělská činnost zemědělských podniků byla před rokem 1989 nazývána přidruženou výrobou a v tomto období hrála významnou roli v rozvoji zemědělství a venkova, stala se vítaným zdrojem prostředků na provoz či rozvoj podniků. Po roce 1989 došlo k její redukci. Některé činnosti zanikly, jiné byly vyčleněny do sektoru průmyslu a služeb, v nichž často fungují až do současnosti. Jen malé procento podniků zachovalo nezemědělskou činnost ve stejném rozsahu jako v předchozím období. Diverzifikace činností zemědělských podniků se opět začíná prosazovat ve druhé polovině 90. let. V roce 2013 se diverzifikací zabývalo téměř 19 % podniků. Jedná se o hodnotu, která se blíží úrovni diverzifikace v zemích západní a severní Evropy. Nejrozšířenějšími aktivitami v Česku jsou smluvní práce pro jiný podnik, stále větší oblibě se těší také aktivity spojené s cestovním ruchem a lesnictvím.

Diverzifikace činností zemědělských podniků představuje změnu nahlížení na zemědělce jako na aktivního správce krajiny, může představovat jednu ze strategií zachování venkova jako prostoru živého a žitého.

Veronika Eretová
Charles University, Faculty of Science
Department of Social Geography and Regional Development
Albertov 6
128 43 Praha 2
Czechia
E-mail: veronika.eretova@natur.cuni.cz

Vít Jančák
Charles University, Faculty of Science
Department of Social Geography and Regional Development
Albertov 6
128 43 Praha 2
Czechia

LANDFORMS AND MORPHOGENETIC PROCESSES IN THE LOCALITY OF GEODETIC OBSERVATORY PECNÝ, ONDŘEJOVSKÁ VRCHOVINA HIGHLAND

TEREZA STEKLÁ[1], JAN KALVODA[1], JAKUB KOSTELECKÝ[2]

[1] Faculty of Science, Charles University, Department of Physical Geography and Geoecology, Czech Republic
[2] Research Institute of Geodesy, Topography and Cartography, Geodetic Observatory Pecný, Czech Republic

ABSTRACT

The presented paper deals with physical-geographical environment and landform patterns in the locality of Geodetic Observatory Pecný (GOPE) in the Ondřejovská vrchovina Highland. Landforms transience of the Ondřejovská vrchovina Highland by erosion and denudation processes is proportional to a high potential energy of the relief due to progressive tectonic uplift of the central part of the Bohemian Massif in the late Cenozoic. The Seradovský potok Brook valley between the Pecný Ridge (545 m a.s.l.) and the Sázava valley bottom (284 m a.s.l.) intersects several levels of planation surfaces and its source area erodes the etchplain exhumed during the Palaeogene. In the lower part of the valley, the stream deepened during the late Quaternary by approximately 50 m, whereas the relatively steep erosional slopes of the canyon-like part of the antecedent Sázava valley have a relative height of 60–75 m.

In the rugged terrain of the GOPE locality, there are visible marks of regelation and frost processes, gully and fluvial erosion, slow slope movements and anthropogenic activities. Intensity of recent morphogenetic processes with its maximum in spring corresponds to combination of seasonal changes of air and soil temperature and at the same time to increased water content in the rock massif and in the weathered mantle. The suitable geodynamic location of scientific observatories on the Pecný ridge, stable from engineering-geological and geomorphological point of view, and in its near neighbourhood is menaced by increasing intensity of anthropogenic activities in the landscape.

Keywords: landform evolution, recent morphogenetic processes, Ondřejovská vrchovina Highland

Received 19 July 2016; Accepted 4 October 2016; Published online 1 March 2017

1. Introduction

1.1 Definition of the topic

The Geodetic Observatory Pecný (GOPE) of the Research Institute of Geodesy, Topography and Cartography and observatories of the Astronomical Institute of the Czech Academy of Sciences are located in the ridge part of Pecný (545.8 m a.s.l., latitude 49°54′49.33″ N and longitude 14°47′08.23″ E) which is the highest summit of the Ondřejovská vrchovina Highland (Fig. 1). Astronomical and geoscientifical observatories in the Ondřejovská vrchovina Highland are a historically important experimental area of Czech science traditionally dedicated to long-term research projects (see for instance Ondřejovská hvězdárna 1998; Kostelecký et al. 2005a,b). From the engineering-geological viewpoint, this is a very stable territory in the central part of the Bohemian Massif (Kalvoda et al. 2004). The large complex of the GOPE with its permanent GPS station and other high-quality geophysical and meteorological equipment has an excellent position for research into recent geodynamics of morphostructural units in Central Europe.

The natural environment of the Ondřejovská vrchovina Highland is quite varied and so is also the dynamic morphostructural and climate-morphogenetic evolution of its landforms in the late Cenozoic. Regional geomorphological research into the Ondřejovská vrchovina Highland and its near territories was already treated in several papers paying attention mainly to orographic aspects and river network development (Daneš 1913; Moschelesová 1930; Novák 1932; Kuncová 2005; Balatka, Štěpančíková 2006; Balatka 2007; Kalvoda 2007; Balatka, Kalvoda 2010). Geological structure of this region

Fig. 1 Aerial photograph of polygenetic relief of the Ondřejovská vrchovina Highland taken from the south. The complex of the Astronomical Institute of the Czech Academy of Sciences and of the Geodetic Observatory Pecný (GOPE) of the Research Institute of Geodesy, Topography and Cartography are located above the village of Ondřejov, partly on forested ridges of the hills of Žalov, Pecný (545 m a.s.l.) and Ostrá Skála. Photo: JAS AIR spol. s.r.o.

https://doi.org/10.14712/23361980.2017.4
Steklá, T. – Kalvoda, J. – Kostelecký, J. (2017): Landforms and morphogenetic processes in the locality of Geodetic Observatory Pecný, Ondřejovská vrchovina Highland
AUC Geographica, 52, No. 1, pp. 38–60

was studied in detail by Orlov (1933), Vajner (1960), Kachlík (1992), Domas et al. (1993) and in the context of the Bohemian Massif's long-term development among others by Chlupáč et al. (2002). The increasing heterogeneity and quality of geophysical and geodetical measurements, a great extent of appropriate databases and efforts to interpret them in a complex way impose at present high requirements on knowledge of types and intensity of recent climate-morphogenetic processes, tectonic and also anthropogenous activities in localities of scientific observatories.

The main aims of the paper are 1) characteristics of the physical-geographical environment and landform patterns in the research observatories locality, 2) evaluation of local climatic conditions in relation to recent morphogenetic processes, and 3) description of geomorphic profile between the Pecný ridge and the Sázava valley and its erosional evolution during the Quaternary. It is a communication of running results of experimental research into recent climate-morphogenetic processes going on in the near-surface part of the rock massif as well as in its weathered mantle. These geomorphological processes determine present changes of landforms having developed during a long period of the late Cenozoic. Detailed exploration of geomorphic processes in the area of GOPE was integrated with systematical studies of physical-geographical phenomena and landform evolution in the Ondřejovská vrchovina Highland. Geomorphological mapping of the region (locality) also supported selection of specific sites to long-term observations of running and/or expected (slow) changes of landforms. The research in the locality of astronomic and geoscientific observatories was carried on simultaneously with the research into the system of river terraces and Sázava valley evolution (Kalvoda 2007; Balatka, Kalvoda 2010; Balatka et al. 2010a,b, 2015), including reconstruction of the progressive development of the deep erosional cutting of this river during the Quaternary.

A complex approach to using available palaeogeographical findings and current experimental data related to geomorphic history and to recent landscape changes enables a progressive integration of geodetical, geophysical and geological measurements and observations and studying of landforms of variable evolution and age (Kalvoda 2005). During the last twenty years complexity of geodetical and geophysical measurements carried on at the GOPE significantly increased, e.g. performing continuous observation of GPS satellites, research into tidal and non-tidal variations of acceleration of gravity, meteorological measurements and the analytical centre

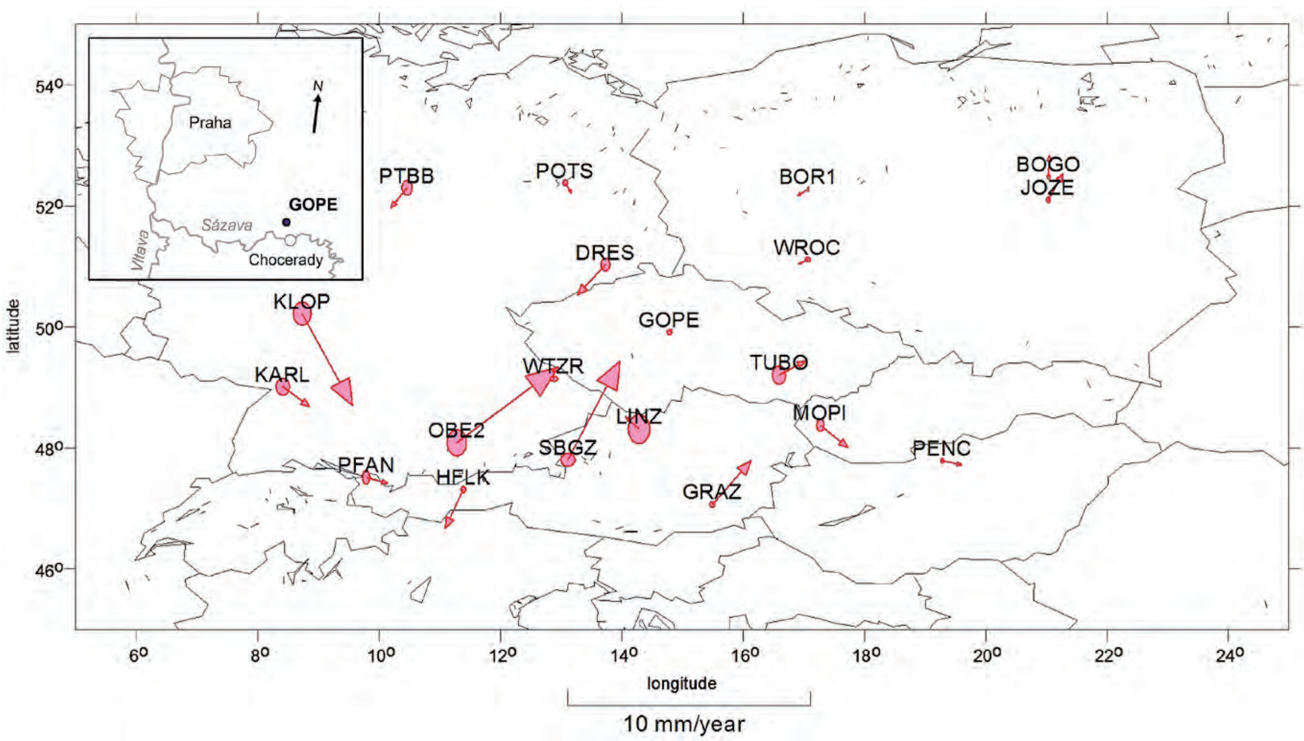

Fig. 2 Relative motions of EUREF Permanent Network (EPN) stations with respect to GOPE in the period from 1996 to 2002 (Kalvoda et al. 2004). The GPS measurements analysis is based on time-changes of coordinates of 20 EPN stations. From the 3D-coordinates of stations referenced to a common epoch a vector was computed (see arrows) with its origin in the GOPE station and the end point in the respective station (one sigma error ellipses, in detail see Kalvoda et al. 2004). The relative stability of morphostructural blocks of the Hercynian Platform (e.g. POTS, BOR1) is confirmed. The approaching of the northern wing of the Eastern Alps nappes and of their molasse foreland (OBE2, SBGZ) to the Hercynian blocks of Central Europe, especially to the Bohemian Massif is obvious. It is highly probably a manifestation of ongoing tectonic activity, including the pressure of alpine structures on the Hercynian consolidated block of the Bohemian Massif. This trend is also proved by the directions of relative movements between the northern part of the Rhine Graben (KLOP) and the molasse foreland and the Helvetian nappes of the northern wing of the Western Alps.

for satellite technology (in detail see Kostelecký et al. 2005a,b). For example, the results of gravity variations measured at the GOPE by the absolute FGS gravimeter were the first ones of this type in the Czech Republic (Pálinkáš, Kostelecký jr. 2003). Their analysis also enables separation of local, mainly hydrological and meteorological phenomena, from global (e.g. non-tidal) changes of the gravitational field. When elaborating and interpreting the time series of GPS technology, application of the continuum was developed for the data obtained from the European network of permanent GPS stations (Kostelecký, Kostelecký 2003). An evaluation and geodynamic interpretation of results of measurings in the network of selected permanent GPS stations in Central Europe was elaborated (Fig. 2). An example of using these experimental papers can be progress in diagnostics of natural hazards and risks and in predicting catastrophic events and phenomena.

1.2 The physical-geographical environment of the research observatories locality in the Ondřejovská vrchovina Highland

Heterogeneity of the natural environment of the locality of scientific observatories located in the southern part of the Ondřejovská vrchovina Highland is due to varied geological structure and to the evolution of its rugged relief in the late Cenozoic. This is the area of Central Bohemian Pluton and of its metamorphosed islands (Fig. 3) following in the east in Palaeozoic sedimentary rocks of the Blanická brázda Furrow. The Central Bohemian Pluton intruded in the zone of Central Bohemian deep fault between the Moldanubian and the Assynt blocks in the Brittany stage of Variscan orogenesis (Mísař et al. 1983). The oldest rocks of this territory originated during the Pre-Cambrian period. After solidification of magmatite rocks, the Central Bohemian Pluton was developing as a whole (Bouček, Kodym 1963). The original mantle of Central Bohemian Pluton (e.g. Říčany granite, granitoid rocks of Sázava type) was contactly metamorphosed during the Upper Proterozoic and the Lower Palaeozoic. Faulted or by faults limited remnants of this mantle are preserved in denudational relics of intruded blocks as metamorphosed islands in the Central Bohemian Pluton. Chocerady, Čerčany and Ondřejov metamorphosed islands affected by contact as well as by regional metamorphosis are of the Proterozoic age. The sensibly younger Voděrady-Zvánovice metamorphosed island was formed mainly in the Ordovician (Vajner 1960; Kachlík 1992; Domas et al. 1993). The area of Central Bohemian Pluton and of its metamorphosed islands is limited in the east by fault system of the Blanická brázda Furrow (Fig. 4) formed in the Upper Carboniferous during the Asturian stage of Variscan orogenesis. After the Variscan orogeny, intermontane basins divided by faults were formed in the territory of the Bohemian Massif in the Upper Palaeozoic (Chlupáč et al. 2002). During the Carboniferous and the Permian, there were depositing in these basins thick groups of layers of fluvial and lacustrine sediments (Domas et al. 1993) which are partly maintained in the Formation of Český Brod and the Formation of Kostelec nad Černými Lesy.

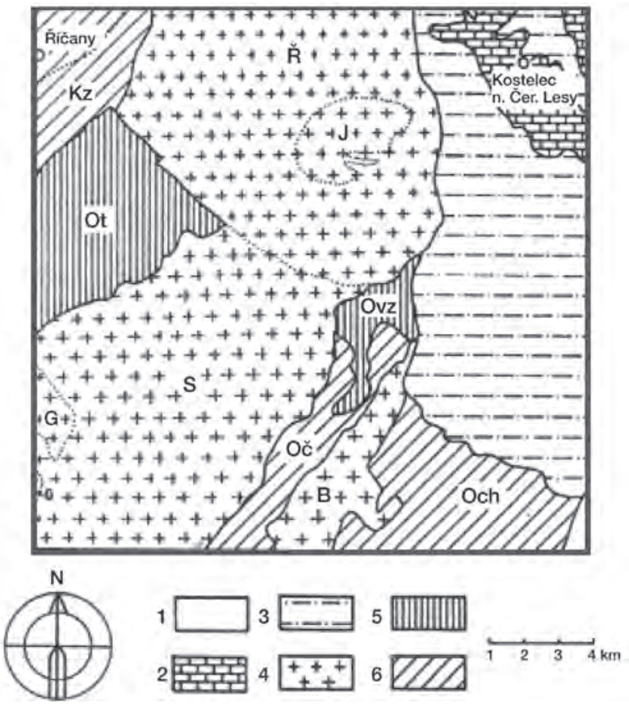

Fig. 3 Main geological units of the Ondřejovská vrchovina Highland (modified according to Domas et al. 1993); 1 – Moldanubian; 2 – sediments of the Bohemian Cretaceous Basin; 3 – Permian-Carboniferous sediments; 4 – magmatites of the Central Bohemian Pluton (G – gabbro bodies; Ř – granites of Říčany type; S – granodiorites to diorites of Sázava type; B – quartz diorite of Benešov type; J – granites of Jevany type); 5 – Lower Palaeozoic rocks of metamorphosed islands (Ot – Tehov island; Ovz – Voděrady-Zvánovice island), 6 – Proterozoic of the Barrandien and island zones (Oč – Čerčany island; Och – Chocerady island, Kz – Kralupy-Zbraslav group).

Fig. 4 The Ondřejovská vrchovina Highland is in the east markedly limited by the northern part of the Blanická brázda Furrow filled by Upper Palaeozoic sedimentary rocks and also by fluvial and slope sediments of the Quaternary age. On the aerial photo (www.strimelice.banet.cz) there are, looking from south to north, in the foreground the village of Stříbrná Skalice and the Hruškovský rybník Pound, in the background on the left the village of Kostelní Střimelice and the eastern hillside of structural-denudational slopes of the Skalka ridge.

Fig. 5 Northern structural-denudational slopes of ridges of Pecný (545 m a.s.l.) and Ostrá Skála rising above the relics of an etchplain-type planation surface in the Ondřejovská vrchovina Highland. Photo: T. Steklá.

During the Neogene, the central part of the Bohemian Massif was characterized by ongoing stages of tectonic activity and stability. During tectonic stability, local planation surfaces were formed at different height levels (Král 1985; Demek et al. 1987). In the Neogene, river valleys were shallow and vale-shaped with prevailing lateral erosion. In the southern part of the Ondřejovská vrchovina Highland, the Pliocene deepening of the Sázava River valley reached 125–145 m, the lowest plateaus in the Pre-Quaternary vales being interpreted as typical valley pediplains. Pliocene sediments in the Ondřejovská vrchovina Highland are of fluvial or fluvial-lacustrine origin, but they are only residues of originally much larger accumulations.

According to regional geomorphological classification, the Ondřejovská vrchovina Highland is a part of the Středočeská pahorkatina Hilly Land (Balatka, Kalvoda 2006). It has the character of planation surface the denudation of which had been going on already since the Upper Palaeozoic. The orographic district of the Ondřejovská vrchovina Highland is followed in the north by the Jevanská pahorkatina Hilly Land and in the east by the Černokostelecká pahorkatina Hilly Land. The Jevanská pahorkatina Hilly Land is formed mainly by volcanic rocks of the Central Bohemian Pluton (Chlupáč et al. 2002), while in the geological structure of the Černokostelecká pahorkatina Hilly Land Permian and Cenomanian sandstones, mudstones and conglomerates prevail. Demek et al. (1987, 2006) characterized the Ondřejovská vrchovina Highland as a flat highland of mean altitude between 450 and 550 m. Still at the beginning of the Cenozoic, the region was a part of denuded relief formed here in the place of the original Variscan mountains. Denudational plateaus are probably relics of Pre-Tertiary etchplain, the thickness of eroded material is not known. Due to water streams erosion, relics of planation surfaces are preserved only on flat or slightly inclined parts of the highland in altitudes about 500 m (Fig. 5). Hilly parts of the Ondřejovská vrchovina Highland are thus situated in a belt of planation surfaces (above 470 m a.s.l.) and they were formed by selective erosion and denudation of crystalline rocks (Kalvoda 2007). In the neighbourhood of Zvánovice and Struhařov, these planation surfaces are bound to milder denudational slopes and flat hills which are considered as the oldest and the highest relics of a planation surface of etchplain type between the catchments of Labe and Sázava. The Ondřejovská vrchovina Highland is situated in the basin of Sázava River rising in the Českomoravská vrchovina Highland. Sázava crosses the Ondřejovská vrchovina Highland from the mouthing of Doubravice (river km 41.25) to the mouthing of a brook in Lštění (river km 35.67) in a length of about 6 km. The locality of scientific observatories near Ondřejov is drained to the south by right-bank affluents of Sázava.

Stepped structure of denudational plateaus and slopes going from the upper parts of the Ondřejovská vrchovina Highland down to the bottom of the Sázava antecedent valley documents a neotectonic uplift of the central part of the Bohemian Massif during the late Cenozoic. This uplift is manifested by a pronounced deepening of the valley of Sázava and its tributaries during the Quaternary; this river forms here a canyon-like valley with valley bottom relics of Pre-Quaternary age. Pleistocene fluvial accumulations are preserved only in the Sázava valley as relics of formerly larger river terraces (Fig. 6). Characteristics of these sediments are substantially influenced by climatic changes in the Quaternary manifesting for instance by frost smashing of the skeleton of underlying rocks and by eolic admixture. At the end of the Pleistocene and in

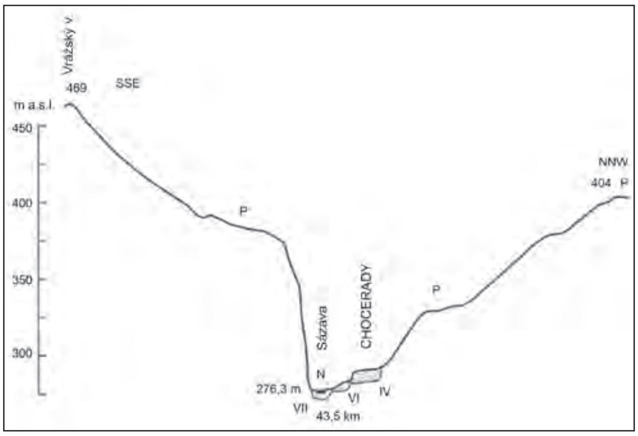

Fig. 6 Crosswise profile of the Sázava valley near Chocerady (Balatka, Kalvoda 2010); P – planation surface; N – Holocene fluvial plain; IV, VI, VII – Pleistocene terraces 10 times exaggerated.

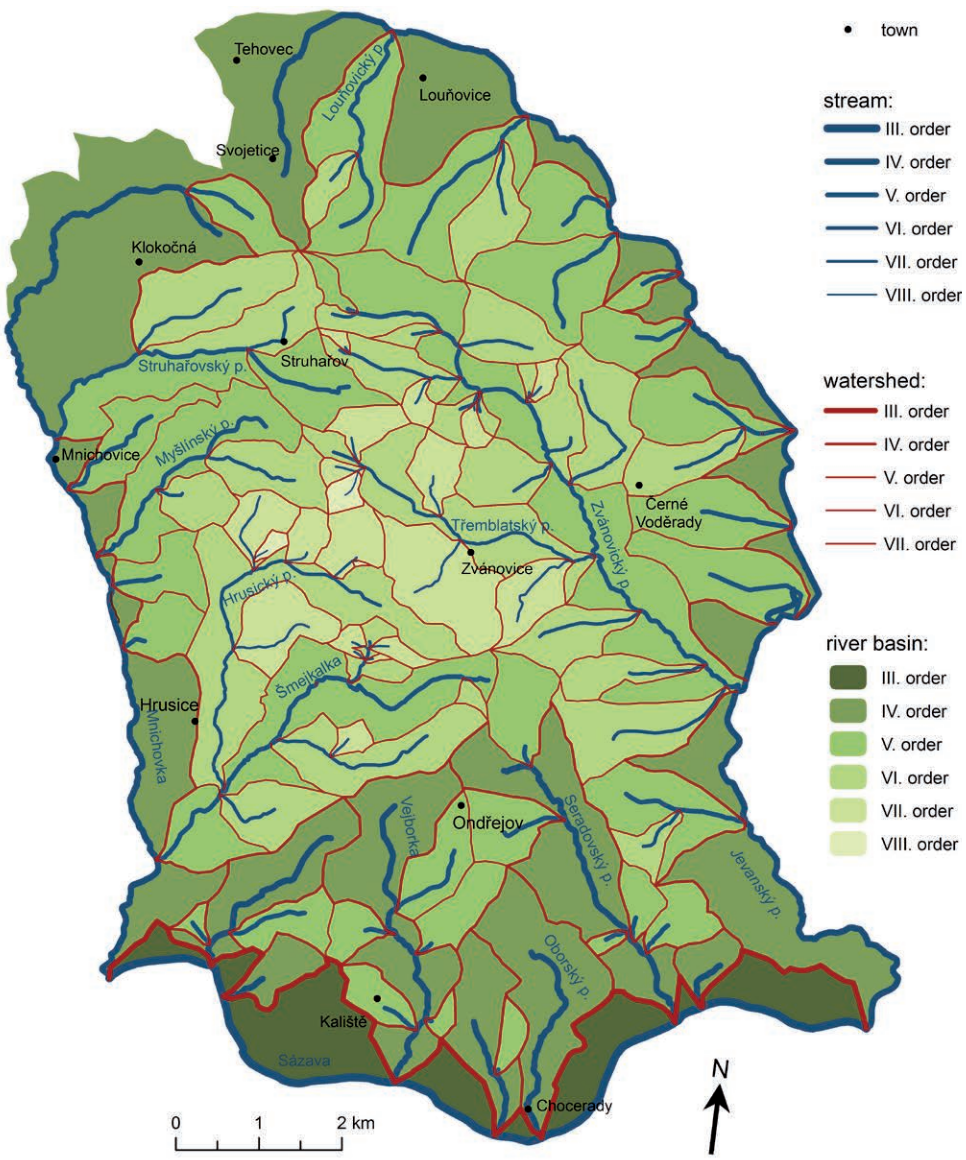

Fig. 7 Hydrographical classification and structure of water streams network in the Ondřejovská vrchovina Highland (Steklá 2012).

the Lower Holocene, a great quantity of linear landslides occurred in the Ondřejovská vrchovina Highland (Domas et al. 1993). The thickness of slope accumulations is variable (maximally 6 m) and depends mainly on variability of the relief and on the character of bedrock.

The relief of the Ondřejovská vrchovina Highland is more influenced by the right-bank tributaries of Sázava which are, in comparison with the left-bank ones, shorter and their gradient is higher (Daneš 1913). Source area of streams generally merges into a flat open dell which disturbs planation surfaces of different ages and geneses. In the middle and lower course, backward erosion formed markedly incised to canyon-line valleys (Kuncová 2005; Kalvoda 2007). The main conspicuous valleys are those of the Jevanský potok Brook, the Zvánovický potok Brook and Mnichovka. Hydrological situation in the Ondřejovská vrchovina Highland is shown in Fig. 7.

The Jevanský potok Brook with its catchment of 75.94 km^2 rises in the village of Svojetice at 450 m a.s.l. Morphological character of its valley is determined above all by its rock underlayer formed in the upper course by Jevany granodiorites, whereas the south-western part of the catchment with a mild gradient is based in Permian-Carboniferous sediments of the Blanická brázda Furrow. The flow of the Jevanský potok Brook manifests a considerable seasonal oscillation with its maxima in spring; the mean flow rate of the Jevanský potok Brook being 0.28 m^3 s^{-1} (Vlček et al. 1984; Osmančik 2005). The elongated shape of the Jevanský potok Brook valley lead in the past to its frequent damming and a regionally important system of pounds was built there (Slezák 2002). At present, only 12 pounds are maintained along the whole course of the Jevanský potok Brook, as Vyžlovský (20 ha), Jevanský (17 ha), Louňovický (7 ha) and Požár (4 ha). The major affluent of the Jevanský potok Brook is the Zvánovický potok Brook rising near the village of Struhařov at 485 m a.s.l. Its oblong catchment of 16.3 km^2 is NW–SE oriented (Kohoutková 2002; Steklá

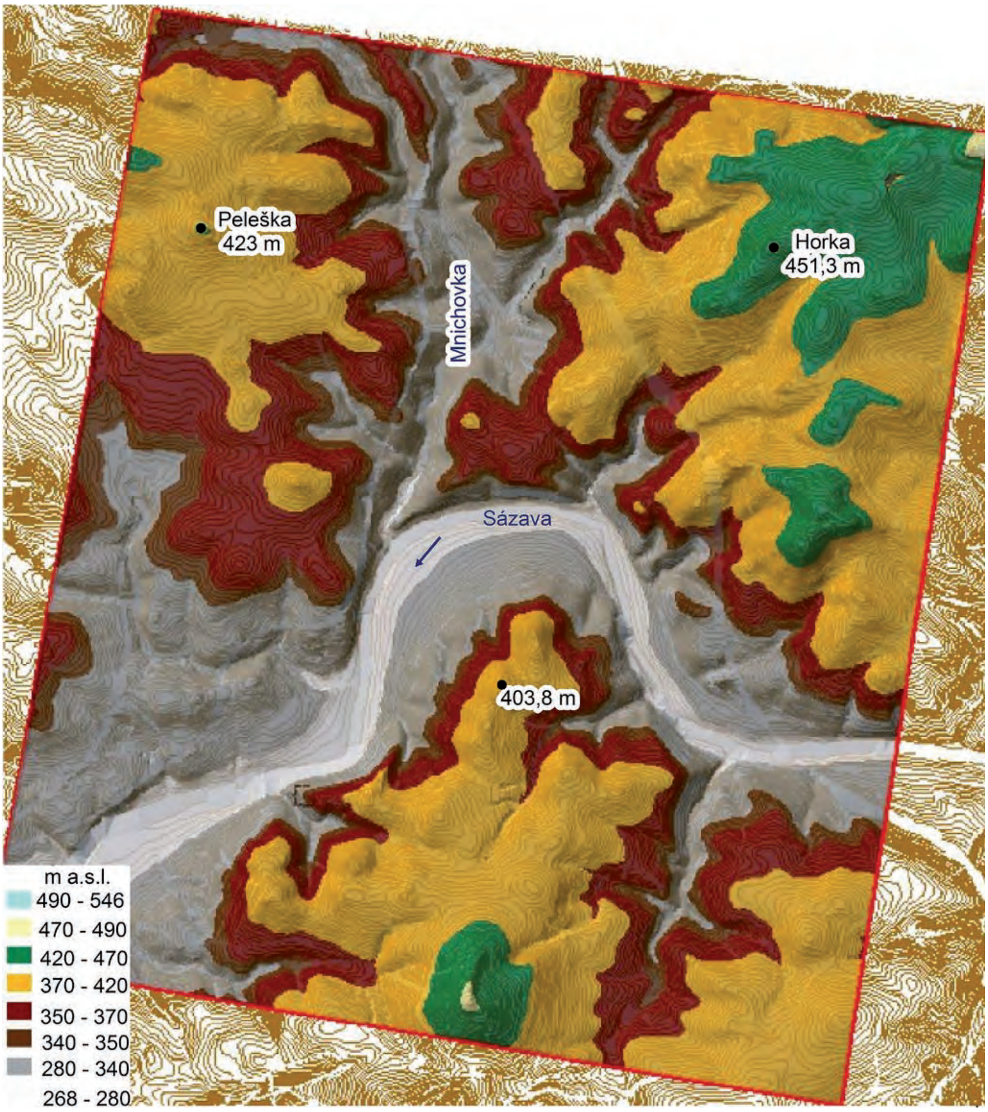

Fig. 8 Topographical scheme of the rugged relief of canyon-like valleys at the Mnichovka mouthing into Sázava (Kuncová 2005).

2012). Crosswise profiles of the valleys of the Zvánovický potok Brook and of its main tributaries, Habrovský potok Brook and Třemblatský potok Brook, are predominantly V-shaped which is typical for the majority of right-bank affluents of Sázava.

Mnichovka, thanks to its uniform underlayer with predominant Sázava granodiorites, has a relatively stable gradient curve (0.08‰). But in its upper and lower course canyon-like valleys were formed witnessing about presence of a fault zone and about backward erosion impact (Fig. 8). The first hundreds of metres from the Mnichovka's mouthing into Sázava are marked concussion slopes of an incised meander with steep erosional slopes (Kuncová 2005). In the middle course of Mnichovka, a larger valley of almost trapezoid shape is preserved. In Novak's opinion (1932), an older stream of N–S orientation used to be in the area of the present-day Mnichovka in the Neogene.

Rocks of the Central Bohemian Pluton in the Ondřejovská vrchovina Highland are characteristic by a predominance of fissure water over pore water found only in the upper weathered zone. Rocks of metamorphosed Upper Proterozoic and Ordovician form a fissure collector with an increased permeability in the near-surface zone (Vajner 1960; Kodym et al. 1963). Fissure water is bound there mainly to crosswise dislocations, transversal fissures are mostly impermeable and abundant sources are situated only in larger faults (Domas et al. 1993). The most abundant sources of underground water in the Ondřejovská vrchovina Highland are however Quaternary sediments and alluvial landforms. In the territory of metamorphosed rocks, especially debris sources are frequent, but their abundance is nevertheless low and irregular. On the contrary, rocks of the Central Bohemian Pluton have permanent and well mineralized sources. Underground water is used for local consumption, when it is not polluted by nitrates, Fe and Mn (Kohoutková 2002). Its quality is negatively influenced by growing anthropogenic activities. Pollution of brooks is mainly due to waste water discharging, the lower Sázava course having strongly polluted water.

Tab. 1 Climatic conditions in the Ondřejovská vrchovina Highland according to classification by Quitt (1971), see also Atlas podnebí Česka (2007).

		SW9	SW10	SW11
1	amount of summer days	40–50		
2	amount of freezy days	110–130		
3	amount of icy days	30–40		
4	amount of cloudy days	40–50		
5	amount of clear days	120–150		
6	amount of days with snow cover	60–80	50–60	
7	amount of days with precipitation over 1 mm	100–120	90–100	
8	mean temperature in January	−3 – −4 °C	−2 – −3 °C	
9	mean temperature in March	6–7 °C	7–8 °C	
10	mean temperature in July	17–18 °C		
11	mean temperature in October	7–8 °C		
12	precipitation amount in vegetation period (mm)	400–450	350–400	
13	precipitation amount in winter period (mm)	250–300	200–250	
14	amount of days with mean temperature over 10 °C	140–160		

SW – slightly warm region

According to regional climatic classification (Quitt 1971), the Ondřejovská vrchovina Highland belongs to three climatic regions MT 9, MT 10 and MT 11. The northern part of this highland belongs to MT 9 region characterized by long, warm and dry summers and mild winters with only a short presence of snow cover. MT 10 region in the western part of the Ondřejovská vrchovina Highland is characterized, in comparison with MT 9 region, by higher air temperature in the first half of the year. MT 11 region situated along the Sázava valley up to the top of Pecný (545 m) is characterized by longer transitional seasons (spring, autumn) and by drier summers than in MT 9 and MT 10 regions (Table 1).

Classification of the Ondřejovská vrchovina Highland as mildly warm climatic region is supported also by the majority of selected climatologic characteristics ascertained in the Ondřejov station in the years 1961–2000 in the framework of the National Climatological Programme of the Czech Republic (Květoň 2001). Long-term monthly mean temperature curve (Table 2) has a simple course with its maxima from June to August and its minima from December to February. The locality of observatories near Ondřejov is characterized by higher rainfall during the growing season and by lower rainfall in winter. According to Sobíšek (2000), the average wind direction in this territory is 247.9° and its average speed is 2.40 m s^{-1}. Due to rugged relief, the microclimate of ridge and valley parts of the Ondřejovská vrchovina Highland is significantly different.

Soils in the Ondřejovská vrchovina Highland are very diverse, mainly because of their varied bedrock with a rich content of minerals. Humus horizons are determined by phytocoenosis of forest and agricultural communities (Pelíšek, Sekaninová 1979). The most frequent reference soil class in the Ondřejovská vrchovina Highland is group of cambisoils. These soils were formed in the dissected relief on volcanic rocks of Central Bohemian Pluton and on metamorphosed rocks of its islands as well as on slope and fluvial non-carbonate sediments (Cicha et al. 1984; Tomášek 2003). Cambisoils in the Ondřejovská vrchovina Highland are mostly acid to strongly acid with low humus content, in suitable habitats they manifest also gleying.

On slightly inclined slopes, typical gleyed luvisoil developed, its parent materials being silica sediments, polygenetic clays and acid intrusive materials. Occasional overwetting of luvisoils causes higher concentrations of iron deposits (Cicha et al. 1984; Tomášek 2003). Near water streams in wet dells typical gleys were formed on subjacent non-carbonate slope, fluvial and alluvial sediments. Due to seasonal overwetting, pseudogleys have locally developed, mainly on weathered silica sediments and acid intrusive rocks, as well as on polygenetic clays. Flat valley bottoms of water streams are covered by typical and gleyey fluvisoil. Humus horizon is here situated directly on alluvial non-carbonate sediments. On weathered limestones south-westwards from Stříbrná Skalice rendzines developed (Cicha et al. 1984; Tomášek 2003). Production potential of soils in the Ondřejovská vrchovina Highland is very variable in agricultural and forest soils (Domas 1993). Soils are here endangered mainly by water erosion and denudation, locally also by stagnation of underground and surface water. Acid rains are another thread as soil is little to middle resistant to them.

According to biogeographical classification (Culek et al. 1996), the Ondřejovská vrchovina Highland belongs to the Sázava region which is a part of Hercynian sub-province. Characteristic for this region is impoverished mesophylic biota formed by oak-hornbeam forests, acidophilic oak forests and flowering beech forests. However, most of the forests were in the past replaced by artificial spruce

Tab. 2 Mean monthly and annual air temperature (°C) in Ondřejov, 1961–2009 (Květoň 2001; *Steklá 2010).

year/month	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	year
1961–1990	−2.8	−1.2	2.5	7.2	12.2	15.3	16.8	16.5	13.1	8.1	2.4	−1.2	7.4
1991–2000	−1.2	−0.2	3.2	8.2	13.0	15.9	17.8	17.9	13.0	7.8	2.3	−1.0	8.1
2003–2009*	−1.5	−0.3	3.3	9.3	13.3	16.9	18.2	17.6	13.7	8.2	3.6	0.6	8.6

and pine monocultures. In lower situated regions, original beech forests mixed with spruce and hazel. Natural forest composition in this region has been intensively influenced since the 18th century, mainly by logging and using of improper seedlings. Damaging of forests was also natural due to strong winds in 1735 and 1737. Today, natural covers and seedlings of local origin are used for forest rehabilitation. Original mostly deciduous forests were superseded by agricultural activities and logging up to the ridge parts of the Ondřejovská vrchovina Highland (Kohoutková 2002; Tomeček 2007). In present-days, agriculturally used areas form the landscape matrix of this region.

According to Neuhäuslová et al. (1998), without anthropogenous interventions into vegetation, there would be in the Ondřejovská vrchovina Highland communities of cow wheat oak-hornbeam forests, wood rush beech forests, fir oak forests and beech forests with Dentaria ennephyllos. At present, the herbaceous layer is formed mainly by Central European flora species. Some local species can be classified as subatlantic flora (wavy bitter cress, mountain speedwell). Exceptionally, mountain species can be found there, for instance mountain arnica or Lastrea libosperma. In valley forests, there grow for instance European wild ginger, Lilium martagon, addersmeat or yellow archangel. On valley rocks, we can find field sagewort, blue fescue, Medicago sativa and others. Dry slopes are covered by yarrow and sheep fescue. According to Culek et al. (1996), there was an island of peat meadows Caricion fuscae near Ondřejov. Fauna of the Ondřejovská vrchovina Highland is a relic of formerly more varied species composition (Kunský 1968). Abundance of roebuck and wild boar is a result of absence of natural predators. The most important beasts of prey are red fox and pine marten. Eurasian eagle-owl is rare. Water birds as wild duck or grey heron live near numerous pounds and water basins. Fish as carp, pike, catfish, perch or sander live in pounds.

The extent of anthropogenous activities and their impact on the natural environment of the Ondřejovská vrchovina Highland was significantly changing in the Upper Holocene. Already in the Neolithic, the extent of settlement was changing and so was land use, especially due to agricultural activities and logging. A more significant impact of human activities was registered as late as in the Bronze Age, when settlement, agriculture and logging developed. Anthropogenous processes led to a significant increase of slope movements and soil erosion which led also to formation of large sediments of alluvial clays (Ložek 1973). In the period of the maximal extent of prehistoric settlement, the Ondřejovská vrchovina Highland was settled only in the immediate proximity of Sázava (up to 300 m a.s.l.) and along the Jevanský potok Brook and Mnichovka.

Near the boundary of the island zone of Central Bohemian Pluton and Permian-Carboniferous sediments, hydrothermal polymetallic mineralization occurred which led to formation of deposits of polymetallic ores and rare metals. These deposits were often exploited in the past. The oldest preserved mining of these deposits is documented near Hradební Střimelice, where copper bearing ores and polymetallic ore veins were mined in the 12th century. Other historic mining localities are Stříbrná Skalice, Kostelní Střimelice and Černé Voděrady, where silver was mined in the 19th century (Domas et al. 1993). On the left bank of the Zvánovický potok Brook between Černé Voděrady and Zvánovice remnants of mill stones made from Říčany granite and used for ore grinding in different degrees of shaping are maintained. Granitoid rocks of Sázava type are used for production of crushed stone, whereas the Říčany granite is used as gravel for construction and material for concrete production. In the present-day landscape, settlement area and other engineering works as roads, water basins, soil heaps and deposits are more and more frequent.

2. Landform patterns and climate-morphogenetic processes of the Pecný ridge

The top of Pecný (545 m) is a part of a structural ridge running in the NE-SW direction. This ridge (520–536 m a.s.l.) forms a watershed region between the Seradovský potok Brook and Šmejkalka. Geological structure of the Pecný ridge is varied (Fig. 9). On an area of about

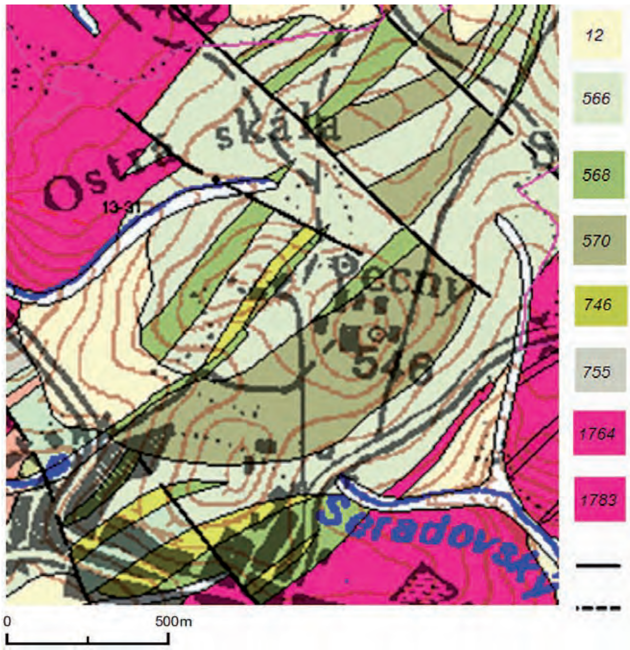

Fig. 9 Geological structure of the Pecný ridge in the Ondřejovská vrchovina Highland (GeoINFO 2004); 12 – sandy-clayey to clayey-sandy diluvial sediments (Holocene); 566 – slates and metagreywackes (Ordovician); 568 –greywackes (Ordovician); 570 – conglomerates, sandstones, quartzites (Ordovician); 746 – coarse-grained greywackes (Proterozoic); 755 – phyllitic slates and greywackes (Proterozoic); 1764 – granodiorite of Benešov type (Carboniferous, Permian); 1783 – granodiorite, tonalite, quartz diorite of Sázava type (Carboniferous, Permian); — fault ascertained; --- fault assumed.

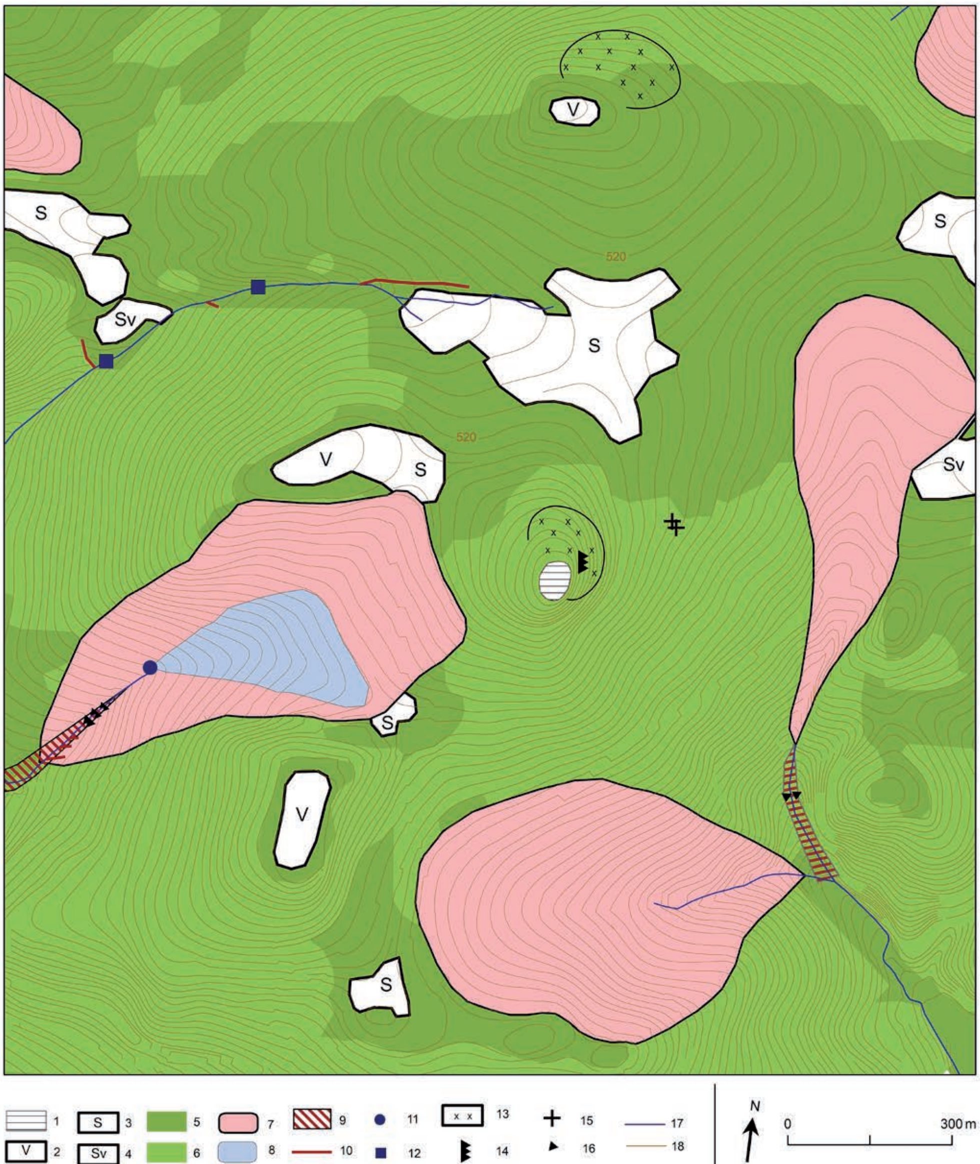

Fig. 10 Geomorphological sketch of the scientific observatories area in the neighbourhood of Pecný (modified according to Steklá 2010); 1 – structural plateau, inclination 0°–2°; 2 – denudational plateaus, inclination 2°, summit; 3 – denudational plateaus, inclination 2°, saddle; 4 – denudational plateaus, inclination 2°, slope; 5 – erosional-denudational slopes, slightly inclined (2°–5°); 6 – erosional-denudational slopes, medium inclined (5°–15°); 7 – dell; 8 – source basin; 9 – ravine; 10 – erosional furrow; 11 – source; 12 – artificial basin; 13 – debris; 14 – frost cliff; 15 – rock outcrop; 16 – steps in riverbed; 17 – water stream; 18 – contour lines (2 m).

3 km^2 there are four rock belts of different origin and age NE–SW oriented. In the eastern part of the locality of scientific observatories (on the Ostrá skála Hill) there are granodiorites of Benešov type linked in the west to Proterozoic rocks of the Čerčany and the Ondřejov metamorphosed islands. South-eastwards from the top of Pecný the bedrock is formed by granodiorites and tonalites of Sázava type. The top of Pecný is built by Ordovician quartzites which are a part of the Voděrady-Zvánovice metamorphosed island. The belt of quartzites is limited in the north by a NW–SE oriented fault zone.

The summit part of the Ondřejovská vrchovina Highland (546–490 m a.s.l.) is a relic of a by denudation lowered surface (etchplain) of probably Pre-Cretaceous age exhumed probably during the Palaeogene (Kalvoda 2007; Pánek, Kapustová 2016). Landforms of the ridge part of Pecný are documented in Fig. 10 (Steklá 2012). The ridge with the Pecný top is asymmetrical with markedly steeper south-eastern slopes (above 10°). Inclination of these slopes is increased mainly by erosion of the Seradovský potok Brook and of its tributaries. Northern and western slopes are milder (up to 7°) and are linked to flat saddles at 520 m a.s.l. (Fig. 11). They have been formed mostly by backward erosion of the Šmejkalka Brook and of its left-bank affluent which have formed large source basins with gley soil type. Rock massif has been exposed in the summit part of Pecný. The weathered mantle has been slowly sliding to the foothill where stony to clayey-stony deluvium is being accumulated having in lower position a thickness up to several metres (Steklá 2012).

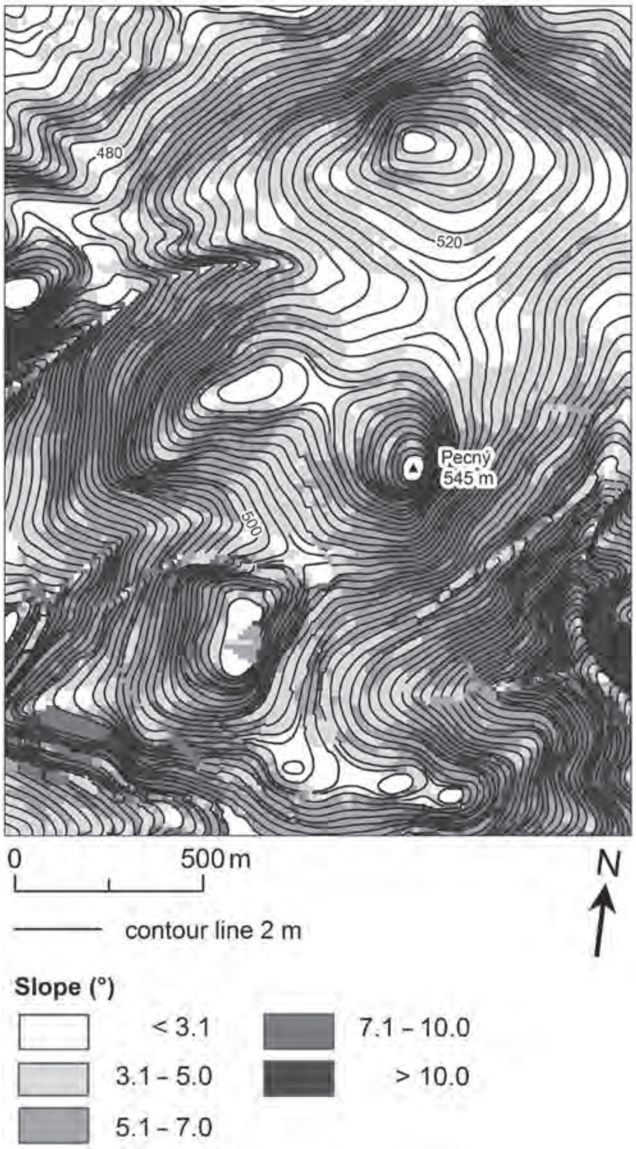

Fig. 11 Inclination of slopes of the rugged relief in the southern part of the Ondřejovská vrchovina Highland (modified according to Steklá 2010).

Fig. 12 Degraded frost cliff of Ordovician sandstones and quartzites (500 m a.s.l.) at the eastern slope of Pecný ridge, partly damaged by quarrying. Photo: T. Steklá.

On weathered quartz sediments of northern and eastern slopes of the Pecný top pseudogleys developed, but the major part of the studied locality is covered by acid cambisoil (Cicha et al. 1984).

Highlands and mountain ranges of the Bohemian Massif were situated in cold periods of Quaternary in the periglacial environment when rocks were long-term and seasonally frozen (Czudek 2005). Also on the Pecný ridge there are relics of cryogenic landforms. At the eastern slope of the Pecný top there is a partly deteriorated frost cliff (Fig. 12) formed in resistant quartzites. A part of the denudational slope is also covered by fossil stone field of debris and boulders of Ordovician quartzites (Fig. 13).

Relics of periglacial processes impact in the Upper Quaternary are relatively frequent on denudational and erosional slopes of the Ondřejovská vrchovina Highland. They are mainly degraded tors (Fig. 14), frost cliffs, stone fields and slope sediments, at present stabilized by vegetation. Locally, there are eolic sediments formed in the coldest period of glacials. Eolian accumulations are the best visible in the neighbourhood of Jevany, where homogenous loess covers are maintained on leeward slopes against south-west oriented air circulation (Brunclík 1956). On these loess covers solifluction streams later developed, they were ascertained also on sandy weathered granitoid rocks (varps, Ambrož 1943) in the upper part of the Zvánovický potok Brook valley. In the Ondřejovská vrchovina Highland there are also frequent fossil landslides, mainly on erosional slopes of stream valleys. These landslides were developing in several stages from the end of the Pleistocene to the Middle Holocene, when significant changes of climatic conditions occurred accompanied by slope processes (Steklá 2012) and development of large accumulations of slope clays.

In the long-term perspective, the natural environment of the scientific observatories area is influenced by anthropogenous activities. The summit part of Pecný has been deforested and GOPE buildings and communications, including a historically important geodetic watching tower (Fig. 13) and stands of measuring devices, have been built there. Deforested have been also neighbouring tops and saddles. During land works connected with the construction of the Ondřejov (astronomical) observatory, Žalov hill has been lowered by several metres. Before the

Fig. 13 By vegetation partly covered and stabilized stone field situated eastwards from Pecný (545 m a.s.l.), in the background is visible historical geodetical lookout tower in the GOPE area. Photo: T. Steklá.

Fig. 14 Degraded tor of Říčany-type granites (430 m a.s.l.) eastwards from the Čihadlo ridge developed mainly by frost weathering of rocks and by regelation processes during the Holocene. Photo: T. Steklá.

beginning of construction of the astronomical observatory, Žalov was covered by pine forest, at present there is an arboretum with rare woody plants (Ondřejovská hvězdárna 1998). Slopes and plateaus near the Pecný top are used for agriculture and a playing field has been built there. The afforested part of Pecný is covered by beech forest passing progressively on northern and eastern slopes into spruce monocultures, whereas southern and western slopes are covered by mixed forest.

Essential for studying recent morphogenetic processes in the GOPE locality are measurings of microclimatic conditions, including monitoring of soil moisture and temperature conditions and underground water level monitoring. In the years 2002–2010, these data had been obtained in the summit part of Pecný, i.e. directly in the GOPE observatories area, mainly by measuring by the automatic measuring station of Department of Physical Geography and Geoecology of the Faculty of Science, Charles University (Kastner et al. 2012). Annual course of air temperature in the GOPE locality has its (expected) maxima in summer months and minima in winter (Tab. 3 and Fig. 15). Annual amplitude of monthly mean air temperature reached in the years 2003–2009 the value of 22.2 °C and absolute annual temperature amplitude 46.5 °C. The number of characteristic days in individual years of this period is given in Tab. 4. In the GOPE locality, there were every year in average 5 tropical days, 27 summer days, 95 frost days, 44 icy days and 6 arctic days (Steklá 2010).

Average monthly rainfall in the year 2004–2008 shows (Table 5) that during growing periods the average rainfall was 380.72 mm and during winter periods only

Tab. 3 Mean monthly and annual air temperature (°C) in the GOPE locality, 2003 – 2009 (Steklá 2010); LA – long-term monthly and annual average

month\year	2003	2004	2005	2006	2007	2008	2009	LA
I.	−2.18	−3.12	0.03	−5.02	3.47	0.96	−4.50	−1.48
II.	−3.31	−1.17	−3.30	−2.20	2.91	2.48	2.34	−0.32
III.	4.68	2.79	1.83	0.49	5.76	2.48	4.98	3.29
IV.	7.62	8.69	9.75	8.19	11.50	7.14	12.13	9.29
V.	15.06	11.04	13.25	12.71	14.42	13.31	12.99	13.25
VI.	19.83	14.94	15.85	16.87	19.47	16.80	13.96	16.82
VII.	18.63	17.09	17.58	21.96	17.54	17.10	17.51	18.20
VIII.	21.00	18.53	15.80	14.85	17.31	17.32	18.38	17.60
IX.	14.33	13.68	14.72	15.64	10.99	11.77	14.72	13.69
X.	5.08	9.42	9.95	10.82	7.58	8.27	6.40	8.22
XI.	4.75	3.25	1.90	5.50	0.54	3.70	5.75	3.63
XII.	−0.22	−0.66	−1.06	3.16	−1.42	−0.18	4.48	0.59
year	8.77	7.87	8.02	8.58	9.17	8.43	9.09	8.56

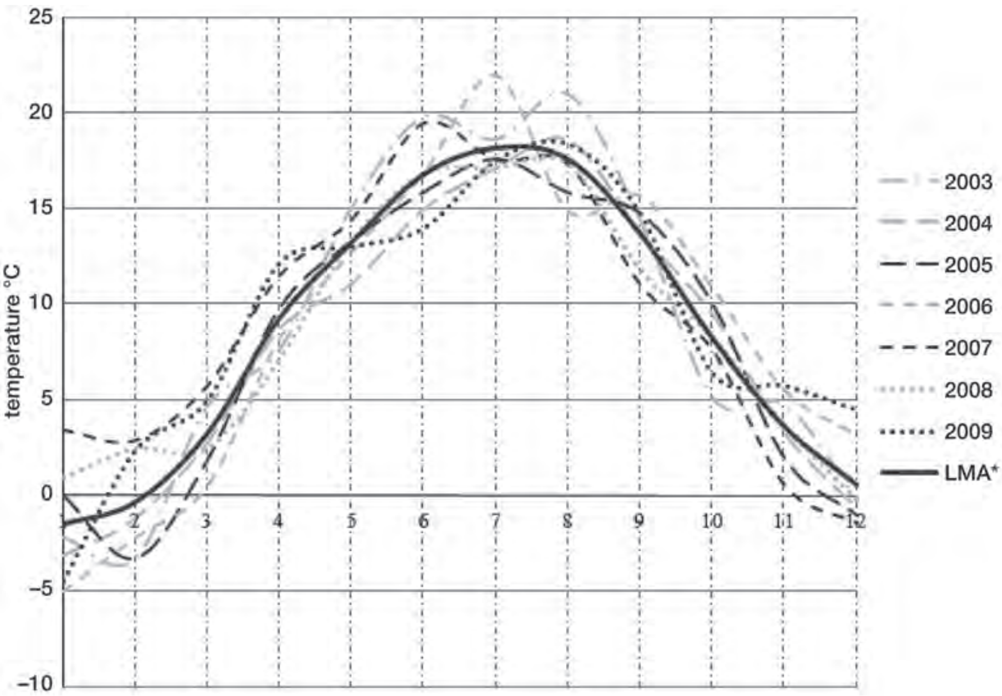

Fig. 15 Annual course of air temperature in the GOPE locality (2003–2009, Steklá 2010); LMA – long-term monthly average.

Tab. 4 Amount of characteristic days in the GOPE locality, 1961–2009 (Květoň 2001; Steklá 2010).

	2003	2004	2005	2006	2007	2008	2009	2003–09	1961–91
tropical days	11	1	3	10	5	1	1	4.57	3.8
summer days	50	12	22	32	31	26	13	26.57	29.0
freezy days	111	104	108	89	67	95	89	94.71	114.8
icy days	47	48	59	49	36	27	43	44.14	45.3
arctic days	8	6	7	9	0	1	12	6.14	1.2
days with mean temperature ≥ 10 °C	173	150	173	177	166	158	173	167.14	×

194.08 mm (Fig. 16). Average annual rainfall was 574.80 mm. Total rainfall higher than 1 mm was registered in average in 102 days per year, and that with significant differences going from 82 days (2008) to 116 days (2004). Water content in soil is higher in winter periods, its maxima being reached in spring when snow is melting. Summer minimum is often disrupted by torrential rains (Steklá 2012). Seasonal soil moisture amplitude is getting smaller in lower depths. Changes in daily course of soil moisture are not significant during most days of the year, maxima are usually reached in morning hours. The highest speed of wind is reached in winter months (Tab. 6). During the year, south-western wind is prevalent (Fig. 17), the least frequent is wind from the north and the south. Values of mean monthly and annual air pressure are given in Tab. 7.

Important meteorological factors determining types and course of recent morphogenetical processes are soil temperature and air temperature. In the observed locality, both daily and annual course of soil temperature are

Tab. 5 Mean monthly sum of rainfall (mm) in the GOPE locality, 2004–2008 (Steklá 2010).

month/ year	2004	2005	2006	2007	2008	2004 –2008
I.	×	41.3	24.9	49.7	7.9	30.95
II.	15.6	48.0	32.3	40.2	4.4	28.10
III.	52.4	19.1	55.5	34.4	21.1	36.50
IV.	31.9	24.4	51.9	0.3	215.3	64.76
V.	83.3	71.1	84.1	59.1	48.0	69.12
VI.	49.9	51.4	137.9	33.4	66.5	67.82
VII.	53.6	124.3	24.2	64.3	84.0	70.08
VIII.	41.5	80.6	136.7	35.5	34.9	65.84
IX.	45.1	36.7	16.0	126.3	17.9	48.40
X.	21.7	10.7	25.3	13.9	54.8	25.28
XI.	65.3	19.7	29.9	76.9	38.9	46.14
XII.	14.1	28.0	19.9	12.0	31.0	21.00

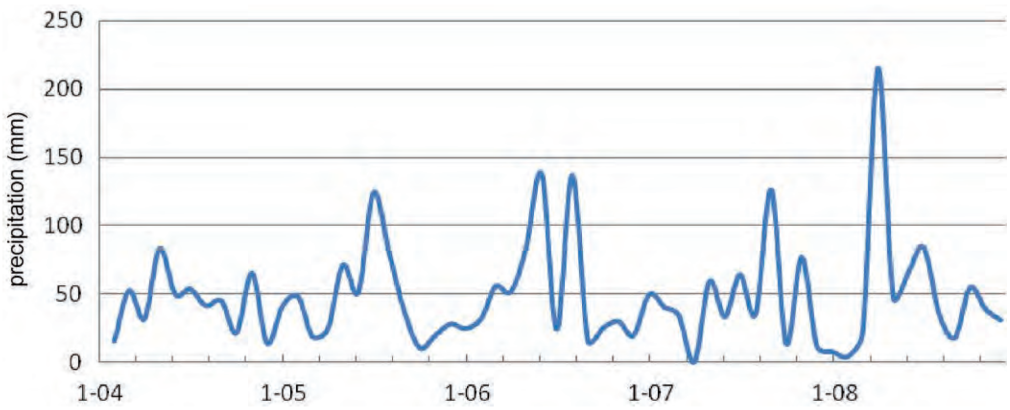

Fig. 16 Average monthly rainfall in the GOPE locality (2004–2008, Steklá 2012).

Tab. 6 Mean monthly and annual wind speed (m s^{-1}) in the GOPE locality, 2003–2009 (Steklá 2010).

month/year	2003	2004	2005	2006	2007	2008	2009	2003–2009
I.	2.56	2.25	3.53	1.77	4.90	2.93	1.74	2.81
II.	1.68	2.25	2.42	2.36	2.59	2.59	2.90	2.40
III.	1.93	2.56	2.63	2.29	2.60	3.10	2.79	2.56
IV.	2.31	2.02	2.01	2.09	2.05	2.24	2.14	2.12
V.	4.06	1.82	1.85	2.16	2.02	1.54	1.79	2.18
VI.	1.43	1.90	1.60	1.40	1.64	1.74	1.94	1.66
VII.	1.73	1.77	2.03	1.37	2.66	1.84	1.99	1.91
VIII.	1.56	1.87	1.74	2.26	1.67	2.01	1.52	1.80
IX.	1.44	1.96	1.44	1.91	2.10	1.66	1.68	1.74
X.	2.06	1.61	1.54	1.66	1.42	1.81	2.39	1.78
XI.	1.97	3.01	1.65	2.79	2.69	2.53	2.91	2.51
XII.	2.56	2.06	2.57	2.13	1.80	2.59	2.51	2.32
year	2.11	2.09	2.08	2.02	2.35	2.22	2.19	2.15

Tab. 7 Mean monthly and annual air pressure (hPa) in the GOPE locality, 2003–2009 (Steklá 2010).

month/year	2003	2004	2005	2006	2007	2008	2009	2003–2009
I.	950.28	945.39	951.70	959.57	945.00	954.62	950.85	951.06
II.	956.38	940.73	943.69	948.84	947.43	960.23	948.44	949.39
III.	958.41	955.14	951.12	946.08	950.91	941.51	947.84	950.14
IV.	952.03	952.93	950.51	949.82	956.61	946.62	951.09	951.37
V.	954.42	951.04	952.72	952.51	948.54	952.66	955.30	952.46
VI.	953.39	953.37	954.64	952.50	950.83	952.56	951.71	952.71
VII.	953.88	954.05	951.94	956.64	950.77	951.78	952.28	953.05
VIII.	956.48	953.45	953.25	947.59	951.86	951.63	955.29	952.79
IX.	958.04	956.12	955.54	954.19	954.19	954.67	956.64	955.63
X.	949.13	949.31	958.24	952.71	958.60	953.70	951.57	953.32
XI.	954.04	953.56	953.25	954.35	951.26	949.68	947.47	951.94
XII.	953.40	954.10	950.52	960.16	957.59	953.09	944.11	953.28
year	954.16	951.60	952.26	952.91	951.97	951.90	951.05	952.26

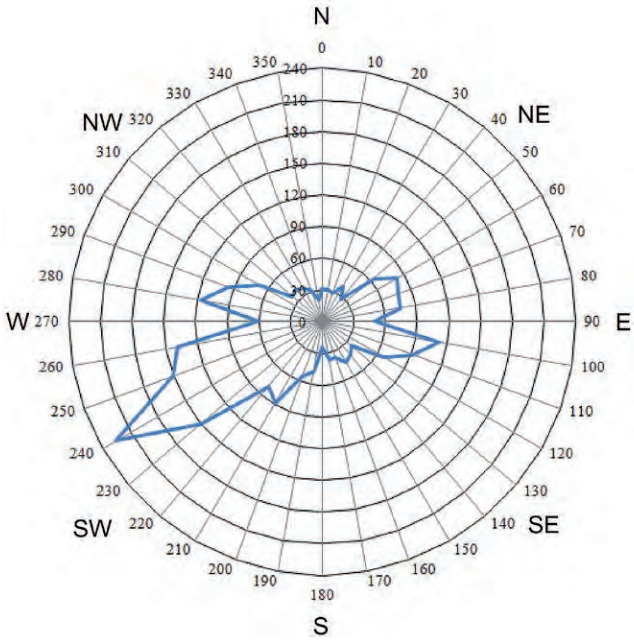

Fig. 17 Wind directions in the GOPE locality (2003–2009, Steklá 2010).

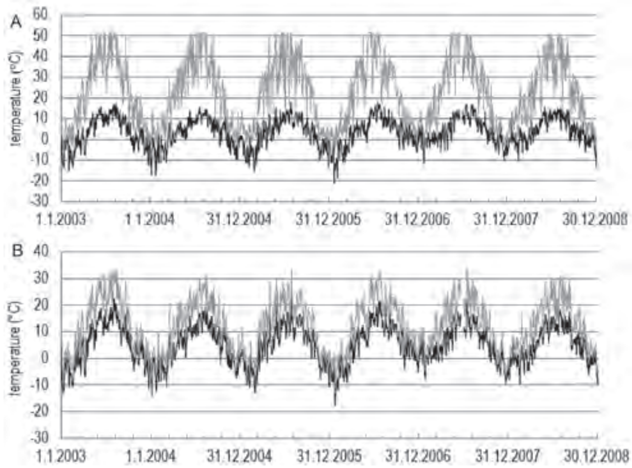

Fig. 18 Annual course of soil and air temperatures in the GOPE locality (2003–2008, Steklá 2012). A – soil temperature, B – air temperature; black line – daily temperature minimum, gray line – daily temperature maximum.

more pronounced than that of air temperature (Fig. 18). Exemplary are periods, when soil temperature repeatedly oscillates near to freezing point. It means that daily soil temperature minima do not exceed 0 °C, whereas daily soil temperature maxima are above zero. Fig. 18 shows that these temperature conditions in the Pecný ridge part occur seasonally from October to April, exceptionally even to May. The highest differences between minimal and maximal daily soil temperatures values are registered in spring (March, April, May) when their difference exceeds 30 °C. The highest temperature amplitude of 48.2 °C was registered on 20 May 2007. Minimal soil temperatures are registered in spring, mostly during morning hours between 5 and 7 a.m., less frequently then about midnight. The highest soil temperatures were measured mostly in afternoon hours between 1 and 2 p.m.

Changes of maximal and minimal values of soil temperature are significantly higher than changes of air temperatures and a similar course is evident also in their annual amplitudes. Mean seasonal soil and air temperatures are compared in Tab. 8. When compared with the daily course of soil temperature, also daily course of air temperature manifests more equilibrated values. The highest difference of minimal and maxima air temperatures was registered in April when it was more than 30 °C. Minimal air temperatures are registered mostly just before daybreak and sometimes about midnight. Maximal air temperatures were registered in afternoon hours.

Soil moisture and underground water level characteristics were elaborated according to a database of continuous measurements in GOPE (Jakub Kostelecký et al.), measuring sensors being placed at about 50 m from the main observatory building on a denudation slope with western exposition. Bedrock of this stand is formed by Ordovician quartzites which act as a fissure collector with an increased permeability in the near-surface zone (Cícha et al. 1993). For soil moisture analysis, a sensor placed south-eastwards from the main building was selected; it measures in the cover of slope weathered material in depths of 12 cm, 32 cm, 60 cm, 86 cm and 120 cm. For basic information on underground water level, long-term measurements in the well north-westwards from the main GOPE building were used.

Seasonal course of soil moisture in the GOPE area is shown in Fig. 19. The quantity of water in soil increases during the winter period and culminates in the beginning of spring when snow and ice melting causes a significant soaking of upper soil layers. On the contrary, the lowest values of soil moisture are registered in summer; occasional increased soil moisture in this period is due to increased rainfall. The daily course of soil moisture manifests the same character almost during the whole year. Soil moisture minima are registered in the afternoon, whereas the maxima are mostly bound to morning hours. Oscillations of soil moisture are not very significant during the day, as at 345 days of the year they do not exceed 3%. The highest differences in soil moisture during the day occur during the period April–September, when they reach up to 10%. More into the depth the seasonal amplitude of soil moisture is getting lower. Whereas soil moisture in

Tab. 8 Mean seasonal soil and air temperature (°C) in the GOPE locality, 2003–2012 (Steklá 2012).

soil	spring	autumn	air	spring	autumn
minimum	3.11	3.09	minimum	5.79	5.80
maximum	22.63	22.37	maximum	13.25	13.19
amplitude	18.59	18.65	amplitude	7.02	6.89

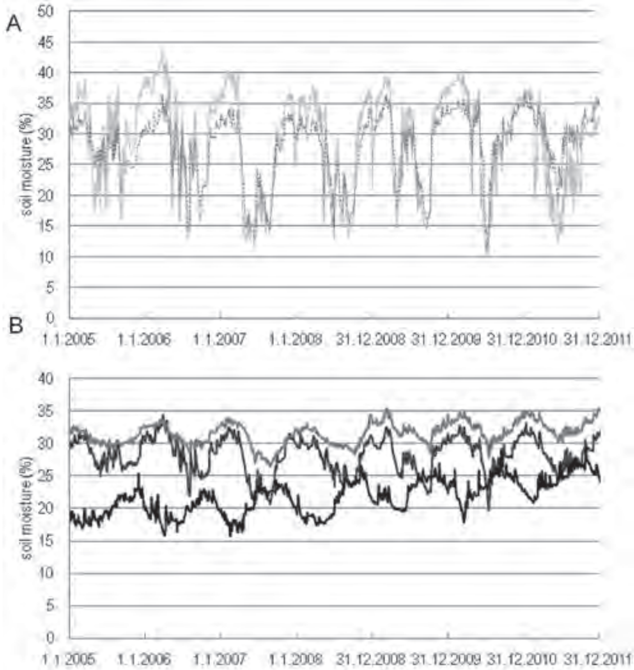

Fig. 19 Mean daily soil moisture in the GOPE locality in depths of 12 to 120 cm (2005–2011, Steklá 2012): A solid line – 12 cm, dotted line – 31 cm; B dark grey line – 60 cm, light gray line – 86 cm, black line – 120 cm.

summer period reaches in depths of 12 and 31 cm nearly the same values, during winter period the difference of soil moisture in these depths reaches about 5%. Fig. 19 shows clearly than in the depths of 60 cm, 86 cm and 120 cm the course of soil moisture is significantly more equilibrated. In the depth of 120 cm the seasonal minima and maxima of soil moisture are even shifted by up to 3 months and maximal soil moisture is registered in this depth in autumn.

Another important element influencing rock weathering processes and soil processes is the level of underground water. Fig. 20 shows seasonal oscillations of water level in the well near the main GOPE building. In winter, the underground water level reaches the lowest values, and that even −10 m, because a great part of water is bound in snow and ice. Underground water level significantly rises in spring because of snow, ice and frozen soil layer melting, when it is about 6 m to 5 m under the surface. Comparing Tab. 5 and Fig. 20 makes it evident that during summer period the underground water level is significantly influenced by rainfall quantities. The shape of the curve of underground water level is influenced mainly by extreme rainfall events; for instance in the years 2005 and 2006 higher rainfall contributed to a longer period with increased level of underground water. In September 2007 extreme rainfall resulted in an increase of the curve of underground water level manifesting a general decrease tendency. On the contrary, the significant rainfall anomaly in April 2008 did not have any more significant impact on the level of underground water. This might have been caused by insufficient rainfall during the precedent winter period which resulted in a significant reduction of the volume of melting water in spring.

Daily amplitudes of underground water levels are equilibrated. A difference higher than 5 cm was registered in underground water levels only in about 20 days in a year. The highest difference in underground water level was measured on 13 July 2002, when it reached 1.97 m. In spring period, the highest changes in underground water level are registered in March, when this difference is nearly 1 m. In autumn, the differences in underground water level are significantly lower (maximally 0.5 m) and they continue to decrease with the coming winter.

To determine the period with the highest intensity of climate-morphogenetic processes, seasonal course of the above-described time series was compared (Steklá 2010, 2012). Optimal conditions for activities of these processes in the weathered mantle and in the near-surface part of rock massif are in spring, when several climatic factors significantly manifest. In the spring period, soil and air temperature frequently oscillate near the freezing point. Differently from the winter period, soil temperature is characterized by more pronounced daily amplitudes reaching up to 30 °C. Frequent oscillations of soil temperatures near 0 °C stimulate activity of regelation and slope processes (Fig. 21), mainly if this oscillation is accompanied by increased soil moisture. This concurrence is typical especially in spring months when soil moisture oscillates about 35%. Nevertheless, more to the depth soil moisture is decreasing during spring months to reach in the depth of 120 cm only about 20%.

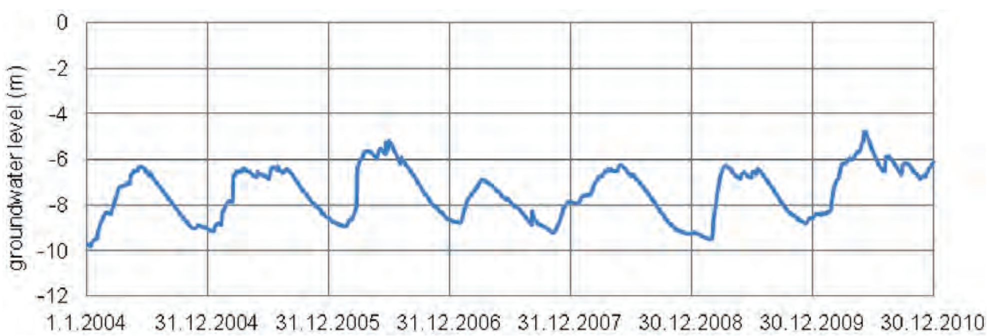

Fig. 20 Mean daily water level depth in a well in the GOPE area (2004–2010, Steklá 2012).

Fig. 21 Biogenic weathering of the granite surface of a degraded tor on a structural-denudational slope of the Čihadlo ridge. Photo: T. Steklá.

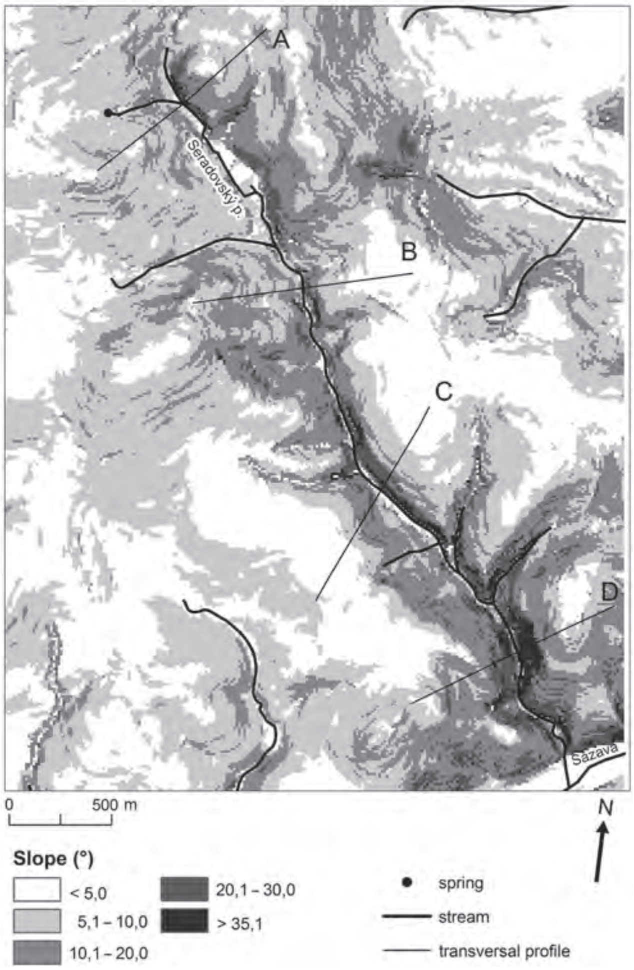

Fig. 22 Slope inclination in the Seradovský potok Brook valley and location of crosswise profiles in the valley. Data: ZABAGED®, Praha ČÚZK; Digital database DIBAVOD [data files], Praha VÚV TGM, 2006.

Daily course of air temperature has in spring months a typical course with minimal temperatures before daybreak and maximal temperatures in the afternoon. Snow, ice and frozen soil melting results in spring also in a significant increase of underground water level. Increased level of underground water causes an increased pressure in rocks (Záruba, Mencl 1987) which contributes to intensity of slope processes, including (in this area mostly slow) slope movements. Another important season of slope processes activities is autumn, when minimal as well as maximal soil and air temperatures are near to spring values. Their mean values are nearly identical and a similar situation was ascertained also in soil moisture. Substantial differences between spring and autumn periods are not found either in underground water level which oscillates around 7 m. Daily course of underground water level is more equilibrated in autumn than in spring and it changes during the day by 2 cm.

3. Geomorphic section between the Pecný ridge and the Sázava valley

Structural-denudational slopes of the south-eastern part of the Pecný ridge rise up above a large asymmetrical source basin and following shallow dell of the Seradovský potok Brook (490–455 m a.s.l.). The height difference between the Pecný top (545 m a.s.l.) and mouthing of this brook into Sázava (284 m a.s.l.) is 261 m at a distance of only less than five km (Fig. 22). This rugged terrain is due to a tectonic uplift of the central part of the Bohemian Massif during the late Cenozoic which significantly increased the intensity of erosional-denudational processes. An example is the development of the Sázava river network in the Quaternary when this tectonic uplift conditioned a pronounced deepening of the Sázava canyon-like valley and significantly influenced also the valleys of its tributaries (Balatka 2007; Balatka, Kalvoda 2010). The impact of deep and retrogressive erosion is evident in the Ondřejovská vrchovina Highland mainly in right-bank affluents of Sázava with V-shaped incised valleys. The most pronounced canyon-like valley southwards from the Pecný ridge is a segment of the lower course of the Seradovský potok Brook mouthing to Sázava (at its river km 46) about 2 km from Chocerady. In the upper part, the Seradovský potok Brook's rock underlayer is formed mainly by wackes and metawackes of the Čerčany metamorphosed island, whereas the lower course valley is deepened into phyllites and porphyries of the Chocerady metamorphosed island. The Central

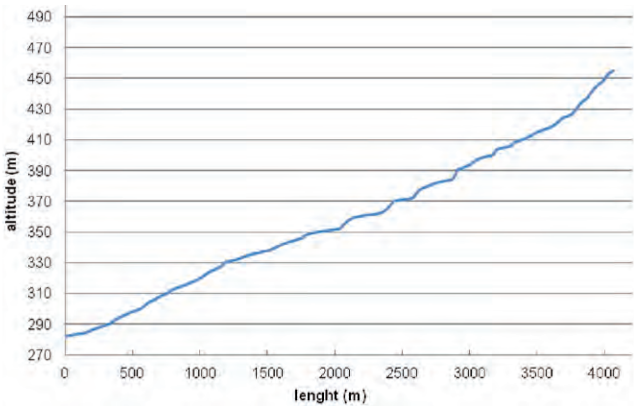

Fig. 23 Lengthwise profile of the Seradovský potok Brook (12 times exaggerated, modified according to Steklá 2012): upper course (river km 4.2–3.5) with maximal valley inclination (51–43‰); middle course (river km 3.5–1.8) with inclination decreased to 38‰ and with frequent changes in the gradient due to accumulations of proluvial sediments and rock steps in the riverbed; lower course (river km 1.8–0.0) with a marked break in the gradient (330 m a.s.l.) at river km 1.2 (up to 42‰) formed by retrogressive erosion of the stream during the Quaternary.

Bohemian Pluton reaches to the Seradovský potok Brook valley by quartz diorites of Benešov type.

Erosional processes in the Seradovský potok Brook valley were examined by geomorphic research inclusive of interpretation of lengthwise and crosswise valley profiles. The shape of the lengthwise profile reflects underlayer lithology variability, presence of discontinuities in the stream bed and vertical movements across the watercourse (compare Bíl, Máčka 1999) as well as changes of erosional base or character of the material in the river bed. For the Seradovský potok Brook valley (Fig. 22) lengthwise profile was created (Fig. 23) as well as four crosswise profiles. Selected crosswise profiles (Fig. 24) are located so as to depict the morphometry of this valley in its different parts (upper course 3.7 km, middle course 2.5 km, lower course 1.5 km and 1 km from its mouthing to Sázava). The position of the documented crosswise profiles is depicted in Fig. 22.

During the 4.07 km of its permanent course, the Seradovský potok Brook has the height difference of 171 m and mean inclination of 42‰. In the lengthwise profile of the Seradovský potok Brook (Fig. 23), three characteristic segments were delimited. The source of the Seradovský potok Brook is in an altitude of 455 m in a large dell situated up to 490 m a.s.l. This dell is deepened into an etchplain of probably Pre-Cretaceous age (546–490 m, Fig. 5) exhumed already in the Lower Palaeogene (Kalvoda 2007; Balatka, Kalvoda 2010). On the upper course between river km 3.4 and 4.0, the Seradovský potok Brook valley inclination is 51‰. From river km 3.7 inclination progressively decreases to 43‰ which is due to more resistant underlying rocks (Benešov granodiorite) as well as to the progressive development of the gradient conditions of the valley. A consequence of lower inclination of the valley bottom is an increased accumulation of proluvial and slope (mostly clayey) sediments of Holocene age. These accumulation landforms are also depicted in the course of crosswise profile A (Fig. 24A) at river km 3.7, where a valley bottom flattening is visible at 430 m a.s.l. These Holocene accumulations are bound to the mouthing of

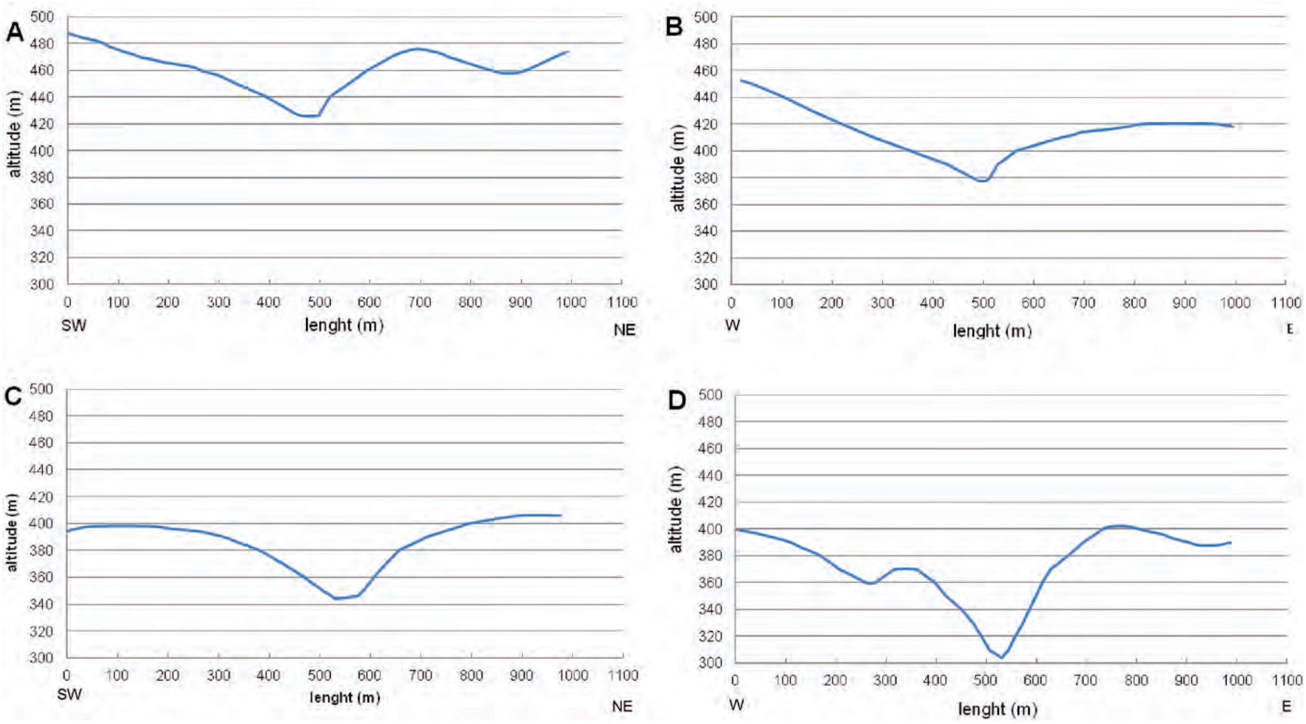

Fig. 24 Crosswise profiles of the Seradovský potok Brook valley (2.5 times exaggerated, modified according to Steklá 2012): position of profiles A to D is depicted in Fig. 22.

the first left-bank affluent of the Seradovský potok Brook. The western part of the profile A cuts the southern margin of a flat dell in the source area of the stream (480 m a.s.l.). The eastern arm of the crosswise profile A depicts a steep slope on the left bank up to the altitude of 480 m, where are relics of mild denudational slopes articulated by erosion of tributaries and ravines of the Seradovský and the Jevanský potok Brooks.

A decreased inclination (38‰) is visible also in the middle course of the Seradovský potok Brook. The bedrock is formed there by medium resistant phyllites of the Chocerady metamorphosed island. In this segment of the crosswise profile there is a great quantity of reduced inclination caused mainly by marked accumulations of proluvial sediments in the place of mouthing of tributaries and ravines and, to a lesser extent, by rock steps in the river bed. At river km 2.5 is the crosswise profile B (Fig. 24B). The western arm of the crosswise profile cuts the eastern slope of the ridge of 493 m a.s.l., i.e. approximately in the altitude of relics of the oldest graded level. Flattening of the valley bottom is caused by a marked alluvial cone at the mouthing of the first right-bank affluent of the Seradovský potok Brook. The right arm of the profile is linked to denudational plateaus and slopes at 420–370 m a.s.l., markedly articulated by stream erosion in the Pleistocene (Kalvoda 2007). Significantly increased inclination in the lower part of the eastern slope is visible in profiles A and B. In profile A, this can be explained by different resistance of the bedrock, whereas in profile B the increased valley slope inclination is probably linked with NW-SE oriented fault zone.

The lowest selected segment of the Seradovský potok valley is situated between river km 0.0 and 2.0. At river km 1.5 is situated the crosswise profile C (Fig. 24C), where the canyon-like character of the valley is already visible (Fig. 25). Due to homogenous bedrock formed by Neo-Proterozoic phyllites and porphyries of the Chocerady island (Fig. 26) the left and the right banks manifest a very similar character. From the flat valley filled by deluvial sediments steep valley slopes rise on both sides, at about 400 m a.s.l. they merge into denudational plateaus and slopes (420–370 m a.s.l.). In the segment between river km 1.0 and 2.0 from the mouthing, the bottom inclination of this valley reaches values only up to 28‰.

Nearer to the Seradovský potok Brook mouthing into Sázava inclination is increasing again to reach values up to 42‰. A break in the gradient of these valley segments is situated in a similar altitude than a pronounced erosional edge of the canyon-like Sázava valley between Ondřejov and Chocerady. Also these parts of the valley are formed in phyllites of Neo-Proterozoic age. These morphological features show that the described break in the Seradovský potok Brook valley gradient represents the reach of the advance of retrogressive erosion during the late Quaternary, when this valley got incised by approximately 50 m. The character of this canyon-like valley is shown in the crosswise profile (river km 1, Fig. 24D). The course of this crosswise profile shows a pronounced canyon-like deepening caused by deep and retrogressive erosion. Profile D is situated in the place of the highest valley gradient and recent erosional activity of the stream, so that no fluvial and slope sediments are deposited there. An increased sediment accumulation is visible in the Seradovský potok Brook valley bottom in the place of a decrease of the gradient, which is at about river km 0.2.

Fig. 25 Canyon-like valley in the lower part of the Seradovský potok Brook is formed by deep and retrogressive erosion stimulated by a tectonic uplift of the Ondřejovská vrchovina Highland during the Quaternary. Photo: T. Steklá.

Fig. 26 Eroded outcrops of metamorphosed basalts and porphyries up to 2 m high at the foot of a steep erosional-denudational slope on the brook left bank in the lower part of the Seradovský potok Brook valley. Photo: T. Steklá.

In the Seradovský potok Brook valley anthropogenous terrain changes are visible in several localities. Erosional activities have been significantly reduced in a large dell of the source area of the first left-bank affluent of the Seradovský potok Brook, where an asphalt road retains water outflow from the neighbouring slopes.

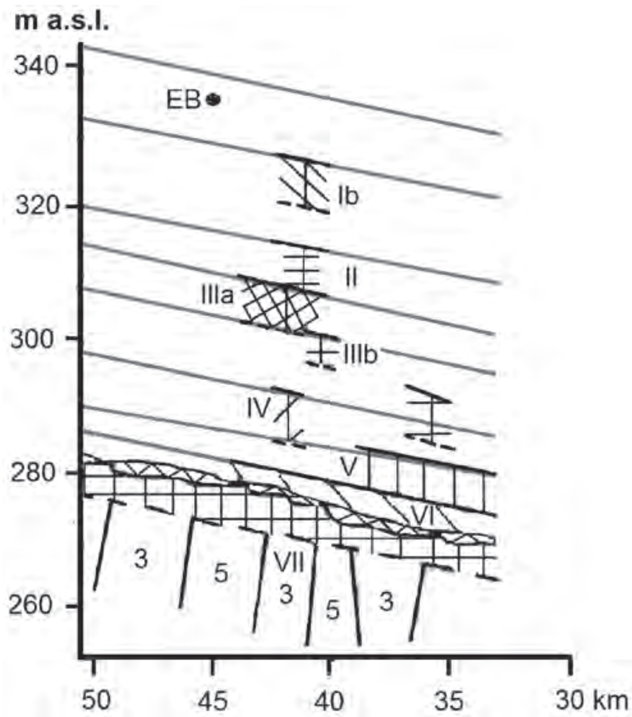

Fig. 27 Segment of the crosswise profile of the Sázava terrace system between river km 35 and 50 in the Ondřejovská vrchovina Highland (Balatka, Kalvoda 2010). I–VII – main levels of Sázava river accumulation terraces of Quaternary age (—— surface, --- base); EB – Pliocene erosional base of the Seradovský potok Brook; 3 – metamorphosed volcanites of the Jílové belt and other metamorphosed Upper Proterozoic rocks, including metamorphosed islands: rhyolites, dacites, andesites, basalts, porphyries, amphibolitic slates and hornstones; 5 – Moldanubian and Central Bohemian Pluton: granites, granodiorites, tonalites and diorites.

Fig. 28 Sázava valley eastwards from Chocerady with relics of the VIth (Poříčí) terrace and flood sediments of Holocene age. Photo: T. Steklá.

Other interventions into the relief are cottages and communications both on erosional slopes and valley bottom accumulations.

Deep and retrogressive erosion of the Seradovský potok Brook is significantly linked to antecedent deepening of the Sázava valley. During the Quaternary, there were formed during the gradual Sázava deepening seven main accumulation terraces and two levels of accumulation or erosion-accumulation origin (Balatka, Kalvoda 2010). It may be ascertained from the local position of relics of river accumulation terraces that the strongest deep erosion occurred in the Middle Pleistocene between the formation of the surface of the IInd and the IIIrd terrace (Fig. 27), when the Sázava valley got deepened by up to 40 m. In the Sázava valley segment between river km 35 and 50, localities of low terrace levels up to 20 m of relative height prevail. In the neighbourhood of Chocerady, only relics of terraces IV, VI and VII are present (Fig. 6), and that in the convex parts of meanders. Near Hvězdonice a small plateau of the IVth (Týnec) terrace is situated (Passer 1967), the surface of which is 17 m above the river level (291 m a.s.l.) and the base 9 m above the water level (283 m a.s.l.). Absence of sediments of the Vth terrace indicates a higher impact of erosion even in the period before the formation of the base of terrace VI. Sediments of the VIth (Poříčí) terrace are maintained in a narrow belt of the fluvial plain (Fig. 28). The surface of this terrace is 5–6 m above the Sázava level and it passes through a mild slope into the alluvial plain with its surface at 283 m a.s.l. and its base at 278 m a.s.l. Sediments of the VIIth terrace form the filling of the present-day valley bottom which is covered by flood sediments.

4. Discussion

The present-day state of the landscape environment in the GOPE locality which can be documented by different observations and measurements is only a short segment of palaeogeographical history of the Ondřejovská vrchovina Highland in the Quaternary. Recent morphogenetic processes are governed by co-evolution of climate, water supply (e.g. soil moisture dynamics) and vegetation. Monitoring of recent landform changes in the area of GOPE confirmed that regelation and frost processes, gully and fluvial erosion, slow slope movements and anthropogenous activities have a significant impact in rugged relief. Intensity of exogenous processes corresponds (according to our expectations) to combination of seasonal air and soil temperature changes and above all to water content in the rock massif and the weathered mantle. Fortunately, rapid geomorphic events and processes in the area of GOPE were not identified during more than 20 years of observations. Serious exceptions were a) the thunderbolt during windstorm in August 2013 which directly hit and damaged meteorological station in the area of GOPE, and b) continuing man-made deforestation of the Pecný ridge. It substantially changes thermal conditions on the surface of slopes, accelerates circulation of precipitation water (and snow) and also supports movements of weathered rocks, slope sediments and soils. Analysis of impacts of recent morphogenetic processes on multiannual course of geophysical (e.g. gravimetrical) measurements is now being performed.

Suitable location of scientific observatories on the ridge of Pecný and in its near neighbourhood is to a certain degree menaced by steadily increasing population density, transport network and growing and forestry activities in the Ondřejovská vrchovina Highland. Efforts to locally limit anthropogenous impacts directly in the observatories area are insufficient and, mainly from the long-term perspective, little efficient. In addition, the whole region is affected by increasing dust and/or industrial air pollution as well as by light pollution (due to Prague and other settlement complexes) which have been long years limiting or excluding number of astronomical and geodetical observations. Unique characteristics of the area of scientific observatories in the southern part of the Ondřejovská vrchovina Highland are: 1) favourable location in the central part of the Bohemian Massif enabling their integration into international networks measuring recent dynamics of main tectonic units in Central Europe and 2) a specifically differentiated geodiversity of this orographical unit with a high energy of the relief which has been developing already since the Palaeogene.

Development of the antecedent Sázava valley in the late Cenozoic had a significant impact on formation of landform patterns of the Ondřejovská vrchovina Highland which is markedly articulated by the valley of Sázava and its tributaries. The present-day river network has been formed already since the Upper Miocene when Saxonian tectonic movements caused breaking of the original Oligocene planation surface. Uplift of the watershed area between Labe and Sázava in the Neogene resulted into significant changes in the Sázava course (Novák 1932; Balatka, Sládek 1962; Balatka, Kalvoda 2010). Erosional activities of this new stream revived at the same time retrogressive and deep erosion on its affluents. The extent of the Pliocene deepening of Sázava in the territory of the Ondřejovská vrchovina Highland is near to the height difference of the Palaeogene planation surface (470–420 m a.s.l.) and the upper erosional edge of the canyon-like Sázava valley (350–340 m a.s.l., Kalvoda 2007).

The ongoing epeirogenetic uplift of the central parts of the Bohemian Massif during the Quaternary resulted into intensification of erosion-denudational processes (Balatka 2007; Balatka, Kalvoda 2010). In the southern part of the Ondřejovská vrchovina Highland lateral and deep erosion formed relatively steep slopes of the canyon-like Sázava valley with a relative height of 60–75 m. Geomorphological analysis and interpretation of valley profiles of the Seradovský potok Brook indicate that during the Quaternary the retrogressive erosion reached river km 1.2 (Steklá 2012). This is documented above all from the position of a pronounced gradient break in the longitudinal profile across the Seradovský potok Brook valley in the place of the probably Pliocene erosional base of the stream. This step is in an altitude of about 330 m, which is near to the local height of the erosional edge of the Sázava antecedent valley between Ondřejov and Chocerady at 350–340 m a.s.l. (Kalvoda 2007). In the lower part of Seradovský potok Brook valley the stream deepened approximately by 50 m during the Upper Quaternary. These phenomena of pronounced deep and retrogressive erosion were ascertained also in the development of valleys of other affluents in the lower course of Sázava (Kuncová 2005; Balatka, Štěpančíková 2006). Right bank Sázava affluents in the Ondřejovská vrchovina Highland and also in its lower course are shorter than the left bank ones and have also a higher gradient. Significant from the morphostructural perspective are lithological characteristics of rocks and boundary of individual geological units.

Geomorphology as a part of the Earth Science deals with the dynamics of landforms at the interface of lithosphere, atmosphere, hydrosphere and biosphere. Determined geomorphic evolution of the Ondřejovská vrchovina Highland during the Quaternary as well as monitoring of present-day climate-morphogenetic processes in the GOPE locality give substantial evidence for high intensity of landform and landscape transience. Observing and measuring of recent geodynamical processes and phenomena must be interpreted on the basis of data on palaeogeographical and current changes of the environment in the area of scientific observatories. Correlation of present-day geomorphic phenomena with running geophysical measurements can also be a contribution to bridge the gap between studies of recent morphogenetic processes and recognition of long-term history of landforms.

5. Conclusions

Astronomical and Earth sciences observatories in the Ondřejovská vrchovina Highland are traditionally an important experimental locality in Central Europe. The large complex of GOPE with its permanent GPS station and other high-quality geophysical and meteorological equipment has an excellent morphostructural position for research into recent geodynamics of orographic units in Europe. This paper deals with the physical-geographical environment and landforms in the GOPE locality, inclusive evaluation of local climatic conditions in relation to recent morphogenetic processes and evolution of geomorphic profile between the Pecný ridge and the canyon-like Sázava valley in the Ondřejovská vrchovina Highland.

In the rugged terrain of the GOPE locality there is a significant impact of regelation and frost processes, gully and fluvial erosion, slow slope movements and anthropogenous activities. Intensity of recent morphogenetic processes and phenomena corresponds to combination of seasonal air and soil temperature changes and above all to water content in the rock massif and its weathered mantle. It was confirmed that optimal conditions for these processes are in spring, when soil and air temperatures often oscillate about the frost point. Differently from the winter period, soil temperature manifests also more pronounced daily amplitudes reaching up to 30 °C. Frequent soil temperature oscillation about 0 °C is very favourable for activities of regelation and slope processes, especially when this oscillation is connected with increased soil moisture of about 35%. Snow, ice and frozen soil melting in spring causes an increased level of underground water which supports intensity of slope processes, including the small ones. Another period of slope processes activities is autumn when both minimal and maximal soil and air temperatures and also increased soil moisture are near to the spring values.

The extent of landform changes in the southern part of the Ondřejovská vrchovina Highland caused by erosional and denudation processes is proportional to the high potential energy of the relief due to tectonic uplift of the central part of the Bohemian Massif in the late Cenozoic. This progressive uplift is documented above all by gradual layout of denudational surfaces and slopes from the hill parts of the Ondřejovská vrchovina Highland down to the antecedent Sázava valley. The extent of erosional and denudational processes between the Pecný ridge (545 m a.s.l.) and the Sázava valley (284 m a.s.l.) was documented by the development of the Seradovský potok Brook valley, the source area and the upper course of which are disturbing in the Palaeogene exhumed etchplain. The middle part of the Seradovský potok Brook valley crosses lower denudational plateaus (420–370 m a.s.l.) the erosional dissection of which occurred probably in the period going from the Upper Pliocene to the Lower Pleistocene. In the lower part of its valley, the Seradovský potok Brook deepened during the late Quaternary approximately by 50 m, whereas the relatively steep erosional slopes of the canyon-like part of the Sázava valley have a relative height of 60–75 m. Besides the tectonic uplift, lithological and structural characteristics of bedrock, development of landforms and specific geodiversity of the Ondřejovská vrchovina Highland were significantly influenced by changes of climatic conditions during the Quaternary.

At present, we analyse and interpret, from the geodynamical perspective, impacts of ascertained climate-morphogenetical processes on multiannual course of geophysical and geodetical measurements in the GOPE locality. Favourable geodynamic location of scientific observatories on the ridge of Pecný, which is stable from engineering-geological and geomorphological perspective, and in its near proximity is to a certain degree menaced by increasing intensity of anthropogenous activities in the landscape.

Acknowledgements

The paper was carried out under auspices of the project LC506 "Recent dynamics of the Earth" of the Ministry of Education, Youth and Sport of the Czech Republic and the programme PRVOUK No. 43 "Geography" of the Charles University. The authors wish to thank to RNDr. Jiří Kastner for his valuable cooperation during meteorological observations at the GOPE.

REFERENCES

AMBROŽ, V. (1943): Periglaciální zjevy u Jevan. Zprávy geologického ústavu pro Čechy a Moravu 1 (5), 219–230.

Atlas podnebí Česka (2007): Climate atlas of Czechia [Měřítko 1 : 2 000 000]. Praha, Czech Hydrometeorological Institute.

BALATKA, B. (2007): River terraces and the Sázava Valley evolution. In: GOUDIE, A. S., KALVODA, J. (eds.): Geomorphological Variations. Praha, P3K, 361–386.

BALATKA, B., KALVODA, J. (2006): Geomorfologické členění reliéfu Čech. Geomorphological regionalization of the relief of Bohemia. – Kartografie Praha a.s., 79 p., 3 maps, Prague.

BALATKA, B., KALVODA, J. (2010): Vývoj údolí Sázavy v mladším kenozoiku. Praha, Nakladatelství České geografické společnosti, 198p.

BALATKA, B., SLÁDEK, J. (1962): Říční terasy v českých zemích. Praha, Geofond v NČSAV.

BALATKA, B., ŠTĚPANČÍKOVÁ, P. (2006): Terrace system of the middle and lower Sázava river. Geomorphologica Slovaca 1, 69–81.

BALATKA, B., GIBBARD, P., KALVODA, J. (2010a): Morphostratigraphy of the Sázava river terraces in the Bohemian Massif. Acta Universitatis Carolinae Geographica 45(1–2), 3–34.

BALATKA, B., GIBBARD, P., KALVODA, J. (2010b): Evolution of the Sázava valley in the Bohemian Massif. Geomorphologia Slovaca et Bohemica 10(1), 55–76.

BALATKA, B., KALVODA, J., GIBBARD, P. (2015): Morphostratigraphical correlation of river terraces in the central part of the Bohemian Massif with the European stratigraphical classification of the Quaternary. Acta Universitatis Carolinae Geographica 50(1), 63–73. https://doi.org/10.14712/23361980.2015.87

BÍL, M., MÁČKA, Z. (1999): Využití spádových indexů řek jako indikátorů tektonických pohybů na zlomech. Geologický výzkum Moravy a Slezska v roce 1998, 2–5.

BOUČEK, B., KODYM, O. (1963): Geologie II. Praha, Nakladatelství ČSAV.

BRUNCLÍK, O. (1956): Ještě k periglaciálním zjevům na Jevansku. Ochrana přírody 11(6), 179–181.

CICHA, I. et al. (1984): Půdní mapa ČR 1 : 50 000, list 13-31 Říčany. Praha, ČGÚ.

CULEK, M. et al. (1996): Biogeografické členění ČR. Praha, Enigma.

CZUDEK, T. (2005): Vývoj reliéfu krajiny České republiky v kvartéru. Brno, Moravské zemské muzeum.

DANEŠ, J. V. (1913): Morfologický vývoj středních Čech. Sborník České společnosti zeměvědné 19, 1–18, 94–108, 169–176.

Data ZABAGED, ČÚZK. Mapové jednotky: 10600716–10700720.

DEMEK, J. et al. (1987): Zeměpisný lexikon ČSR. Hory a nížiny. Praha, Academia.

DEMEK, J., MACKOVČIN, P. (eds) et al. (2006): Zeměpisný lexikon ČR. Hory a nížiny. Brno, 2. vydání, AOPAK ČR.

DIGITÁLNÍ DATABÁZE DIBAVOD [datové soubory]. Praha VÚV TGM, 2006.

DOMAS, J. et al. (1993): Vysvětlivky k souboru geologických a ekologických účelových map přírodních zdrojů 1 : 50 000, list 13-31 Říčany. Praha, Český geologický úřad.

GeoINFO: geovědní informace na území ČR [online]. 2003 [cit. 2012-01-15]. Dostupné z www: <http://mapy.geology.cz/website/GEOinfo/>.

CHLUPÁČ, I. et al. (2002): Geologická minulost České republiky. Praha, Academia.

KACHLÍK, V. (1992): Litostratigrafie, paleogeografický vývoj a metamorfní postižení hornin pláště v SV části ostrovní zóny středočeského plutonu. Kandidátská disertační práce, PřF UK v Praze.

KALVODA, J. (2005): Activities of Czech Geomorphologists in the Research Centre for Earth Dynamics. In: PANIZZA, M.: International Association of Geomorphologists. Geomorphology 66(1–4), 385–388, 386–387.

KALVODA, J. (2007): Morphostructural evolution of the relief in the locality of the Geodynamic Observatory Pecný, the Ondřejovská vrchovina Highland, Czech Republic. In: GOUDIE, A. S., KALVODA, J. (eds.): Geomorphological Variations. Praha, P3K, 387–407.

KALVODA, J., KOSTELECKÝ, J. (JR.), KOSTELECKÝ, J. (2004): A pilot morphotectonic interpretation of position changes of the permanent GPS stations in Central Europe. In: DRBOHLAV, D., KALVODA, J., VOŽENÍLEK, V. (eds): Czech Geography at the Dawn of the Milenium. Olomouc, Palacky University in Olomouc, 113–123.

KASTNER, J., KOSTELECKÝ, J., KALVODA, J. (2012): Soubor meteorologických dat stanice Pecný. Archiv údajů monitoringu v lokalitě GOPE (VÚGTK), Katedra fyzické geografie a geoekologie PřF UK.

KOHOUTKOVÁ, P. (2002): Vegetace a přírodní podmínky povodí Zvánovického potoka. Magisterská práce. PřF UK.

KOSTELECKÝ, J. (Jr.), KOSTELECKÝ, J. (2003): Analysis of the relative velocities of the EPN – new results after four years. Proc. EGS-AGU-EUG G17 Symposium: Geodetic and geodynamic programmes of the CEI. (Nice, France, April 2003). Reports on Geodesy 1(64), 121–132.

KOSTELECKÝ, J., VONDRÁK, J., ZEMAN, A., KALVODA, J., SCHENK, V. (2005a): Center of Earth's Dynamics Research (CEDR) – results of five years activity. Proc. EGU G9 Symp. (Vienna, Austria, April 2005). Reports on Geodesy 2(73), 67–83.

KOSTELECKÝ, J. et al. (2005b): Projekt Výzkumného centra dynamiky Země „Recentní dynamika Země". Praha, VCDZ.

KOSTELECKÝ, J. et al.: Soubor dat vlhkosti půdy a hladiny podzemní vody v areálu GOPE. Ondřejov, Archiv VÚGTK, LM2010008 CzechGeo/Epos MŠMT ČR.

KRÁL, V. (1985): Zarovnané povrchy České vysočiny. Praha, Academia.

KUNCOVÁ, M. (2005): Geomorfologie středního toku Sázavy v okolí Senohrab. Praha, Magisterská práce, PřF UK.

KUNSKÝ, J. (1968): Fyzický zeměpis Československa. Praha, Státní pedagogické nakladatelství.

KVĚTOŇ, V. (2001): Normály teploty vzduchu na území České republiky v období 1961–1990 a vybrané teplotní charakteristiky období 1961–2000. Praha, Národní klimatický program ČR.

LOŽEK, V. (1973): K historii eroze půdy v holocénu. In: ŠILAR, J. (ed.): Ochrana a tvorba životního prostředí (Úlohy geologických věd). Sborník referátů symposia konaného 26. dubna 1972 k 10. výročí založení Ústavu geologických věd PřF UK v Praze, 16–25.

MÍSAŘ, Z. et al. (1983): Geologie ČSSR I. Český masiv. Praha, Státní pedagogické nakladatelství.

MOSCHELESOVÁ, J. (1930): Vlnité prohyby o velké amplitudě v jižních Čechách. Sborník Československé společnosti zeměpisné 36, 155–158.

NEUHÄUSLOVÁ, Z. et al. (1998): Mapa potenciální přirozené vegetace České republiky. Praha, Academia.

NOVÁK, V. J. (1932): Vývoj úvodí a údolí řeky Sázavy. Věstník Královské České společnosti nauk 11, 47.

OBEC ONDŘEJOV [online]. JAS AIR spol. s.r.o. [cit. 2017]. Dostupné z: http://www.obecondrejov.cz

ONDŘEJOVSKÁ HVĚZDÁRNA 1898−1998 (1998): Sborník o české a moravské astronomii uspořádaný ke 100. výročí Ondřejovské hvězdárny a 650. výročí University Karlovy. Praha, Astronomický ústav AV ČR.

ORLOV, A. (1933): Problémy středočeského plutonu. Věda přírodní 16(2/3), 43–48.

OSMANČIK, V. (2005): Hodnocení břehové vegetace Jevanského potoka. Praha, Magisterská práce, PřF UK.

PÁLINKÁŠ, V., KOSTELECKÝ, J. (JR) (2003): One year of repeated measurements by the absolute gravimeter FG5 No. 215 and calibration of tidal gravimeters by absolute gravity measurements. In: TZIAVOS, I. N. (ed.): Proc. 3rd Meeting IGGC Gravity and Geoid, August 2002, Thessaloniki, Ziti Edit., 61–65.

PÁNEK, T., KAPUSTOVÁ, V. (2016): Long-Term Geomorphological History of the Czech Republic. In: PÁNEK, T., HRADECKÝ, J. (eds): Landscapes and Landforms of the Czech Republic. World Geomorphological Landscapes, Springer International Publishing, 26 – 39. https://doi.org/10.1007/978-3-319-27537-6_5.

PASSER, M. (1967): Závěrečná zpráva Mirošovice – Soutice – Měřín. Surovina: cementové stabilizace. Geologický průzkum. Praha, MS Geofond P 20 266.

PELÍŠEK, J., SEKANINOVÁ, D. (1979): Pedogeografická mapa ČSR 1 : 200 000, list Praha B3. Brno, Geografický ústav ČSAV.

QUITT, E. (1971): Klimatické oblasti Československa. Brno, Geografický ústav ČSAV.

SLEZÁK, M. (2002): Pasportizace a návrh ochranného managementu rybníků Jevanské soustavy. Praha, Diplomová práce, ČZU.

SOBÍŠEK, B. (2000): Rychlost a směr větru na území České republiky v období 1961–1990. Praha, Národní klimatický program ČR.

STEKLÁ, T. (2010): Přírodní prostředí lokality geodynamické observatoře Pecný v Ondřejovské vrchovině. Bakalářská práce, PřF UK.

STEKLÁ, T. (2012): Recentní morfogenetické procesy v lokalitě geodynamické observatoře Pecný. Magisterská práce, PřF UK.

Strimelice.banet [online]. 2012 [cit. 2007]. Dostupné z: www.strimelice.banet.cz

TOMÁŠEK, M. (2003): Půdy České Republiky. Praha, Česká geologická služba.

TOMEČEK, J. (2007): Geomorfologie lokality Skalka v Ondřejovské vrchovině. Magisterská práce, PřF UK.

VAJNER, V. (1960): Přehled geologických poměrů území mezi Říčany a Ondřejovem ve středních Čechách. Diplomová práce, PřF UK.

VLČEK, V. et al. (1984): Vodní toky a nádrže – zeměpisný lexikon ČSR. Praha, Academia.

ZÁRUBA, Q., MENCL, V. (1987): Sesuvy a zabezpečování svahů. Praha, Academia.

RESUMÉ

Povrchové tvary a morfogenetické procesy v lokalitě Geodetické observatoře Pecný, Ondřejovská vrchovina

Práce se zabývá fyzicko-geografickým prostředím a souborem povrchových tvarů v lokalitě Geodetické observatoře Pecný (GOPE), hodnocením místních klimatických podmínek ve vztahu k recentním morfogenetickým procesům a kvartérnímu

vývoji reliéfu mezi hřbetem Pecného a kaňonovitým údolím Sázavy v Ondřejovské vrchovině. V členitém reliéfu lokality GOPE se výrazně uplatňují regelační a mrazové procesy, stružková a fluviální eroze, pomalé svahové pohyby a antropogenní činnost. Intenzita recentních morfogenetických procesů a jevů odpovídá kombinaci sezónních změn teploty vzduchu a půdy a zejména množství vody v horninovém masivu a zvětralinovém plášti. Bylo potvrzeno, že optimální podmínky pro aktivitu těchto procesů jsou na jaře, kdy dochází k častému kolísání teploty půdy a vzduchu kolem bodu mrazu. Na rozdíl od zimního období se teplota půdy vyznačuje také výraznějšími denními amplitudami, které dosahují až 30 °C. Častá kolísání teploty půdy okolo 0 °C jsou velmi příznivá pro aktivitu regelačních a svahových procesů zejména tehdy, je-li toto kolísání spojeno se zvýšenou vlhkostí půdy, která se pohybuje kolem 35 %. Vlivem tání sněhu, ledu a zmrzlé půdy dochází na jaře i k výraznému nárůstu hladiny podzemní vody, což podporuje intenzitu svahových procesů, včetně svahových pohybů. Dalším významným obdobím aktivity svahových procesů je podzim, kdy jsou minimální i maximální teploty půdy a vzduchu a také zvýšená vlhkost půdy velmi blízké jarním hodnotám.

Rozsah změn povrchových tvarů Ondřejovské vrchoviny působením erozních a denudačních procesů je úměrný vysoké potenciální energii reliéfu, která vznikla postupným tektonickým výzdvihem centrální části Českého masivu v mladším kenozoiku. Údolí Seradovského potoka mezi hřbetem Pecného (545 m n. m) a dnem údolí Sázavy (284 m n. m.) protíná několik úrovní zarovnaných povrchů, přičemž jeho pramenná oblast eroduje etchplén exhumovaný v paleogénu. Údolí střední a dolní části Seradovského potoka prochází napříč denudačními plošinami (420–370 m n. m.), a k jejich eroznímu rozčlenění došlo pravděpodobně v období od svrchního pliocénu do staršího pleistocénu. Ve spodní části údolí Seradovského potoka došlo během mladšího kvartéru k zahloubení toku přibližně o 50 m. Poměrně strmé erozní svahy kaňonovité části antecedentního údolí Sázavy mají relativní výšku 60–75 m. Kromě tektonického výzdvihu, litologických a strukturních vlastností hornin se na vývoji povrchových tvarů a specifické geodiverzity Ondřejovské vrchoviny významně podílely změny klimatických podmínek v kvartéru.

V současné době se zabýváme analýzou a geodynamickou interpretací vlivů zjištěných recentních klimato-morfogenetických procesů na víceletý chod geofyzikálních a geodetických měření v lokalitě GOPE. Výhodné geodynamické umístění areálu vědeckých observatoří na inženýrsko-geologicky stabilním hřbetu Pecného a v jeho blízkém okolí je ohrožováno zvyšující se intenzitou antropogenní činnosti v krajině.

Tereza Steklá
Faculty of Science, Charles University
Department of Physical Geography and Geoecology
Albertov 6, 128 43 Praha 2
Czech Republic
E-mail: tereza.stekla@gmail.com

Jan Kalvoda
Faculty of Science, Charles University
Department of Physical Geography and Geoecology
Albertov 6, 128 43 Praha 2
Czech Republic
E-mail: kalvoda@natur.cuni.cz

Jakub Kostelecký
Research Institute of Geodesy, Topography and Cartography
Geodetic Observatory Pecný
251 65 Ondřejov 244
Czech Republic
E-mail: jakub.kostelecky@pecny.cz

SNOW ACCUMULATION AND ABLATION IN DIFFERENT CANOPY STRUCTURES AT A PLOT SCALE: USING DEGREE-DAY APPROACH AND MEASURED SHORTWAVE RADIATION

MICHAL JENÍČEK, ONDŘEJ HOTOVÝ, ONDŘEJ MATĚJKA

Charles University, Faculty of Science, Department of Physical Geography and Geoecology, Czech Republic

ABSTRACT

The knowledge of water volume stored in the snowpack and its spatial distribution is important to predict the snowmelt runoff. The objective of this study was to quantify the role of different forest types on the snowpack distribution at a plot scale during snow accumulation and snow ablation periods. Special interest was put in the role of the forest affected by the bark beetle (*Ips typographus*). We performed repeated detailed manual field survey at selected mountain plots with different canopy structure located at the same elevation and without influence of topography and wind on the snow distribution. A snow accumulation and ablation model was set up to simulate the snow water equivalent (SWE) in plots with different vegetation cover. The model was based on degree-day approach and accounts for snow interception in different forest types.

The measured SWE in the plot with healthy forest was on average by 41% lower than in open area during snow accumulation period. The disturbed forest caused the SWE reduction by 22% compared to open area indicating increasing snow storage after forest defoliation. The snow ablation in healthy forest was by 32% slower compared to open area. On the contrary, the snow ablation in disturbed forest (due to the bark beetle) was on average only by 7% slower than in open area. The relative decrease in incoming solar radiation in the forest compared to open area was much bigger compared to the relative decrease in snowmelt rates. This indicated that the decrease in snowmelt rates cannot be explained only by the decrease in incoming solar radiation. The model simulated best in open area and slightly worse in healthy forest. The model showed faster snowmelt after forest defoliation which also resulted in earlier snow melt-out in the disturbed forest.

Keywords: snow accumulation, snowmelt, degree-day model, forest disturbance

Received 15 September 2016; Accepted 11 November 2016; Published online 27 February 2017

1. Introduction

The effects of forest cover on snow accumulation and ablation have been widely studied in last decades. However, at a catchment scale, there is still no comprehensive explanation how sensitive is snowmelt runoff to changes in mountain forest cover (Pomeroy et al. 2012). At a small spatial scale, the snow accumulation and ablation is controlled dominantly by local topography and vegetation (Jost et al. 2007). The differences between snow water equivalent (SWE) in a forest compared to open area have been described in many studies. These differences may be explained by 1) the increase in snow interception on forest canopy which reduces snow accumulation on the earth surface due to snow sublimation and evaporation (Essery et al. 2003; Varhola et al. 2010), and 2) the decrease in incoming solar radiation with increasing canopy density (Ellis and Pomeroy 2007; Hribik et al. 2012). Generally, forest significantly affects energy exchange between the snowpack and atmosphere. The forest reduces the ablation rates by attenuating solar radiation and near-surface wind speed (López-Moreno and Stähli 2008; Molotch et al. 2009).

Many studies showed that snow accumulated in forests is by 40–50% lower than that in nearby open areas (see e.g. Bartík et al. 2014; Jenicek et al. 2016, 2015; Jost et al. 2007; Stähli and Gustafsson 2006). The study performed in experimental forested mountain plots in central Europe showed that up to 60% of cumulative snowfall was intercepted and sublimated (Holko et al. 2009).

The shortwave radiation is reflected on tree needles causing its reduction under forest canopy. Up to 90% of the incoming shortwave radiation is reflected back to the atmosphere in case of dense coniferous forest (e.g. Aubin et al. 2011; Sicart et al. 2004). This reducing effect is important during snow ablation period causing faster snowmelt in open area compared to forest.

Previously mentioned effects are widely influenced by changes in canopy structure caused by harvesting or various forest disturbances such as windstorms and the bark beetle attacks. The changes in forest structure significantly affect the snow interception and amount of shortwave and longwave radiation. It strongly affects both the snow accumulation (with expected increase in maximum SWE due to reduced snow interception) and snow ablation (with expected faster snowmelt after forest decay due to increasing shortwave radiation), although the impacts are not fully described and may be influenced by several other parameters (Biederman et al. 2014; Pomeroy et al. 2012).

The objective of our study was to quantify the role of different forest types on the snowpack distribution at a plot scale during snow accumulation and snow ablation periods. More specifically, we performed detailed manual filed survey at selected plots located at the same elevation and without influence of topography and wind on the snow distribution. Thanks to this sampling configuration it was possible to explore the effect of canopy structure on the snowpack distribution separately. This is not a new topic, but our study focused more on the effect of different forest types including disturbed forest due to the bark beetle during both snow accumulation and snow ablation periods. We benefit from detailed repeated manual snow depth and SWE measurement supported by continuous monitoring of meteorological variables including snow depth, SWE and shortwave radiation (both incoming and reflected).

2. Material and methods

2.1 Study area and data monitoring

We performed detailed field survey of snow depth, snow density and SWE in four plots located in the Ptačí Brook catchment, which is an experimental catchment of the Charles University (Fig. 1). The Ptačí Brook catchment covers an area of 4 km^2 and it is located in the Šumava Mountains (Bavarian forest) in the southwest part of the Czech Republic. The catchment is located from 1130 to 1330 m a.s.l with prevailing west, north and east oriented slopes with mean slope gradient 6° (with maximum up to 30°). The Ptačí Brook has snow-dominating runoff regime with highest runoff volume approximately from late March to beginning of May caused by melting snow. The dominant tree species is Norway spruce (*Picea abies*), although large parts of forests were damaged by the bark beetle (*Ips typographus*). Both windstorms and the bark beetle are the main factors causing land cover changes in the Šumava Mountains, which has an effect on interception, evaporation and consequently runoff (Kliment et al. 2011; Kocum et al. 2016; Langhammer et al. 2015a, 2015b).

Studied catchment is equipped with measurement of precipitation (only warm period), air, snow and soil temperature, air moisture, shortwave and longwave radiation, SWE and ultrasonic measurement of snow depth. The winter precipitation using heated rain gauge is measured at the meteorological station Modrava which is located 4 km from the Ptačí Brook catchment. The SWE is measured directly in the study catchment in open area using Snow Pack Analyzer SPA (Sommer Messtechnik). This device uses three strips measuring the impedance of the snowpack and calculates the ratio of ice, air and liquid water in the snowpack which is further used to calculate the snow density. Two strips are placed horizontally in 5 cm and 25 cm above the earth surface and the third strip is placed diagonally providing the aggregate information from the entire snow column.

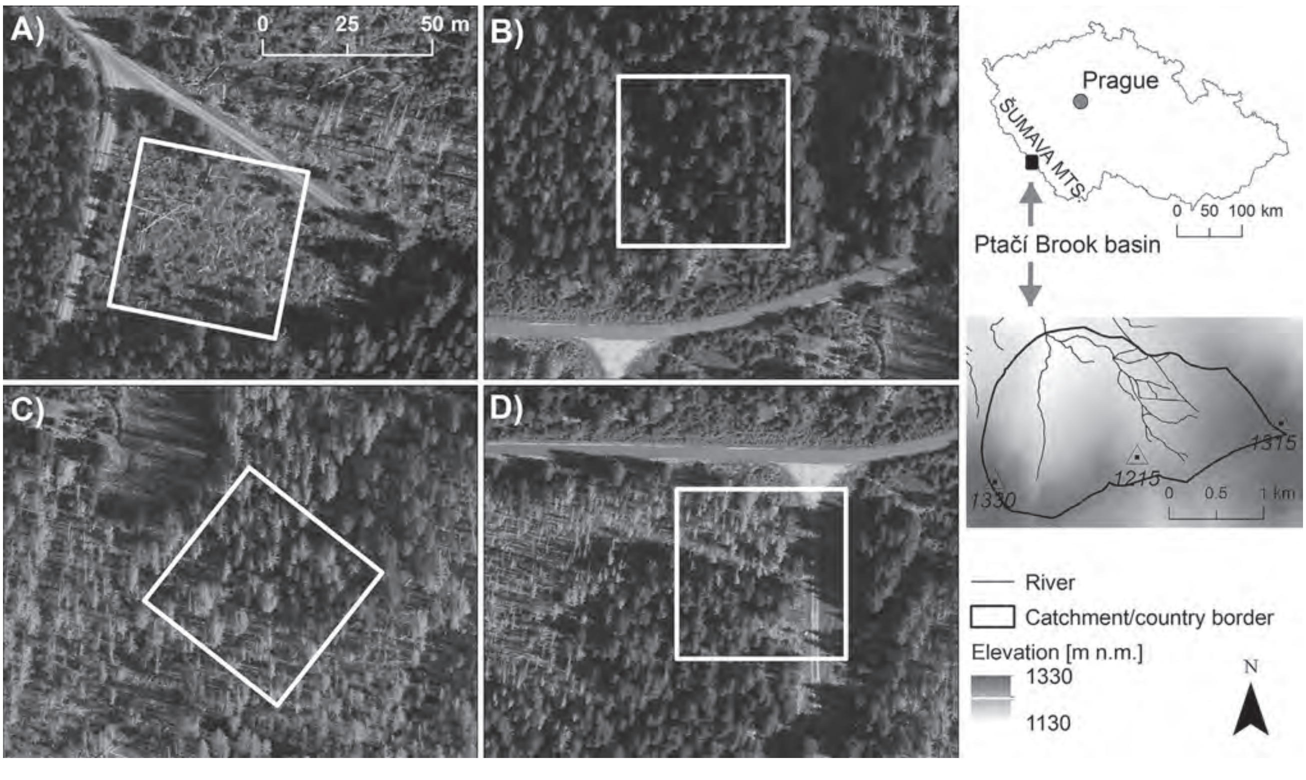

Fig. 1 Geographical location of the Ptačí Brook catchment. Airborne images of individual sampling sites show their vegetation structure; open area (A), healthy coniferous forest (B), disturbed forest due to the bark beetle (C) and mixed vegetation (D) (Data: Czech Office for Surveying, Mapping and Cadastre ČÚZK).

The incoming and reflected shortwave and longwave radiation is measured using CNR4 Net Radiometer (Kipp and Zonen). This device consists of two pyranometers (first is oriented upward, second is oriented downward) and two pyrgeometers (same configuration as for pyranometers). Thanks to this configuration, the global and reflected radiation is measured enabling albedo calculation. The device was supplemented with air temperature measurement. We used three net radiometers placed in open area (neighboring area to plot A, Fig. 1), healthy coniferous forest (plot B) and disturbed coniferous forest due to the bark beetle (plot C).

2.2 Sampling strategy and spatial data interpolation

We applied a simple sampling design at a plot scale at four locations representing major vegetation categories typical for the study area; open area (plot A), healthy (green) coniferous forest (plot B) and disturbed forest due to the bark beetle (plot C). First three plots represent these three categories; the fourth plot has a mixed vegetation consisting with all previously specified vegetation categories (plot D, Fig. 1).

Each plot has an area 50 × 50 meters. The snow depth was manually measured each tenth meter which results in raster containing 36 values of the snow depth. The bulk snow density was measured five times using a snow tube and a digital scale (measurement resolution 10 g). The five points with snow density measurement were located uniformly within the plot; one in the middle and the four were located near every corner always 10 meters from the plot edges (inside the plot). The mean bulk snow density was used to calculate the SWE in each raster cell resulting in 36 SWE values for each plot.

Manual field surveys of snow depth, snow density and SWE were carried out five times during one winter season 2015/2016; 4 February 2016, 19 February 2016, 19 March 2016, 1 April 2016 and 6 April 2016. The first three sampling dates represent snow accumulation period (interrupted with partial snowmelt due to rain-on-snow event) with maximum snow storage close to 19 March 2016. A period between last two sampling dates (01 Apr – 06 Apr) represents snowmelt caused by high air temperature and high solar radiation without precipitation. This period represents the major snowmelt period in the study area.

Data were interpolated using Natural neighbor method. Interpolated rasters containing SWE data from all plots in 1 Apr 2016 and 6 Apr 2016 were used to calculate ablation rates by subtracting the rasters from each other. The size of raster pixel was set to 0.5 m.

2.3 The snow accumulation and ablation model based on the degree-day approach

A snow accumulation and ablation model was set up to simulate the snow evolution in plots with different vegetation cover. Although, we are aware that the snow ablation is driven by the complex energy balance, our aim was to apply simple procedures to enable easier application in areas without detail meteorological monitoring. The simplified equation of the model calculating the snow water equivalent S for time interval t is (Eq. 1):

$$S_t = S_{t-1} + P_\mathrm{t} - A_r - m_\mathrm{f}\,(T_\mathrm{t} - T_\mathrm{cmelt}), \qquad (1)$$

All parameters with detailed explanation are listed in Table 1. The model was written in R programming language (R Core Team 2016). The model accounts for snow and rain interception using multiplication factors applying for precipitation P (ICFS, Interception Correction Factor for Snow; ICFR, Interception Correction Factor for Rain). Different factors for different vegetation cover were applied. In case of our model, the initial value of the ICFS was based on measured differences between SWE in the open area (plot A) and in other sampling locations. Solid precipitation was adjusted for undercatch using Snowfall Correction Factor (SFCF) due to wind affecting the capture of the snow flake into a rain gauge. Because the data of precipitation phase were not available, the differentiation between snow and rain has been done by a threshold temperature (T_crain) which was set up to 1 °C representing widely used value. Constant ablation rate A_r

Tab. 1 Parameters of the snow accumulation and snow ablation model.

T [°C]	Air temperature (usually daily mean). The data from meteorological station in Ptačí Brook were used.
P [mm]	Precipitation (usually daily sum). The data from heated rain gauge placed in meteorological station Modrava (4 km from Ptačí Brook) were used
SFCF [–]	Snowfall Correction Factor enables to account for snow undercatch
T_cmelt [°C]	Critical temperature for snowmelt initiation (degree-day approach)
T_crain [°C]	Critical temperature differentiating between snow and rain
LR [°C/100 m]	Lapse rate accounting for temperature decrease with elevation (typically 0.6 °C per 100 m)
ICFS [–]	Interception Correction Factor for Snow accounting for snow interception in vegetation with different canopy structure
ICFR [–]	Interception Correction Factor for Rain accounting for rain interception in vegetation with different canopy structure
A_r [mm]	Constant ablation rate used to account for snow ablation caused by sublimation and ground melt. Constant ablation rate is applied only for snow accumulation (for snowmelt, all processes causing ablation are considered within the melt factor m_f)
m_f [mm °C^{-1} d^{-1}]	Melt factor or degree-day factor representing the SWE decrease in a day caused by the air temperature T change by 1 °C compared to the critical air temperature T_cmelt in which the melting process begins

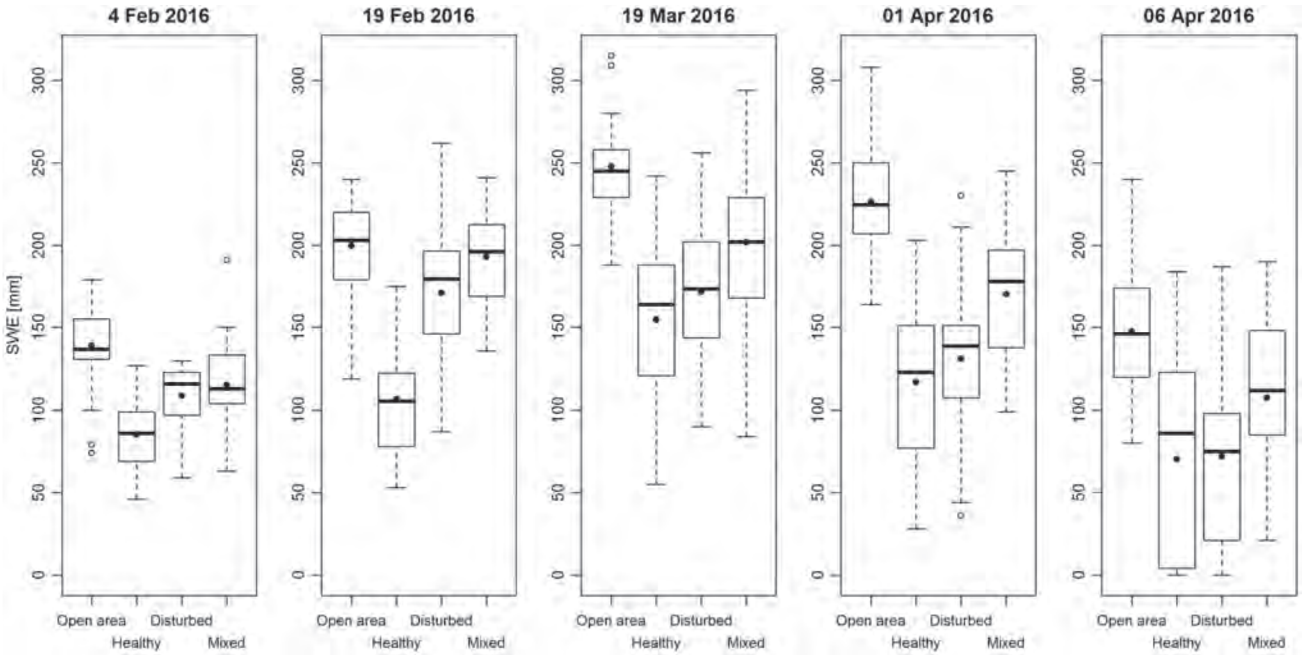

Fig. 2 The SWE in study plots in relation to vegetation. Boxes represent 25% and 75% percentile (with median as a thick line), whiskers represent 1.5 multiplier of interquartile range (IQR), black points represent mean value and transparent points represent outliers (higher than 1.5 of IQR, if existing).

was applied for snow accumulation periods to account for ground melt and sublimation. Constant ablation was not applied for snowmelt period since it is included in melt factor m_f.

The degree-day approach (see e.g. Hock 2003; Jenicek et al. 2012) was used in this study to simulate the snowmelt in plots with different vegetation cover. The degree-day approach represents the simplified energy balance of the snowpack, which is described using the air temperature T and melt factor m_f.

The melt factors for different types of vegetation were calculated based on measured SWE decreases between last two sampling dates where there was no influence of precipitation. Air temperature measured at meteorological station located in the immediate vicinity of sampling locations was used in the model. Critical temperature T_{cmelt} was set up to 0 °C in this case.

The parameters related to interception and critical temperatures were calibrated based on measured SWE in all sampling locations in order to get the best simulation fitted to observed data. The data from snowpack analyzer SPA and snow depth sensor were used to estimate the SFCF. The melt factors were not calibrated since they were calculated based on measured data. The validation of the model was not possible since data from one winter season were available at the time of study processing. The Nash-Sutcliffe efficiency NSE was used to assess the goodness-of-fit of the model (Nash and Sutcliffe 1970). A value 1 indicates perfect fit of simulations with observations, value 0 means that the model is as good as the mean of observed data.

3. Results

3.1 The development of SWE and snow density at individual plots in time

The development of SWE at individual plots in winter season 2015/2016 is displayed in Fig. 2. Until 19 March 2016 there was an increase in snow storage in all plots and this date was close to the date with maximum snow accumulation (although the snow accumulation period was influenced by several partial thawing periods). The average SWE measured in the date with maximum snow storage was 322 mm in open area, 242 mm in healthy forest, 256 mm in forest disturbed by the bark beetle and 294 mm in plot with mixed vegetation (healthy and disturbed coniferous forest and open area).

The SWE in the healthy forest was on average by 41% lower than in open area during accumulation period (first three sampling dates). The disturbed forest caused the SWE reduction by 22%, which clearly indicated reducing snow interception after forest defoliation and thus increasing snow storage. It is expected that the snow interception effect is likely to decrease in disturbed forest due to the gradual fall of branches and trunks, and thus snow accumulation increases.

The snow ablation in the healthy forest was slower than in open area and in disturbed forest. The SWE in open area decreased by 79 mm from 1 Apr 2016 to 6 Apr 2016 while the SWE decreased only by 47 mm in healthy forest and by 60 mm in disturbed forest in the same period. The dominant process which explains mentioned differences is reduced amount of incoming shortwave radiation in forest sites. We can expect faster snowmelt in disturbed forest next years due to further decay of the forest and thus increasing amount of incoming solar radiation.

Similarly to SWE, the snow density also differs in different types of vegetation. As expected, there was lower snow density in all vegetation categories during snow accumulation compared to snow ablation (Fig. 3). The median of snow density was lowest in the healthy forest, although the variability was highest when compare all vegetation categories. In forest disturbed by the bark beetle, the snow density slightly increased compared to the healthy forest while the variability decreased. The highest snow density was expectedly in open areas and in the plot with mixed vegetation cover, probably due to the combined effect of wind and higher incoming solar radiation. Generally, the snow density variability is caused by combined effects of 1) snow interception and canopy drip, 2) snow redistribution by wind, 3) equi-temperature metamorphism and 4) melt-freeze cycle metamorphisms. Mentioned effects additionally cause the increasing snow density at specific localities in time (with increasing day of year).

3.2 The SWE variability at a plot scale

To describe the variability of SWE at a plot scale we used the coefficient of variation C_v (Fig. 4). The C_v was calculated using standard deviation of SWE values (36 values) at specific sampling plot divided by its mean. The higher was the value, the higher was the SWE variability at the specific sampling plot. The C_v was calculated for each plot and for each sampling date.

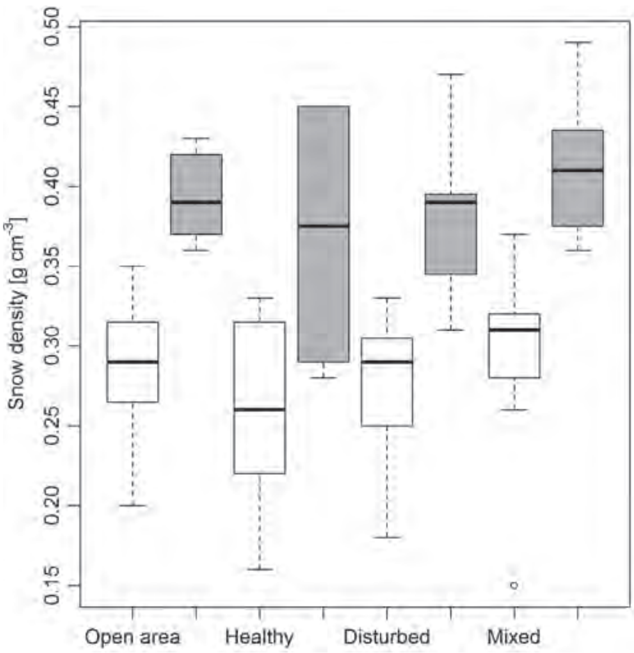

Fig. 3 The snow density in individual plots. White box plots represent sampling dates during snow accumulation; grey box plots represent snowmelt dates. Boxes represent 25% and 75% percentile (with median as a thick line), whiskers represent 1.5 multiplier of IQR.

The results showed general higher variability during snowmelt than during snow accumulation period. This was expected since the snowpack is influenced by even more factors during snow ablation than during snow accumulation (such as increase in solar radiation). The results also showed higher variability in the forest than in other vegetation categories which indicated the influence of canopy structure on the snowpack variability.

The histogram of SWE values for different canopy covers and dates is shown in Fig. 5. The individual lines represent the SWE distribution in individual sampling dates and in different vegetation. Histograms of SWE at the time of each sampling date showed that the distribution and the variability changed in the course of the accumulation and ablation season. It is clear that variability markedly increased during snowmelt season (last two sampling dates) which is indicated by histograms with wider base. Both Fig. 4 and Fig. 5 show the fact, that the SWE variability was generally higher in forest sites than in open area.

3.3 Ablation rates in relation to forest type and shortwave radiation

The snowmelt rates and melt factors m_f were calculated using data measured in 1 April and 6 April. These sampling dates define the period with high air temperature and high amount of incoming solar radiation. The snowmelt in the plot with disturbed forest markedly increased and its snowmelt rates was almost same as in open area (16.1 mm d^{-1} for open area; 15 mm d^{-1} for disturbed forest, table 2). The average snowmelt rate in healthy forest with dense treetops was much lower (10.9 mm d^{-1}). The spatial differences in snowmelt rates in forested plots were probably caused by different amount of shortwave radiation resulting from different canopy structure and thus shading effects (Fig. 6). Additionally, the snowmelt in the open area was influenced by surrounding trees, especially on its edges. These surrounding trees affected non-uniform snow ablation with higher snowmelt rates especially in the north part of the plot due to the reducing shading effect. Additionally, the presence of surrounding trees probably caused wind speed reduction and thus the snow redistribution due to wind was minimized.

The ablation rates and melt factor m_f as a key parameter in degree-day approach showed different snowmelt dynamics in different forest types (Table 2, Fig. 6, Fig. 7). The melt factors increased due to the increase in incoming solar radiation (caused by sparser canopy cover) and thus decrease of shading effects. The snow ablation in healthy forest was by 32% slower compared to sites in open area. On the contrary, the snow ablation in disturbed forest (due to the bark beetle) was on average only by 7% slower than in open area which indicates considerable increase in incoming solar radiation after forest defoliation. It is

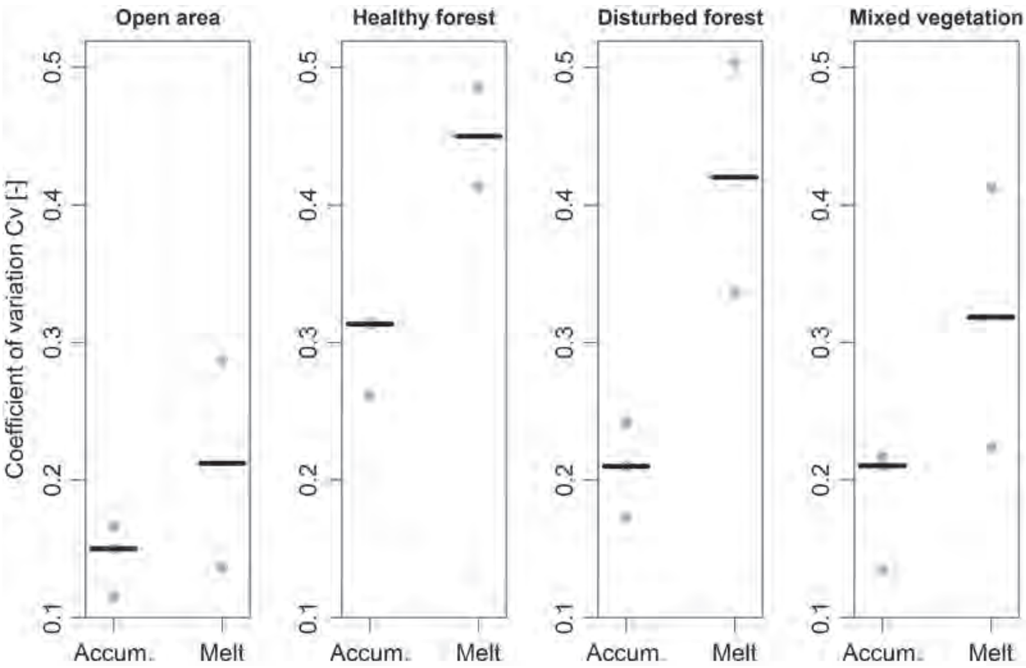

Fig. 4 The coefficients of variation C_v describing the SWE variability at a site level in an open area, healthy forest, disturbed forest and mixed vegetation in the Ptačí Brook catchment during snow accumulation and snow ablation period. The grey points indicate the individual C_v, horizontal lines indicate the median of C_v.

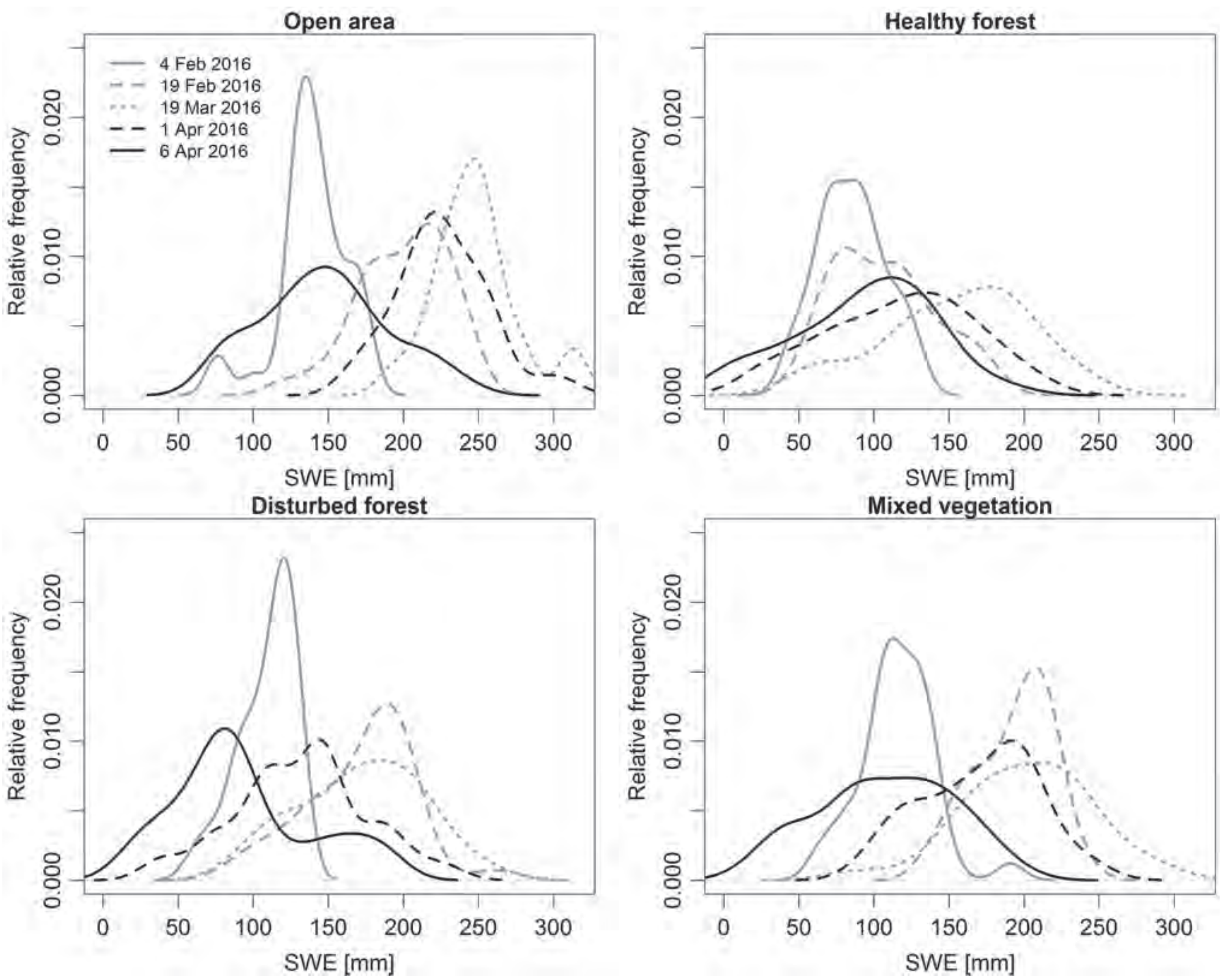

Fig. 5 Histograms of SWE in the time of each data sampling at individual plots. Only points with existing snow cover were included.

Tab. 2 Snowmelt rates, melt factors and relative amount of shortwave radiation compared to open area in individual sampling locations.

Location	Snowmelt rate [mm d⁻¹]	Melt factor m_f [mm °C⁻¹ d⁻¹]	M_f relatively compared to open area	Relative amount of shortwave radiation compared to open area
Open area	16.1	3.09	100%	100.0%
Healthy forest	10.9	2.09	68%	6.3%
Disturbed forest	15.0	2.88	93%	23.9%
Mixed vegetation	12.9	2.46	80%	NA

important to mention that the effect of faster snowmelt after forest decline is rather temporary since one can expect increasing shading effects and thus decreasing melt factors during forest regeneration and growth.

As described in the methodology part, the shortwave radiation was measured automatically in plots located in open area, healthy forest and forest disturbed by the bark beetle in order to measure the reduction of shortwave radiation which represents one of the major heat input accessible for snowmelt. The incoming solar radiation in healthy forest decreased to 6.3% of amount typical for open area (due to shading effect) and to 23.9% in disturbed forest compared to open area (Fig. 8).

Calculated melt factors and melt rates confirmed generally know expectations of how the snowmelt is influenced by vegetation and its canopy structure. The canopy structure caused strong decrease in incoming solar radiation and thus melt rates decreased as well. However, the relative decrease in incoming solar radiation in the forest compared to the open area was much bigger compared to the relative decrease in snowmelt rates. This indicated that the decrease in snowmelt rates cannot be explained only by the decrease in incoming solar radiation, and that there are still other processes which accelerated the snowmelt in the forest, such the longwave radiation.

3.4 The modelling of snow accumulation and ablation in plots with different forest type and in the open area

The set-up model was used to simulate the snow accumulation and ablation in all samplings plots (Fig. 9). We performed two separated model runs. First, the model

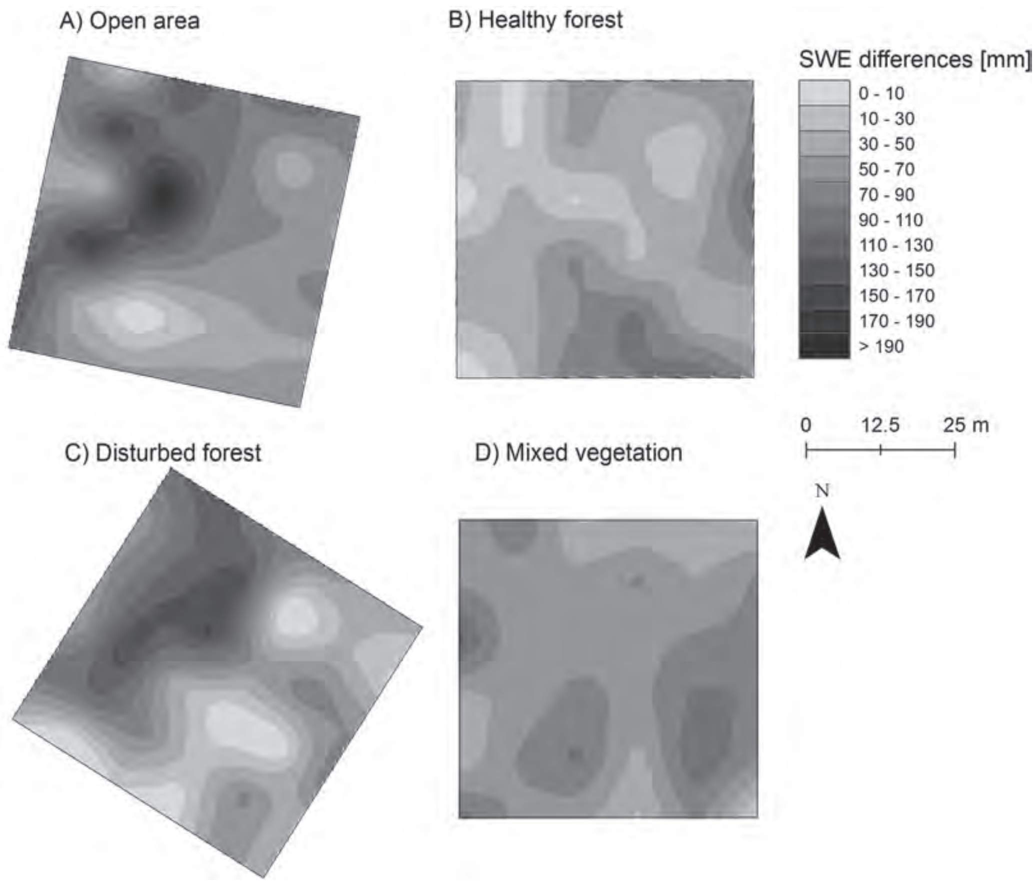

Fig. 6 Snowmelt rates showing the SWE decrease in sampling locations with different vegetation structure between 1 April 2016 and 6 April 2016.

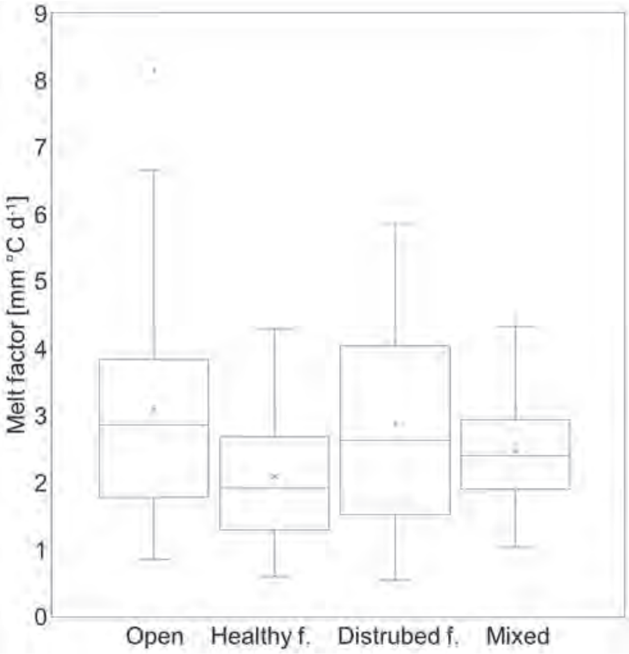

Fig. 7 Melt factors m_f for different vegetation in the sampling locations calculated from measured SWE. Boxes represent 25% and 75% percentile (with median as a thick line), crosses represent mean values and whiskers represent IQR.

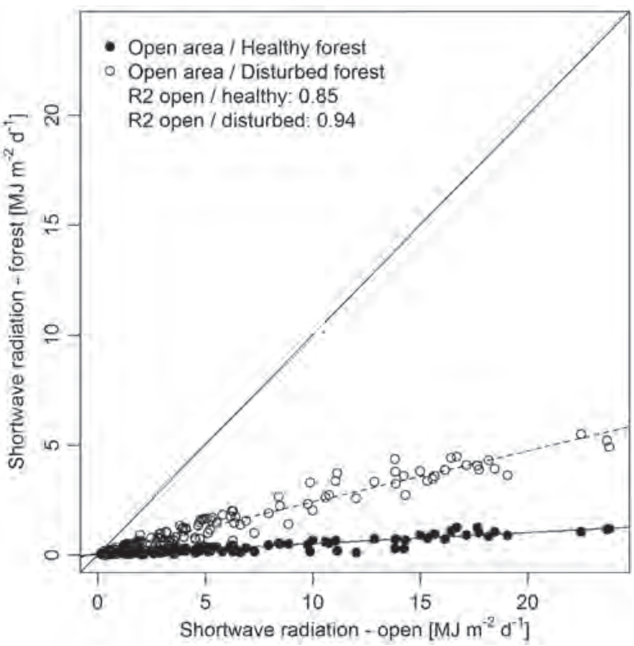

Fig. 8 The daily incoming shortwave radiation measured in open area compared to incoming shortwave radiation measured in healthy forest (black points) and disturbed forest (transparent points) during winter 2015/2016.

started to simulate the SWE at the beginning of the winter season (Fig. 9, left). Second, model simulation started in 19 March 2016 which represents sampling date close to the date with maximum snow storage (Fig. 9, right). The initial values of SWE for the second model run were adjusted in order to represent real measured data. Thus, this model run represents only snowmelt period enabling more detailed look on snowmelt dynamics in different plots with different canopy structure.

The results of the model correspond to general expectation of snow accumulation and snowmelt in different vegetation categories. The results are not surprising since the model was forced to achieved best possible fit with observations (using both manual snow sampling data and the SWE measurement using Snowpack analyzer SPA). The SWE underestimation by the model compared to the SPA data from 12 Jan to 17 Jan (Fig. 9, left) was probably caused by heavy snowfall which was not fully captured by the heated rain gauge in Modrava meteorological station (the record from this rain gauge was used as an input into the model).

The results showed the joint effect of reducing snow accumulation (due to snow interception) and slower snowmelt (due to shortwave radiation) in forest plots and enabled to derive melt-out days (the day of snow disappearance at specific plot). Despite the initial SWE in open area was almost by 60% higher than in the healthy forest when snowmelt began, the melt-out day in the forest was only 4 days earlier than in open area. On the contrary, the melt-out day in disturbed forest was 4 days earlier than in healthy forest despite the higher SWE in the day of snowmelt onset (Fig. 9, right). Faster ablation recorded by the automatic SWE sensor (SPA) was probably caused by the fact that this sensor is placed in open area (however inside the plot D with mixed vegetation) and thus most exposed to solar radiation when comparing all plots.

Tab. 3 Nash-Sutcliffe efficiency used to compare measured and simulated SWE in individual plots.

Location	Nash-Sutcliffe efficiency [–]
Open area	0.92
Healthy forest	0.88
Disturbed forest	0.69
Mixed vegetation	0.73

The model simulated best in open area and slightly worse in healthy forest (Table 3). The worst simulation was achieved in disturbed forest and in plot formed by mixed vegetation. The reason was probably the large SWE variability within the plot caused by large differences in canopy structure. Additionally, in plot with disturbed forest the worst fit may by influenced by inaccurate measured data. This could happen because of many death trees lying in the ground. In such conditions there was very difficult to find representative points for snow depth and SWE measurement. It means, that data measured in disturbed forest are burden with higher portion of uncertainty than data measured in healthy forest and in open area. However, when simulate the SWE in forests sites, the model highlighted the importance to use some factor accounting for snow interception.

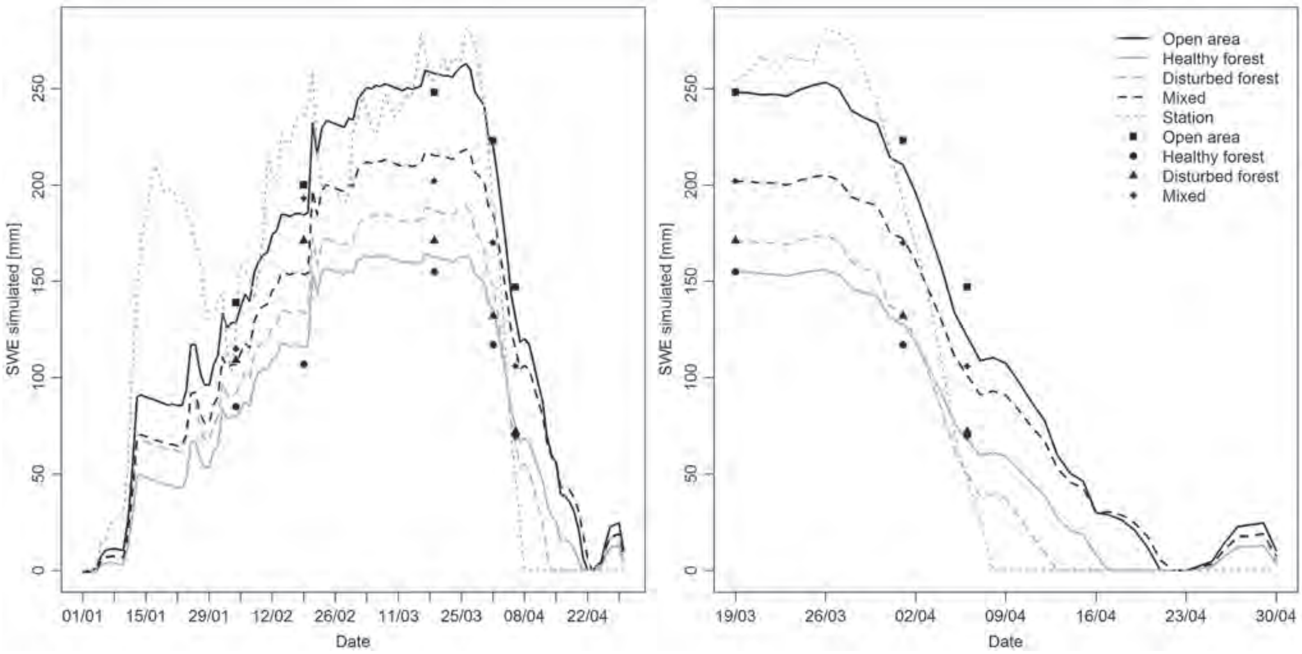

Fig. 9 Simulated SWE from 01 Jan 2016 to 30 Apr 2016 (left). Simulated SWE during snowmelt from 19 Mar 2016 to 30 Apr 2016 (right). Grey line "station" shows the SWE measured by the automatic sensor (SPA).

4. Discussion

4.1 Snow sampling design

The snowpack variability in snow dominated regions is bigger than the variability of precipitation. This is caused by several subsequent processes influencing the snowpack variability after snow accumulation, such as snow redistribution due to wind and earth gravity, snow metamorphosis and snowmelt. All mentioned processes are influenced by meteorological and site conditions which strongly influence individual elements of snowpack energy balance. Site characteristics cause the high snow variability even at a plot scale, where the precipitation may be considered as spatially invariable.

Besides manual sampling design as used in this study a lot of promising results have been also reported using remote sensing approaches such as the use of unmanned aerial systems (UAV) (Lendzioch et al. 2016; Nolan et al. 2015), aerial or terrestrial laser scanning (Bühler et al. 2015; Grünewald et al. 2013; Revuelto et al. 2016) and MODIS satellite data (Duchacek 2014; He et al. 2014; Krajčí et al. 2016). A camera placed on UAV platform was tested to monitor the snow depth characteristics in our study area, more specifically in the plot D with mixed vegetation (Lendzioch et al. 2016).

Selected locations are homogeneous in term of elevation and topography. All localities are placed at the same elevation and they are on a flat area. The only difference between localities is their vegetation cover, influencing interception and the amount of shortwave and longwave radiation. However, both plots located in the healthy forest and disturbed forest are not perfectly homogeneous in term of canopy structure, it means that canopy structure is partly changing within one locality. On the one hand, it represents an advantage because the small scale variability of snow depth and SWE caused by small scale variations of the canopy structure may be assessed. On the other hand, it represents a potential uncertainty when comparing localities between each other; characteristics of the mean were used to describe the snowpack in individual locality. This approach smooths the possible within-plot variations.

Additionally, the snowpack in open area was influenced by surrounding trees, especially on its edges. However, in such forested study area there was not possible to select different plot representing open area which would be large enough to avoid the snowpack distribution influence by surrounding trees. On contrary, the influence of wind on snow redistribution was therefore minimized and thanks to this fact, we argue that spatial snow depth and SWE differences were caused mainly by spatial differences in interception and solar radiation.

4.2 Uncertainties arising from measured meteorological variables

The air temperature used to melt factors calculation and to simulate the snowmelt dynamics was measured at a meteorological station located in the vicinity of sampling plots. Although, air temperature data were automatically measured every 10 minutes, the snow model set-up in this study used daily temporal resolution which cannot capture small scale variations of air temperature due to the small scale variability of topography. This effect might be important in spring especially in clear sky conditions at night and early morning (frost pockets). Diurnal variations caused that the mean daily air temperature might not be representative to describe snowmelt conditions (if occurred during the day). Local temperature conditions are also affected by the forest structure (Tesař et al. 2006) which is often connected to topography (Hais and Kučera 2009).

The incoming and reflected shortwave radiation was measured in open area, healthy forest and disturbed forest. Since radiometer detectors were not heated, these light detectors were covered with snow in some winter days giving the unreliable data. The identification of such situations was based on simple fact that shortwave radiation from downward facing sensor was higher than from upward facing sensor (which is unlikely in common situations during daylight). If this situation happened, we assumed that the upward facing sensors were covered with snow. Thus, all such measured values were removed from all analysis.

4.3 Vegetation structure and its possible consequences to runoff

For snow dominating regions with significant portion of forested areas, there is a well-documented difference between snow storages in forests and in open areas (see e.g. Holko et al. 2009; Jenicek et al. 2015; Jost et al. 2012; Pomeroy et al. 2012; Šípek and Tesař 2014). The results presented by Jenicek et al. (2016) who performed similar survey of snow storages at a catchment scale (same catchment as in this study) demonstrated similar differences in snow storages accumulated in open areas compared to forest sites (on average by 45% lower snow storages under healthy coniferous forest and 29% by lower snow storage in disturbed forest). On the contrary, Bartík et al. (2014) reported larger decrease of SWE deposited in a disturbed forest compared to open area in the West Tatra Mountains (decrease by 53%).

The melt factors presented in Jenicek et al. (2016) are somewhat higher than in this study, especially for open areas. This might be influenced by previously mentioned fact that open area in this study is rather small and the snowpack distribution might by affected by surrounding trees.

The effect of harvesting was documented by Schelker et al. (2013) who showed the increase in SWE after forest clear-cut by 27% which caused higher runoff from catchment. Additionally, the clear-cutting caused the earlier occurrence of the snowmelt. Pomeroy et al. (2012) performed a wide range of hypothetical scenarios at Marmot Creek in Canada and concluded that the total spring and summer runoff volume increased by less than 10% in case of forest burning and logging, however, the snowmelt volume increases by 45%.

4.4 Simplified snowpack energy balance based on degree-day approach

The snow accumulation and ablation model based on degree-day approach was originally created for daily time resolution and the same temporal resolution was also used in this study. The partial inaccuracies may arise in cases of air temperature fluctuations near zero (Kutlakova and Jenicek 2012). When the mean daily air temperature is negative, the model calculates no snowmelt. However, the positive air temperature which occurred during day might cause partial snowmelt which was not captured by the model (Hock 2003). Although the model allowed for a correction of such situations using critical temperature T_{cmelt}, there is still some portion of uncertainty in simulated snowmelt dynamics.

It is important to mention that only a simplified energy balance was taken into account in the model which means that many processes were not included into calculation, such as latent heat transfers (e.g. water refreezing after liquid precipitation) and longwave radiation. The sublimation and heat flux from earth surface (ground melt) was included in our model, however we used only simplified approach to estimate these two parameters. Further development of the model and testing it on different catchments and/or different years would bring more reliable results.

5. Conclusion

We analyzed the snowpack variability in four selected plots with different land cover in a forested mountain catchment. We were interested in the effect of forest structure on both snow accumulation and ablation. Our study was based on repeated manual measurements of the snow depth and SWE in winter season 2015/2016. Based on results, we draw up following conclusions:

- The snow depth and SWE spatial variability at a plot scale markedly increased during snowmelt season. The variability was generally higher in forest sites than in open area.
- The SWE in the plot with healthy forest was on average by 41% lower than in open area during snow accumulation period. The disturbed forest caused the SWE reduction by 22% compared to open area indicating reducing snow interception after forest defoliation and thus increasing snow storage.
- The snow ablation in healthy forest was by 32% slower compared to open area. On the contrary, the snow ablation in disturbed forest (due to the bark beetle) was on average only by 7% slower than in open area. The dominant process which explains mentioned differences is reduced amount of incoming shortwave radiation in forested sites.
- The measured incoming solar radiation in healthy forest decreased to 6.3% of amount measured in open

area in the same period and to 23.9% in disturbed forest compared to open area. However, the relative decrease in incoming solar radiation in the forest compared to open area was much bigger compared to the relative decrease in snowmelt rates. This indicated that the decrease in snowmelt rates cannot be explained only by the decrease in incoming solar radiation.

– The results of the model showed the joint effect of reducing snow accumulation (due to snow interception) and slower snowmelt (due to shortwave radiation) in forest plots and enabled to derive melt-out days at individual plots. Despite the initial SWE in disturbed forest was by 10% higher than in the healthy forest when snowmelt began, the melt-out day in the disturbed forest was by 4 days earlier then in the healthy forest. The model simulated best in open area and slightly worse in healthy forest. The worst simulation was achieved in disturbed forest and in the plot formed by mixed vegetation.

Acknowledgements

Support from the Czech Science Foundation (project No. 13-32133S "Headwaters retention potential with respect to hydrological extremes") and European Union (project EU COST Action 1306, no. LD15130 "Impact of landscape disturbance on the stream and basin connectivity") is gratefully acknowledged.

REFERENCES

AUBIN, I., BEAUDET, M., MESSIER, C. (2011): Light extinction coefficients specific to the understory vegetation of the southern boreal forest, Quebec. Can. J. For. Res. 30, 168–177. https://doi.org/10.1139/x99-185

BARTÍK, M., SITKO, R., OREŇÁK, M., SLOVIK, J., ŠKVARENINA, J. (2014): Snow accumulation and ablation in disturbed mountain spruce forest in West Tatra Mts. Biologia (Bratisl). 69, 1492–1501. https://doi.org/10.2478/s11756-014-0461-x

BIEDERMAN, J. A., BROOKS, P. D., HARPOLD, A. A., GOCHIS, D. J., GUTMANN, E., REED, D. E., PENDALL, E., EWERS, B. E. (2014): Multiscale observations of snow accumulation and peak snowpack following widespread, insect-induced lodgepole pine mortality. Ecohydrology 7, 150–162. https://doi.org/10.1002/eco.1342

BÜHLER, Y., MARTY, M., EGLI, L., VEITINGER, J., JONAS, T., THEE, P., GINZLER, C. (2015): Snow depth mapping in high-alpine catchments using digital photogrammetry. Cryosph. 9, 229–243. https://doi.org/10.5194/tc-9-229-2015

DUCHACEK, L. (2014): Vertical variability in the position of the zero isochion in geomorphologic regions of Czechia. Geografie 119, 145–160.

ELLIS, C. R., POMEROY, J. W. (2007): Estimating sub-canopy shortwave irradiance to melting snow on forested slopes. Hydrol. Process. 21, 2581–2593. https://doi.org/10.1002/hyp.6794

ESSERY, R., POMEROY, J., PARVIAINEN, J., STORCK, P. (2003): Sublimation of Snow from Coniferous Forests in a Climate Model. J. Clim. 16, 1855–1864. https://doi.org/10.1175/1520-0442(2003)016<1855:SOSFCF>2.0.CO;2

GRÜNEWALD, T., STÖTTER, J., POMEROY, J. W., DADIC, R., MORENO BAÑOS, I., MARTURIÀ, J., SPROSS, M., HOPKINSON, C., BURLANDO, P., LEHNING, M. (2013): Statistical modelling of the snow depth distribution in open alpine terrain. Hydrol. Earth Syst. Sci. 17, 3005–3021. https://doi.org/10.5194/hess-17-3005-2013

HAIS, M., KUČERA, T. (2009): The influence of topography on the forest surface temperature retrieved from Landsat TM, ETM + and ASTER thermal channels. ISPRS J. Photogramm. Remote Sens. 64, 585–591. https://doi.org/10.1016/j.isprsjprs.2009.04.003

HE, Z. H., PARAJKA, J., TIAN, F. Q., BLÖSCHL, G. (2014): Estimating degree-day factors from MODIS for snowmelt runoff modeling. Hydrol. Earth Syst. Sci. 18, 4773–4789. https://doi.org/10.5194/hess-18-4773-2014

HOCK, R. (2003): Temperature index melt modelling in mountain areas. J. Hydrol. 282, 104–115. https://doi.org/10.1016/S0022-1694(03)00257-9

HOLKO, L., ŠKVARENINA, J., KOSTKA, Z., FRIČ, M., STAROŇ, J. (2009): Impact of spruce forest on rainfall interception and seasonal snow cover evolution in the Western Tatra Mountains, Slovakia. Biologia (Bratisl). 64, 594–599. https://doi.org/10.2478/s11756-009-0087-6

HRIBIK, M., VIDA, T., SKVARENINA, J., SKVARENINOVA, J., IVAN, L. (2012): Hydrological effects of norway spruce and european beech on snow cover in a mid-mountain region of the Polana Mts., Slovakia. J. Hydrol. Hydromechanics 60, 319–332.

JENICEK, M., BEITLEROVA, H., HASA, M., KUCEROVA, D., PEVNA, H., PODZIMEK, S. (2012): Modeling snow accumulation and snowmelt runoff – present approaches and results. AUC Geographica 47, 15–24.

JENICEK, M., PEVNA, H., MATEJKA, O. (2016): Canopy structure and topography effects on snow distribution at a catchment scale: Application of multivariate approaches. J. Hydrol. Hydromechanics. Submitted.

JENICEK, M., PEVNA, H., MATEJKA, O. (2015): Snow accumulation and ablation in three forested mountain catchments. Acta Hydrol. Slovaca 16, 208–216.

JOST, G., DAN MOORE, R., SMITH, R., GLUNS, D.R. (2012): Distributed temperature-index snowmelt modelling for forested catchments. J. Hydrol. 420, 87–101. https://doi.org/10.1016/j.jhydrol.2011.11.045

JOST, G., WEILER, M., GLUNS, D.R., ALILA, Y. (2007): The influence of forest and topography on snow accumulation and melt at the watershed-scale. J. Hydrol. 347, 101–115. https://doi.org/10.1016/j.jhydrol.2007.09.006

KLIMENT, Z., MATOUSKOVA, M., LEDVINKA, O., KRALOVEC, V. (2011): Trend Analysis of Rainfall-Runoff Regimes in Selected Headwater Areas of the Czech Republic. J. Hydrol. Hydromechanics 59, 36–50. https://doi.org/10.2478/v10098-011-0003-y

KOCUM, J., OULEHLE, F., JANSKÝ, B., BŮZEK, F., HRUŠKA, J., VLČEK, L. (2016): Geochemical evidence for peat bog contribution to the streamflow generation process: case study of the Vltava River headwaters, Czech Republic. Hydrol. Sci. J. 61, 1–11. https://doi.org/10.1080/02626667.2016.1140173

KRAJČÍ, P., HOLKO, L., PARAJKA, J. (2016): Variability of snow line elevation, snow cover area and depletion in the main Slovak basins in winters 2001–2014. J. Hydrol. Hydromechanics 64, 12–22. Hydromechanics 64, 12–22. https://doi.org/10.1515/johh-2016-0011

KUTLAKOVA, L., JENICEK, M. (2012): Modelling snow accumulation and snowmelt in the Bystrice River basin. Geografie 117, 110–125.

LANGHAMMER, J., HARTVICH, F., KLIMENT, Z., JENÍČEK, M., BERNSTEINOVÁ, J., VLČEK, L., SU, Y., ŠTYCH, P., MIŘIJOVSKÝ, J. (2015a):. The impact of disturbance on the dynamics of fluvial processes in mountain landscapes. Silva Gabreta 21, 105–116.

LANGHAMMER, J., SU, Y., BERNSTEINOVÁ, J. (2015b): Runoff Response to Climate Warming and Forest Disturbance in a Mid-Mountain Basin. Water 7, 3320–3342. https://doi.org/10.3390/w7073320

LENDZIOCH, T., LANGHAMMER, J., JENICEK, M. (2016): Tracking forest and open area effects on snow accumulation by unmanned aerial vehicle photogrammetry. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLI-B1, 917–923. https://doi.org/10.5194/isprsarchives-XLI-B1-917-2016

LÓPEZ-MORENO, J. I., STÄHLI, M. (2008): Statistical analysis of the snow cover variability in a subalpine watershed: Assessing the role of topography and forest interactions. J. Hydrol. 348, 379–394. https://doi.org/10.1016/j.jhydrol.2007.10.018

MOLOTCH, N. P., BROOKS, P. D., BURNS, S. P., LITVAK, M., MONSON, R. K., MCCONNELL, J. R., MUSSELMAN, K. (2009): Ecohydrological controls on snowmelt partitioning in mixed-conifer sub-alpine forests. Ecohydrology 2, 129–142. https://doi.org/10.1002/eco.48

NASH, J. E., SUTCLIFFE, J. V. (1970): River flow forecasting through conceptual models part I – A discussion of principles. J. Hydrol. 10, 282–290. https://doi.org/10.1016/0022-1694(70)90255-6

NOLAN, M., LARSEN, C., STURM, M. (2015): Mapping snow depth from manned aircraft on landscape scales at centimeter resolution using structure-from-motion photogrammetry. Cryosph. 9, 1445–1463. https://doi.org/10.5194/tc-9-1445-2015

POMEROY, J., FANG, X., ELLIS, C. (2012): Sensitivity of snowmelt hydrology in Marmot Creek, Alberta, to forest cover disturbance. Hydrol. Process. 26, 1891–1904. https://doi.org/10.1002/hyp.9248

R CORE TEAM (2016): A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.r-project.org/ (accessed 8.1.16).

REVUELTO, J., VIONNET, V., LÓPEZ-MORENO, J. I., LAFAYSSE, M., MORIN, S. (2016): Combining snowpack modeling and terrestrial laser scanner observations improves the simulation of small scale snow dynamics. J. Hydrol. 533, 291–307. https://doi.org/10.1016/j.jhydrol.2015.12.015

SCHELKER, J., KUGLEROVÁ, L., EKLÖF, K., BISHOP, K., LAUDON, H. (2013): Hydrological effects of clear-cutting in a boreal forest – Snowpack dynamics, snowmelt and streamflow responses. J. Hydrol. 484, 105–114. https://doi.org/10.1016/j.jhydrol.2013.01.015

SICART, J. E., ESSERY, R. L. H., POMEROY, J. W., HARDY, J., LINK, T., MARKS, D. (2004): A Sensitivity Study of Daytime Net Radiation during Snowmelt to Forest Canopy and Atmospheric Conditions. J. Hydrometeorol. 5, 774–784. https://doi.org/10.1175/1525-7541(2004)005<0774:ASSODN>2.0.CO;2

STÄHLI, M., GUSTAFSSON, D. (2006): Long-term investigations of the snow cover in a subalpine semi-forested catchment. Hydrol. Process. 20, 411–428. https://doi.org/10.1002/hyp.6058

ŠÍPEK, V., TESAŘ, M. (2014): Seasonal snow accumulation in the mid-latitude forested catchment. Biologia (Bratisl). 69, 1562–1569. https://doi.org/10.2478/s11756-014-0468-3

TESAŘ, M., ŠÍR, M., LICHNER, L., ZELENKOVÁ, E. (2006): Influence of vegetation cover on thermal regime of mountainous catchments. Biologia (Bratisl). 61, 311–314. https://doi.org/10.2478/s11756-006-0179-5

VARHOLA, A., COOPS, N. C., WEILER, M., MOORE, R. D. (2010): Forest canopy effects on snow accumulation and ablation: An integrative review of empirical results. J. Hydrol. 392, 219–233. https://doi.org/10.1016/j.jhydrol.2010.08.009

RESUMÉ

Akumulace a úbytek sněhu v různých vegetacích v lokálním měřítku: použití přístupu degree-day a měřené krátkovlnné radiace

Informace o objemu vody ve sněhové pokrývce a jejím prostorovém rozložení jsou důležité pro předpovědi odtoku z tajícího sněhu. Cílem této studie bylo kvantifikovat vliv různé struktury lesního porostu na prostorové rozložení sněhové pokrývky v lokálním měřítku během akumulace a tání sněhu. Dílčí zájem představoval vliv lesa poškozeného lýkožroutem smrkovým (*Ips typographus*).

Na vybraných malých horských plochách byla v zimní sezóně 2015/2016 provedena opakovaná detailní měření výšky sněhu a vodní hodnoty sněhu (SWE). Jednotlivé plochy se nacházely blízko sebe ve stejné nadmořské výšce bez vlivu reliéfu a větru na rozložení sněhu. Tím bylo možné sledovat pouze efekt vegetace (ovlivňující intercepci sněhu a radiační podmínky) na distribuci sněhu. Byl sestaven model akumulace a úbytku sněhu, který simuloval průběh SWE na vybraných plochách. Model by založen na přístupu degree-day a zohledňoval intercepci sněhu v různých strukturách vegetace. Model byl kalibrován jak na manuálně měřených hodnotách SWE, tak na datech z automatické stanice umístěné v blízkosti ploch a měřící kromě srážek a teploty vzduchu také výšku sněhu, SWE a globální a odraženou krátkovlnnou radiaci.

Měření ukázala, že SWE ve zdravém lese byla době akumulace sněhu v průměru o 41 % nižší, než na otevřené ploše. Naproti tomu, poškozený les způsobil pouze o 22 % nižší akumulaci sněhu než na otevřené ploše. Ve zdravém lese bylo naměřeno o 32 % pomalejší tání sněhu ve srovnání s otevřenou plochou. Naproti tomu, v poškozeném lese bylo tání pouze o 7 % pomalejší než na otevřené ploše, což lze vysvětlit vyšším úhrnem krátkovlnného záření dopadající na plochu po rozpadu lesa. Avšak pokles krátkovlnné radiace jak ve zdravém, tak poškozeném lese je mnohem vyšší než by vysvětloval pokles rychlosti tání sněhu. To ukazuje na fakt, že krátkovlnná radiace nemůže sama vysvětlit změnu v tání sněhu po rozpadu lesa. Sestavený a kalibrovaný model očekávaně modeloval nejpřesněji průběh SWE na otevřené ploše, o něco hůře ve zdravém a poškozeném lese. Model prokázal obecně zrychlení tání sněhu po rozpadu lesa, což mělo také za následek rychlejší roztátí sněhu na ploše s poškozeným lesem (navzdory vyšším sněhovým zásobám na počátku tání sněhu).

Michal Jeníček, Ondřej Hotový, Ondřej Matějka
Charles University, Faculty of Science
Department of Physical Geography and Geoecology,
Albertov 6, 128 43 Prague
Czech Republic
E-mail: michal.jenicek@natur.cuni.cz

POST-COMMUNISTIC TRANSFORMATION AND POPULATION AGEING VERSUS THE CHANGING MIGRATORY PATTERNS OF SENIORS: THE CASE OF THE SLOVAK REPUBLIC

ARNOLD KAKAŠ, BRANISLAV BLEHA

Department of Human Geography and Demography, Faculty of Natural Sciences of Comenius University in Bratislava, Slovak Republic

ABSTRACT

Vigorous socio-economic changes, the transformation to a market economy, the transformation of demographic reproduction and rapid ageing. These terms are associated with the development of Central and Eastern Europe after 1990. Many studies exist that evaluate the changes in international migration, fewer studies analyse the internal migration. The area of migration of seniors and their response to population ageing and socio-economic changes associated with the transformation remains almost completely unexplored. In the study we analyse the migration of seniors in the example of the Slovak Republic using detailed migration data and changes in this migration during the last quarter of a century full of transformational changes. Using regression statistical models we reveal the essential factors of migration. We try to determine to what extent the migration of seniors is selective, and to what extent seniors reflect the general migration trends associated with the change of political regime.

Keywords: migration, seniors, ageing, transformation, migration factors

Received 2 January 2017; Accepted 23 February 2017; Published online 22 March 2017

1. Introduction

Redistribution of the population is not a random process. Some regions are preferred over others; consequently, the immigration levels may vary from place to place. Similarly, the characteristics of migrants as a group are not identical with those of the general population that does not migrate. Migration is a selective process therefore the redistribution of the population has two dimensions: (a) the number of migrants, which includes the size and direction of migration flows and (b) the demographic and socio-economic characteristics of migrants (Longino, Biggar 1982). Bradley et al. (2008) state that the ageing of generations from the baby-boom period will cause a significant increase in the absolute number of older migrants since it presumes a relatively unchanging rate of mobility. In addition, that the migration of seniors could be an important factor in the structural changes of the destination communities. Countries that have long been facing the problems of ageing have developed a method in which seniors become the persons involved in countryside development (economically and socially) (Murakami, Atterton, Gilroy 2008; Bleha, Kobayashi, Ohzeki 2011).

Investigating the migration of seniors, due to the many specificities of this population group, is not just a demographic but also a sociological phenomenon. Many sociological factors that distinguish the migrant seniors from the productive population should be included in the interpretation of the results of demographic methods, as the (most often) used economic theories are practically inapplicable.

This work deals with the analysis of the migration of seniors[1] in Slovakia, in a transforming country with a lower life expectancy, poorer social situation of seniors and lower quality of health of seniors in comparison with Western Europe. The spatial mobility of seniors has not been a very frequent topic among scholars in Central and Eastern Europe. The population ageing will very likely induce the raising concern on this topic. On the other hand population ageing is currently a hot topic among the scholars and politicians. Slovakia will become one of the oldest countries in Europe and the world (Bleha, Šprocha, Vaňo 2013; EUROSTAT 2015). The proportion of seniors, which is currently around 17%, will rise by 2020 to more than 21%, by 2030 to around 25% and in 2050 they should represent more than 35% of the Slovak population. Simultaneously, the representation of the "oldest old" over 80 years will rise dramatically: in 2060 their share will be almost 13%. Šprocha, Vaňo and Bleha (2013) anticipate stagnation, in some ways even an increase in regional demographic disparities that could be the driving force of migration. From this point, Slovakia is a convenient country for the research of migration of seniors.

The migration of seniors in Slovakia accounts for about 7% of the total internal migration in Slovakia. Senior housing is influenced by many factors: age, family and health status, household composition, kinship, quality and accessibility of social services and social support

1 The definition of seniors is discussed in chapter Data and Methods.

https://doi.org/10.14712/23361980.2017.6
Kakaš, A. – Bleha, B. (2017): Post-communistic transformation and population ageing versus the changing migratory patterns of seniors: the case of the Slovak Republic
AUC Geographica, 52, No. 1, pp. 73–88

(Kinsella, Velkoff 2001). Migration of seniors in the future will generate an ever greater social pressure to meet their living needs, particularly in health and social areas.

The main research questions of the study are as follows:

(1) Is the (internal) migration in the case of seniors selective? Do younger seniors, some of whom have recently stepped out of the labour market, migrate more than old seniors, for whom severe forms of disability are more frequent and their social situation can also be different? This research question embraces the search of key qualifying factors – driving mechanisms of the migration of seniors in a transforming, regionally differentiated country and with a rapidly ageing population?

(2) Are assumptions of Life-Cycle Hypothesis present among Slovak seniors and can they influence decisions on migration of seniors? Has the demographic structure of migrant seniors changed between the observed periods, and what influences the changing structure of seniors?

(3) The unevenness of age structure causes a shift of variously large generations to senior or retirement age. Has the mobility of seniors increased after the shift of generations with large populations to the age of 55 years or more?

2. Theoretical basis

The main theoretical bases of our work are the ideas of American authors: geographer and demographer Everett S. Lee and sociologist Eugene Litwak and Charles F. Longino. Lee in his fundamental and well-known work entitled *A Theory of Migration* brought forth an expanded view of the migration process, which he formulated in his own version of the Push-pull theory (Lee 1966). He summed up factors influencing the decision to migrate and the migration process in four areas:

- Factors associated with the original location;
- Factors associated with the destination location;
- Incoming obstacles;
- Personal factors.

According to the author, numerous factors exist in any space that keep people in a place, attracting them or forcing them out. Some factors affect humans the same way, others are perceived subjectively. The perception of these factors changes depending on depending on the age of the respective person. Whether migration flows occur or not depend on the potential benefits obtained by migration overcome the costs associated with incoming obstacles e.g.: overcoming distance, finding new accommodation but also the loss of social capital in the form of breaking relations with family and friends. Even in such a case, the perception of these obstacles is largely subjective and is influenced by the actual life cycle or age of the prospective migrant. Furthermore, various personal factors influence the decision to migrate, more or less constant throughout life. Migration itself is not only the result of the comparison of factors in the original location and destination location. The nature (sensitivity) of man, intelligence, awareness of the situation in other places, access to information and other effects also play their role. It is also necessary to take into account the fact that not every migration is caused by the decision of the migrant; for example, children migrate with their parents, seniors with serious medical problems are transferred to social facilities if their family is unable to care for them, etc. Sjaastad interpreted the decision to migrate after considering the risk and profit ratio as the return on investment of an individual in his human capital (Sjaastad 1962). This theory is one of the most common and generally accepted migration theories. Its advantage is that it is universally applicable (e.g. contrary to the various economically based theories) on the micro and macro levels. At the same time, it is not based on the existence of any conditions (such as the migration network theory and others).

Character of migration, changes hand in hand with the changing phase phase of life of potential migrants. Litwak and Longino studied migration patterns among seniors and they defined three types of migration movement of this part of the population (Litwak, Longino 1987):

Movement 1: If a person has an intact marriage, is relatively healthy and has a sufficiently high income, social pressure for relocation may occur in some cases.

Movement 2: This movement occurs if a person starts suffering from a medium strong chronic disease that makes it difficult to manage daily activities such as shopping, cooking, and cleaning but also the ability to defend oneself and others. The presence of a husband/wife is the motivation for managing these activities, so the movement may occur in particular after becoming a widow(-er). If a person lives in this state far from his or her children, he or she must move in order to get the services he needs.

Movement 3: This movement occurs with people suffering from severe chronic diseases and the family cannot take care of them or provide adequate healthcare, or these are the persons described in "Movement 2" that do not have a family. In these cases, these persons move to social facilities in which trained staff takes care of them.

The social care and healthcare system is related especially to the second and third type of movement. In its broader sense it covers, besides public/state providers of these services, also the trends in family behaviour (caring, or not caring for a close person). Three types of social care for seniors are provided in Slovakia: ambulatory, field and with stay (Káčerová, Ondačková, Mládek 2013a, see also MPSVR 2014b). The adoption of Act 485/2013 Coll. should allow citizens to stay as long as possible in their natural environment and be provided with community-oriented social services (MPSVR 2014a). These changes should act to reduce mobility, especially of younger seniors. A focus on field social services or community-based care as a result of current demographic and socio-economic development is probably the only form of care provision that would allow, mainly in the future, the fulfilment of the expected stay of seniors in their "natural" environment. The combined effect of the diminishing number of potential carers (traditionally caring was the task of the younger family members), increase of pressure of the labour market (especially at younger family members) and longer persistence in the labour market (of seniors) increase the exigence of social care (Hoff, Feldman, Vidovićová 2010).

Litwak and Longino (1987) regard the migration of seniors as a consequence of changes in old age, both somatic and psychological. While somatic changes in the last stage usually result in terms of mobility in the placement of seniors in facilities that provide care and healthcare, psychological changes can lead to migration caused by changes in the hierarchy of values. The three types of movements above suggest the existence of certain sub-populations of seniors influenced by these movements. In addition to somatic and psychological changes, ageing also brings social – status changes. According to Havlíková (2007), the social process of ageing refers to the socially defined age structure and the age standards (expectations). These standards specify the appropriate behaviour. Thus, there are social roles, expected patterns of behaviour that are associated with the social position of the individual. The social role is linked to what sociology calls the representation of status. These are the expectations through which a person in a particular social position shall demonstrate his affiliation to the group of those who are in the same position (Kövérová 2002).

Subjective understanding of the age identity of individuals themselves plays an important role in the context of migration of seniors. Subjective perception is reflected in the ability to adapt to the ageing process. The most important determinants of subjective age are education, self-esteem, satisfaction and financial health (Piscová 2011). Flynn, who examined interstate migration within the USA[2], concluded that older migrants concentrate in fewer number of migration flows as compared to the migration of productive population, in other words, their migration is less spatially atomised (Flynn 1980 as quoted in Longino, Biggar 1982). For this reason, redistribution of the older population may have potentially huge implications for the main emigration and immigration regions. Migration to these regions will eventually change the overall characteristics of the older population, and therefore affects the level of services required. Older migrants have a much greater impact on demand as on the pressure on the labour market (Longino, Biggar 1982). This demand is reflected in different dimensions of the housing market, through transport possibilities, availability of different services that can be highly specific (pensioners clubs and other organizations) to healthcare.

Special type of housing for seniors are retirement houses. According to Káčerová, Ondačková and Mládek (2013b) Number of these facilities increased by more than 100% between years 1997 and 2010. Authors also claim that this type of facility accounts for more than 47% of all facilities dedicated to social support of seniors. Overall capacity is approximately 5 beds to 100 seniors.

3. Data and methods

3.1 How to define the seniors?

A significant methodological problem is the very definition of the age of persons who can be included among seniors. The literature has not yet created a single concept (Haas *et al.* 2006). The inconsistency in the age definition of "old age" is confirmed by the work of different authors, of which, for example, Forman et al. (1992) used for the purpose of his analysis the division of seniors to young seniors ("young old") aged 60–69 years, middle-aged seniors ("middle old") aged 70–79 years old and the very old seniors ("very old") aged 80 years or more. A different division was used by Zizza et al. (2009) in their study of water consumption of the elderly. In their work we encounter age groups of 65–74 years ("young-old"), 75–84 years ("middle-old") and 85 or more years ("oldest-old"). Some qualitative studies (Denney, Lennon 1972; Denney, Denney 1973) investigated the differences between people in middle age and advanced age (seniors, "elderly"), while the lower age limit of the group of seniors participating in the study in the examples was 67, respectively 75 years. According to Holmerová, Jurašková and Zikmundová (2007) about 80–90% of seniors (65 years and more) are self-sufficient with the help of family and the local environment, 13% need help in the household, 7–8% need a more systematic home care and 2% (sometimes it is indicated 5%) need institutional care.

When working with concepts such as senior, economic activity, marginalization, social role and others in the context of mobility, one needs to pay attention to the difference between retirement migration and migration in old age. Also, according to Haas et al. (2006), migration in older age ("later-life migration") and retirement migration ("retirement migration") cannot be conceptually or methodologically confused.

Moreover, as it becomes evident, neither would the use of retirement age as the lower age limit be trouble free, for two reasons:

a) The age of retirement is not stable and within a short period of time can change several times, depending mainly on pension reforms (Table 1).
b) Part of the population remains economically active even after reaching this age; with increasing age their share declines but, according to Holmerová, Jurašková and Zikmundová (2007), it never completely

2 Interstate migration in the USA is, in our opinion, a priori closer to inner migration than international migration despite the possible distances that migrants overcome.

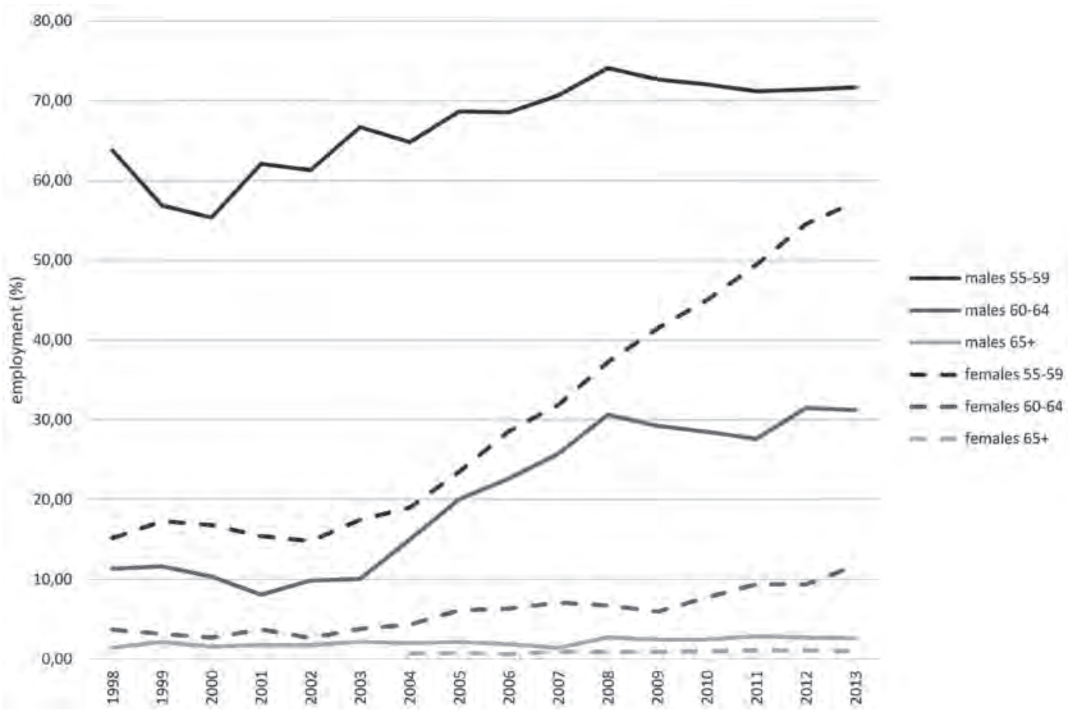

Fig. 1 Employment of seniors.
Source: Population by sex, age, citizenship and labour status (Eurostat, accessed 4-24-2015) http://ec.europa.eu/eurostat/en/web/products-datasets/-/LFSA_PGANWS.

disappears. On the contrary, part of the population is becoming economically inactive even before reaching this age (early retirement, disability pension).

Tab. 1 The highest official retirement age and real retirement age.

Year	Male		Female	
	Real	Official	Real	Official
1996	60.3	60 years	55.6	57 years
1997	59.9	60 years	55.1	57 years
1998	59.7	60 years	54.5	57 years
1999	59.4	60 years	55.1	57 years
2000	59.4	60 years	55.9	57 years
2001	59.7	60 years	55.9	57 years
2002	59.4	60 years	56.1	57 years
2003	59.8	60 years	56.1	57 years
2004	59.7	60 years and 9 months	56.0	57 years and 9 months
2005	59.2	60 years and 9 months	55.5	57 years and 9 months
2006	59.4	61 years and 6 months	55.1	58 years and 6 months
2007	59.3	61 years and 6 months	54.5	58 years and 6 months
2008	59.3	62 years	55.4	59 years and 3 months
2009	59.9	62 years	56.2	59 years and 3 months
2010	59.9	62 years	56.9	60 years
2011	60.4	62 years	57.7	60 years and 9 months
2012	60.9	62 years	58.7	60 years and 9 months
2013	n/a	62 years	n/a	61 years and 6 months

Source: http://www.oecd.org/els/emp/Summary_1970+values.xls

Thus, we speak about the difference between the official retirement age and the actual retirement age. According to the OECD data[3] the real retirement age in Slovakia in 2012 was 60.9 years for males and 58.7 years for females (Table 1). In contrary to Hurd's (1990) findings the average age of retirement had not fallen, rather it is relatively stable (Table 1). In case of female seniors there is evidence of growth of average retirement age, which suggest that there is longer persistence of female seniors in the labour market (Figure 1).

Our categorisation used for age is not the result of random selection, although the limits of individual categories might suggest so. This classification is the result of several attempts to select the most appropriate, while maintaining the following conditions:

The classification should correspond to the characteristics of the population (in particular social, economic and demographic):
- Taking into account the retirement age and the employment rate;
- Taking into account the most significant differences between the sexes (life expectancy, retirement age).

The categorization should be at least partially comparable with previous classifications.

Although the changes do not happen suddenly but gradually, the selected limits should create categories of

3 http://www.oecd.org/els/emp/Summary_2012_values.xls, accessed 4-24-2015

persons that, as a migrating entity, differ significantly from each other[4].

Therefore, we have taken into account the following variables (separately for males and women): changes of demographic structures by age, changes of reasons of migration, life expectancy, health life expectancy based on EHIS 2009 (according to health and chronic diseases).

The result is the following categorization[5]:

1. People of "higher middle" age of 55 to 59 years as an additional category to seniors. It was created for comparison or for adding some conclusions. Given the actual retirement age, there is a possibility of retirement migration before the official retirement age, as demonstrated by the data of Figure 1. Nevertheless, this population is to a large extent economically active. Given the impossibility of individual selection of data on migration, it is necessary to work also with this category. Slovak migration data unfortunately make it impossible to determine whether the migrant is or is not a pensioner or for how long he or she has been retired. If such information existed, the range of research questions could be considerably expanded. It would be possible to examine in particular the relationship between the change in economic activity (status in terms of labour) and the change in probability of migration. Our definition attempts to be a certain approximation, the best possible given the data limitations.

60–69 years – group of young seniors who are the closest after retirement age[6]. We assume their best health status (within the group of seniors) and best options or potential for migration.

70–79 years – group of middle-aged seniors. We assume they have increased symptoms of chronic diseases. The persons have an increased need for healthcare. A study from the US environment (Neuman, Cubanski, Damico 2015) shows that people in this age receive 32% of healthcare (provided to all persons) and their expenditures represent 30% of total healthcare spending.

80 and more years – group of oldest seniors for which we expect a significant deterioration in health and limitation of migration to the third type of movement referred to in the chapter.

4 However, it is likely that persons close to the limit ages are similar in characteristics, even though they do not fall into one category defined by us.

5 We have considered using other alternatives, for example differentiation of age categories by gender or different definition for the years 1996–1998 and 2011–2013. Such classifications (should they occur only mechanically – quantitatively) would allow more accurate identification of groups of seniors but at the cost of decreased possibility of interpreting the results.

6 We are aware that part of the population in this age is still economically active, in their case, however, we expect a lower participation rate on internal migration precisely due to their employment acting as a pull factor in the place of residence.

3.2 Theoretical basis

The advantages of this categorization come from easy comparison of the results with other works, as the classification is very similar to established classifications abroad. Another advantage is that the limits of the categories form a sort of natural break points, corresponding to break points in several indicators used for the classification. Furthermore, the break points are logical and static in time, allowing a good interpretation of the resulting data. A certain disadvantage might be that this classification was defined by a mechanical approximation of "hard" data. Therefore it probably does not correspond to the subjective perception of the very people concerned.

We are also aware that the situation in Slovakia may differ from Western European countries, as Slovakia's population, despite ageing rapidly, is relatively younger, with lower life expectancy and lower retirement age. For example, compared to Germany, life expectancy in 2013 was lower by 5.7 years for males and 3.1 years for females (Eurostat, 2015), and the average retirement age was lower by 1.2 years (OECD). At the same time, between 1996 and 2013 life expectancy in Slovakia increased by 2.8 years for females and up to about 4 years for males (processed according to Infostat-VDC) and the retirement age increased by 0.6 years for males and 3.6 years for women.

3.3 Methods

In this paper we used primary migration data from the years 1996–2013, and we worked in detail with the three periods 1996–1998, 2003–2005 and 2011–2013. The data is anonymized and provides detailed information on individual migration. Each migration is characterized by the following features: date of migration, gender of the migrant, marital status of the migrant, migrant's education, reason for migration, district (district – LAU 2) and municipality (municipality – NUTS V) prior to migration, district and municipality after migration.

Internal migration in Slovakia is officially defined as the movement across the municipal boundaries bound with the change of so called "permanent residence" of migrant. The method to record migration using the "Migration Report" is not entirely flawless. For the purposes of our analysis the biggest defaults are the following: failure to report changes of permanent residence, which means that part of the population that has actually changed residence keeps permanent residence in the original location (for seniors in particular it may be the case of persons accommodated in social facilities). The second problem lies in the method of stating the reason for migration. In this case the migrant can choose only one of the nine above reasons that are not entirely apparent or may overlap, thereby substantially reducing the information value. In any case, it is the best and only complex source of data on internal migration in Slovakia.

The selected period allowed us to perform an in-depth analysis of the structure of migrant seniors and their changes over time. Although it would be preferable to have initiated the time series in 1990 or 1993, data are only available since 1996. The second selected period is related to Slovakia's entry into the EU. It is clear that the entry into the EU had a much greater effect on Slovak foreign migration than on the internal migration. Nevertheless, it is possible that starting from this period changes occurred also in this relatively small proportion of internal migration in Slovakia and mainly due to the development of social services (e.g. use of European funds) and changes in state social policy (e.g. under the concepts that originated from some of the EU projects and others).

We used cumulative values for three years in order to eliminate potential random fluctuations and also to achieve a sufficiently large set of values in terms of statistical analysis. Through this cumulation, the numbers of statistical units (migrations of seniors) were: for the period 1996–1998 20,846, for the period 2003–2005 it was 22,103 and finally for the period the number decreased to 15750.

The basic indicator is the mobility rate:

$$mm = \frac{M_x^{m/w}}{P_x^{m/w}} \times 1000(‰) \qquad (1)$$

where $M_x^{m/w}$ is the number of migrants – males or females aged x, $P_x^{m/w}$ is the size of the population of males or females aged x. The principle of calculation is the same as for other age-specific rates and eliminates the effect of population size.

We also use the method of direct standardization, which removes the impact of differences in age structures of populations. In this work we used it to remove the effects of the changing demographic structure since 1996. The result is a mobility rate that would be achieved by the Slovak population in the years 2003–2005 and 2011–2013 in the case of maintaining the initial age structure.

$$mm^{stp} = \frac{\sum_x mm_x P_x^{st}}{\sum_x P_x^{st}} \qquad (2)$$

where mm^{stp} is a directly standardized mobility rate, mm_x is the mobility rate of x aged population which is standardized, P_x^{st} is the absolute number of inhabitants aged x in the population we chose as standard.

4. Results

4.1 Seniors of Slovakia and their migration behaviour.

Population ageing is common problem in most of developed countries. Population of Slovakia was during its socialist period characterized by relatively high fertility rates. After political and social changes in early 90s there are visible some certain behavioural changes which could be identified as signs of second demographic transition (Lesthaeghe,Van de Kaa 1986; Van de Kaa 1987, 1994, 2002). Another aspect of population deformation is impact of post war baby boom and population wave from 70s. These factors caused current problems with population ageing in Slovakia.

Focusing on seniors, in 1996 males aged 55 and more accounted for 12.5% of the total population and females aged 55 and more accounted for 20.4% of the total population of women. This proportion increased slightly and in 2013 the proportions were already at the level of 13.8% for males and 21.3% for women. As we can see from these values, the proportion of males has increased more significantly than the proportion of women, which is mostly due to the improving mortality ratios of men. From the early 90s until 2011, the average life expectancy of males increased by 5.6 years and for females by 4.1 years (Šprocha, Vaňo, Bleha 2013). Males will continue to "catch up" with the better mortality rates of women, particularly given the scale of their reserves in the mortality rate, reducing the current significant male excess mortality, but full adjustment to the mortality rates of females is not expected (Bleha, Šprocha, Vaňo 2013). The second reason for increasing the share of these persons as a whole is the already mentioned shift in the age generations that have large numbers (ageing from the middle of the age pyramid). Figure 2 shows the development of the average age of our defined cohort of late middle aged persons and seniors in the group and in the group of 25–54 years old. The course of the two curves shows the alleged transfer of numerous generations born after the Second World War. As a result of this transfer a decrease occurred in the average age among seniors whereas the proportion of young seniors increased (and also the number of seniors as a whole) and also the average age in the category 25–54 years old decreased, due to the shift of a large number of people in late middle age being replaced by smaller generations.

Despite the relatively large and steadily increasing representation in the population, seniors participate in the migration only to a very small extent. In the years 1996–1998 only 6.66‰ of all males aged over 55 years and 8.05‰ of all females over 55 years participated on

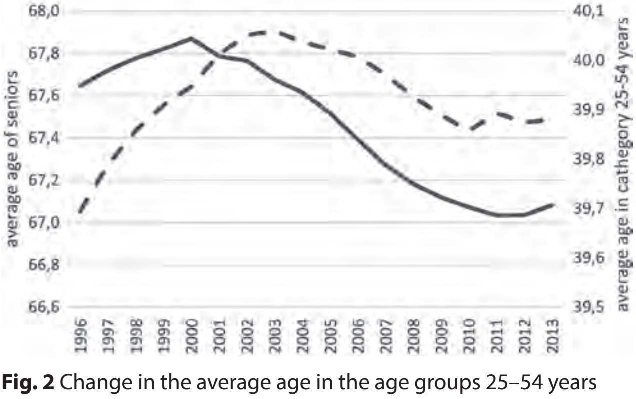

Fig. 2 Change in the average age in the age groups 25–54 years and 55 and years.
Source: SO SR.

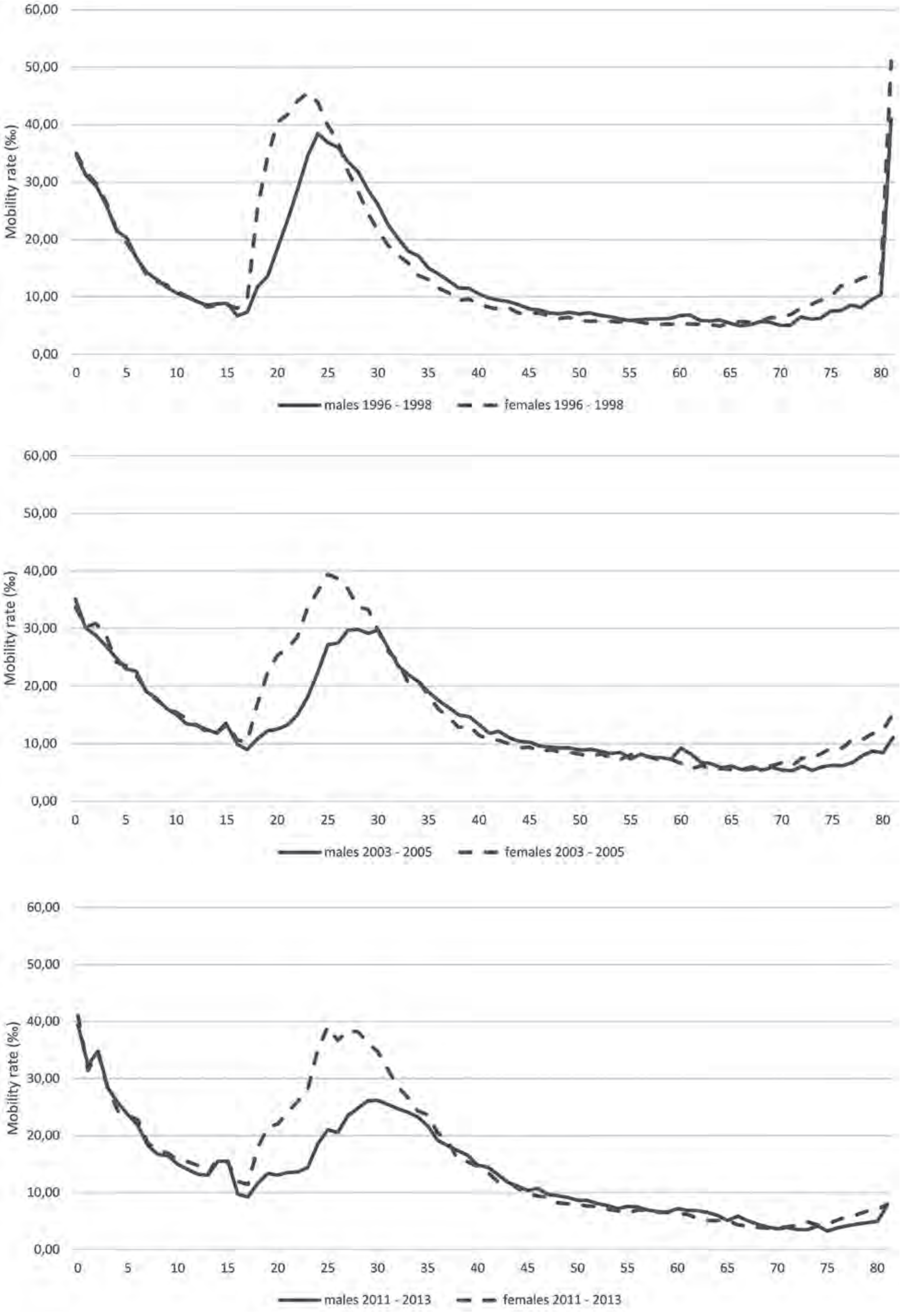

Fig. 3 Mobility rate (‰) according to age.
Source: SO SR.

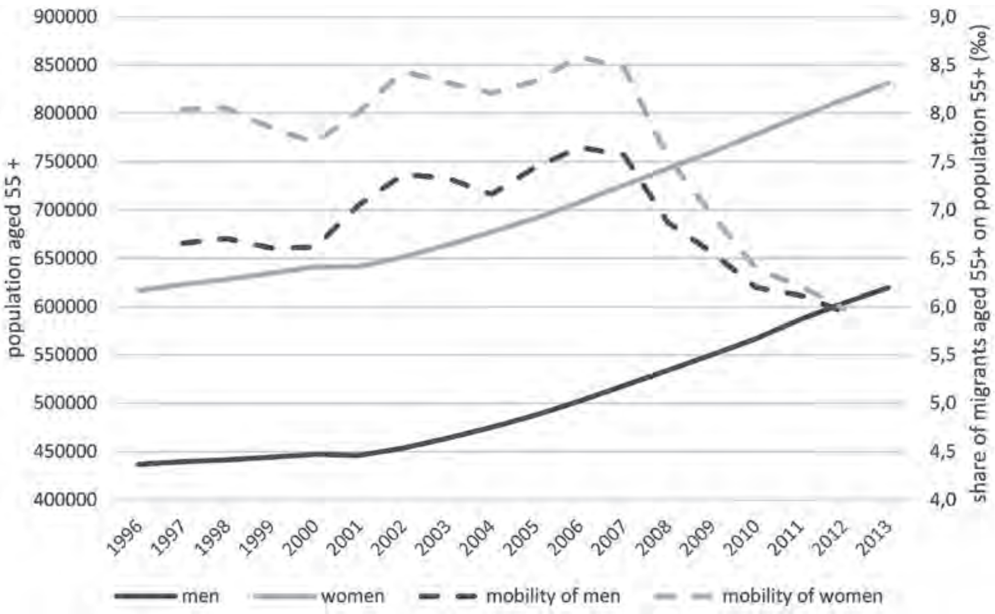

Fig. 4 Numbers and mobility of seniors.
Source: SO SR.

internal migration. This low mobility was relatively stable until 2007 with minor fluctuations in its intensity. Since 2007 a significant decrease in both sexes has occurred, which cannot be understood merely as a random fluctuation. At the same time, there is a convergence of mobility rates of males and females who are currently at approximately the same level of around 6‰. For comparison, mobility rates culminate at age from 24 (in 1996–1998) to 33 (in 2011–2013) and with maximum close to 40‰ (in case of female, males show slightly lower rates). Figure 3 shows mobility rates in each of three periods. It is obvious that impact of population ageing affects also age structure of migrants. Regardless of the period it is clear that there is the same pattern of mobility distribution among the age groups of population. In principle higher rates occur within age group of new-borns, subsequently as age increases the mobility declines. At the age of 18 there is break in declining trend, and increase ends at the age of 32 (we can assume that this age will increase in future as consequence of the shift of large – within the meaning of the number – generations to higher age groups). After this second peak of mobility rate there is simultaneous decline of mobility with rising age. The last increase of mobility appears among older seniors and falls short of mobility rates among young adults. Since we focus on mobility of seniors it is important to find out why the older seniors are more mobile than younger ones. This could be result of some changes which occur with rising age. Venti and Wise (2002, 2004) identified them as precipitating shocks (spouse's death, health shocks), Hurd (1990) relates them with Life-Cycle Hypothesis. Consideration of these factors is ongoing in the following sections.

Relatively low mobility is also reflected in the low share of senior migrants among migrants in the total of – a relatively stable share of 9–10%.

Although the mobility of seniors has been declining since 2006, their absolute number has increased by 17%, while the number of all migrants has increased only by 5.46%. This means that seniors have a 29.7% share in the total increase of internal migrants in Slovakia. The increase relates mainly to the number of male-seniors (an increase of 33.95%), the number of migrant female-seniors is growing more slowly (an increase of 7.12%). In absolute numbers, however, males still do not reach the numbers of females in 1996 (Figure 4).

The standardization of values of mobility rates by age structure in 1996–1998 shows that in the case of cessation of ageing of the population, the mobility rate of current seniors would be significantly lower than it is today. The influence of age structure is already visible in the period 2003–2005; more significantly, however, it is reflected in the period 2011–2013. The development of non-standardized mobility rates also reflects the differences in the number of migrant seniors and the total number of

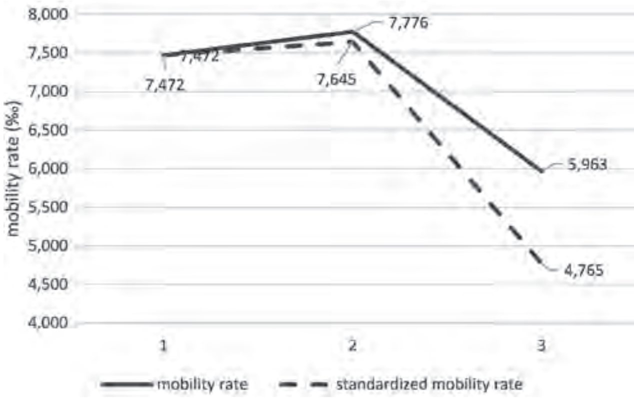

Fig. 5 Standardized mobility rates.
Source: SO SR.

seniors in the population of Slovakia, more specifically the different intensity of changes in these two variables. Between the periods 1996–1998 and 2003–2005 the number of migranting seniors grew faster than the total number of seniors (the increase, however, concerned mainly seniors younger than 65 years) resulting in an overall increase in the mobility of seniors. From the 2003–2005 period, however, a significant change in migration patterns of seniors occurred and had led to a significant drop in the mobility of migrants (Figure 5).

We evaluate the direction of migrations of seniors by comparing the type of settlement before and after migration. Settlements in Slovakia are divided into two basic types: rural municipalities (communes, villages) and urban municipalities (cities and towns, in general over 5 thousand inhabitants with several exceptions). If we assume the existence of push and pull factors that differentiate two spatial units between which the migration occurs, we could establish two highly probable hypotheses:

a) Seniors are increasingly moving to higher order settlements (to cities) which are also the seat of higher order services. Cities should be centres with institutions for the provision of services for seniors (e.g. retirement clubs, social facilities, community centres etc.), health centres and state and municipal institutions. It is also likely that with this movement seniors concentrate on a smaller number of courses because cities make up only a small part of the settlement structure of the Slovak Republic (138 towns out of 2,927 municipalities).

b) The second hypothesis is based on the premise of improving the health, economic and social conditions of seniors in Slovakia. The combination of these changes may lead to some form of suburbanization and amenity migration[7], reflected in deconcentration migrations of seniors from cities to rural municipalities.

The analytical results (Table 2) show that there has been a significant change in the migratory directions of seniors. A common feature of all the periods is that most migrant seniors come from towns, but their proportion has relatively substantially increased (from 54.55% to 68.01%). Likewise, in all periods the target places are cities, in this case their proportion has declined (from 62.79% to 54.28%). The change is continuous in both cases; it appears that in this case the entry in the EU did not affect the migration of seniors. When dividing the two types of settlements, there are four types of spatial movement: from city to city (a), from the city to the countryside (b), from the countryside to the city (c) and from the countryside to the countryside (d). Our two hypotheses concern in particular types "b" and "c". Figure 6 shows the change of proportion of these four types of movements. Also, in this division a continuous change in the structure of spatial direction of seniors is evident. The basic characteristic of this change is a stable proportion of migrants from city to city.

Significant proportion of this type of migration is migration between the city districts of Bratislava and Košice, which are de facto migrations within one city[8].

Tab. 2 Direction of migrant seniors according to the type of municipality (%).

1996–1998				
type		**after**		**Σ**
		urban	**rural**	
before	**urban**	34.13	20.42	54.55
	rural	28.66	16.78	45.45
Σ		62.79	37.21	100.00
2003–2005				
type		**after**		**Σ**
		urban	**rural**	
before	**urban**	33.74	28.47	62.22
	rural	24.16	13.62	37.78
Σ		57.90	42.10	100.00
2011–2013				
type		**after**		**Σ**
		urban	**rural**	
before	**urban**	34.07	33.94	68.01
	rural	20.20	11.79	31.99
Σ		54.28	45.72	100.00

Source: SO SR

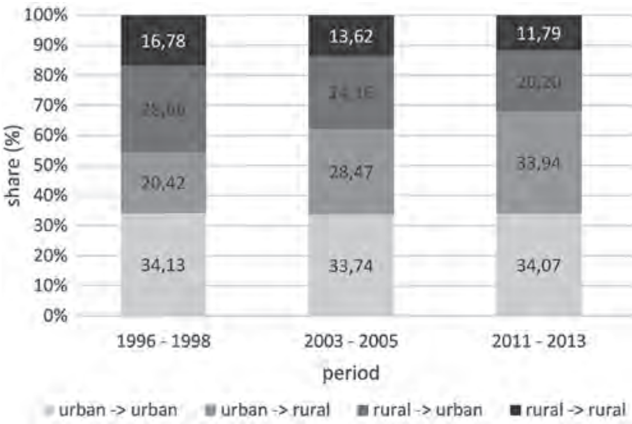

Fig. 6 Direction of seniors by type of settlement.
Source: SO SR.

7 Amenity migration and suburbanisation are two different processes which, in spite of this, are related. In a broader sense, the suburbanization triggered by the need to improve the living environment of the migrant could be considered as amenity migration. However, not all suburbanisation can be described as amenity migration. Gosnell and Abrams (2011) offer in their work a comprehensive analysis of the concepts and development of understanding amenity migration.

8 In the Slovak Republic migration is considered the spatial movement during which there was a change in the address of

Tab. 3 Structure (%) of reasons of migration of seniors according to their age in periods 1996–1998 and 2011–2013.

Age	Change of workplace	Approximation to workplace	Study	Health reasons	Marriage	Divorce	Housing reasons	Follow of the family	Other reasons	Sum (%)
1996–1998										
Males										
55–59	2.32	2.76	0.00	9.62	1.97	2.66	44.08	7.20	29.39	100
60–69	0.96	0.99	0.00	20.22	1.46	0.93	36.63	7.32	31.48	100
70–79	0.51	0.18	0.00	37.59	0.69	0.37	21.41	6.66	32.59	100
80+	0.07	0.00	0.00	52.86	0.37	0.00	9.90	5.94	30.87	100
Average	1.03	1.05	0.00	27.12	1.22	1.05	30.45	6.91	31.18	100
Females										
55–59	0.79	0.98	0.00	9.64	1.07	1.40	45.69	12.30	28.13	100
60–69	0.65	0.30	0.00	23.89	0.62	0.25	32.12	10.37	31.80	100
70–79	0.54	0.20	0.00	44.88	0.22	0.02	16.10	6.85	31.18	100
80+	0.36	0.05	0.00	54.31	0.15	0.00	7.97	5.28	31.87	100
Average	0.56	0.30	0.00	36.70	0.43	0.27	22.49	8.16	31.09	100
2011–2013										
Males										
55–59	1.12	1.52	0.00	3.27	0.84	2.74	51.47	6.16	32.89	100
60–69	0.51	0.75	0.00	6.37	0.93	1.35	47.25	8.27	34.57	100
70–79	0.15	0.15	0.00	19.04	0.51	0.29	32.99	9.81	37.06	100
80+	0.22	0.11	0.00	37.79	0.65	0.00	14.77	9.77	36.70	100
Average	0.66	0.90	0.00	9.54	0.82	1.61	44.19	7.82	34.46	100
Females										
55–59	0.87	1.17	0.00	2.88	0.57	1.24	49.75	11.04	32.47	100
60–69	0.47	0.55	0.00	7.55	0.34	0.62	47.15	11.41	31.90	100
70–79	0.14	0.11	0.00	27.40	0.32	0.04	25.11	10.83	36.05	100
80+	0.10	0.16	0.00	43.23	0.16	0.00	11.24	9.43	35.68	100
Average	0.44	0.55	0.00	17.57	0.36	0.55	36.09	10.78	33.66	100

Secondly, a significant increase in the proportion of migrations from the city to the countryside, which was already in the period 2003–2005 higher than the migration from the countryside to the cities. The last characteristic is the decline in the proportion of migration from the countryside to the cities and from the countryside to the countryside. This change may be due to differences in the development of mobility of seniors living in rural municipalities and towns. The changing mobility could be associated with the changing ratio of push and pull factors of the city and the countryside. The proportion of migration from the countryside to the countryside was already the least represented type of movement in the period 1996–1998, which could also be expected. To compare, persons aged 25–54 years in the 2003–2005 period came more often from the cities than seniors did. In the years 2011–2013, however, the proportion of those leaving the cities was already lower than for seniors. But what is constant in all three periods is that these people often prefer rural municipalities for their housing, as can be seen with seniors, despite the fact that the differences in the direction of these two population groups are gradually decreasing.

permanent residence, while crossing the administrative boundaries of the municipality. Therefore, migration between the city districts of Bratislava and Košice distort the results (migration in other cities does not qualify for the condition of crossing the administrative boundaries and therefore is not recorded).

4.2 Sex and age structure of migrants – seniors

Changes in the age structure that occurred between 1996 and 2013 have the same course for males and women, they only differ in intensity.

The fundamental features of gender and age structure of the population of seniors in Slovakia are the following:

As in the case of all migrants in Slovakia, even among seniors migrant females prevail and, with increasing age, their share is increasing, under the effect of male excess mortality and thus ultimately increasing the representation of females with increasing age. This phenomenon is valid in both reporting periods.

An important change is the significant increase in the proportion of migrants under the age of 69 years, which is caused by the ageing of large generations born after the Second World War.

Most of senior migrants are aged 55 to 69 years. The decrease in the mobility of seniors during the observed period is a possible consequence of changing age structure of seniors. Since we already know that mobility of seniors increase with age, rejuvenation of senior population (rise of share of younger seniors) decreases mobility of whole cohort. Another aspects that could play some role in the context of Slovak reality are improving health conditions of seniors, improving accessibility and the creation of new field forms of medical and social care, and the implementation of some of the objectives of the state policy in the area of addressing the challenges of ageing populations. The existence of these changes improves the quality of life of seniors and creates favourable conditions for old seniors to remain in their own homes, which is the aim of national and supranational (European) institutions supporting the concept of active ageing. With younger migrants, particularly until 60 years, the influence of factors related to labour mobility should not be omitted. In this age group, the level of economic activity, particularly for men, is still relatively high.

4.3 Marital status

The structure of the senior migrants by marital status is partially a reflection of trends in the demographic processes of marriage and divorce in the past. According to Marenčáková and Pastor, demographic and socio-economic factors influence these processes (Marenčáková, Pastor 2006).

The composition of migrant seniors by marital status differs significantly between the sexes. These differences relate mainly to the category of married and widowed migrants. The proportion of married migrant males at

Tab. 4 Structure (%) of reasons of migration of seniors according to their family status in periods 1996–1998 and 2011–2013.

Family status	Change of workplace	Approximation to workplace	Study	Health reasons	Marriage	Divorce	Housing reasons	Follow of the family	Other reasons	Sum (%)
1996–1998										
Males										
Single	3.49	1.80	0.00	38.62	0.11	0.00	17.14	2.96	35.87	100
Married	1.00	1.43	0.00	16.30	2.11	0.48	41.44	9.24	28.01	100
Divorced	0.71	0.89	0.00	23.15	0.89	6.32	30.19	3.12	34.73	100
Widowed	0.22	0.09	0.00	45.14	0.13	0.00	14.90	5.93	33.59	100
Average	1.03	1.05	0.00	27.12	1.22	1.05	30.45	6.91	31.18	100
Females										
Single	4.40	1.63	0.00	34.23	0.14	0.00	18.04	3.48	38.07	100
Married	0.41	0.32	0.00	18.57	1.41	0.18	34.67	16.57	27.88	100
Divorced	0.18	0.53	0.00	25.09	0.00	3.07	35.09	6.32	29.74	100
Widowed	0.07	0.06	0.00	45.36	0.17	0.00	17.01	5.95	31.38	100
Average	0.56	0.30	0.00	36.70	0.43	0.27	22.49	8.16	31.09	100
2011–2013										
Males										
Single	1.45	1.35	0.00	21.14	0.52	0.00	29.43	4.15	41.97	100
Married	0.70	0.85	0.00	4.82	1.19	0.15	51.95	10.09	30.26	100
Divorced	0.57	1.19	0.00	7.26	0.31	7.21	40.02	3.25	40.19	100
Widowed	0.07	0.36	0.00	26.25	0.22	0.00	26.83	7.83	38.43	100
Average	0.66	0.90	0.00	9.54	0.82	1.61	44.19	7.82	34.46	100
Females										
Single	2.23	1.56	0.00	21.07	0.22	0.00	28.44	4.99	41.47	100
Married	0.37	0.58	0.00	5.41	0.80	0.12	46.93	16.80	28.99	100
Divorced	0.42	0.71	0.00	9.07	0.08	3.09	44.76	6.64	35.23	100
Widowed	0.10	0.25	0.00	30.04	0.15	0.00	25.55	8.85	35.06	100
Average	0.44	0.55	0.00	17.57	0.36	0.55	36.09	10.78	33.66	100

each age is higher than the proportion of married migrant females when compare the absolute numbers, and married male record a higher rate of mobility too. Conversely, the proportion of widowed females is always higher than the proportion of widowers and this is due to the fact that widows are typically represented in higher age groups dominated by women. The proportion of divorced is significant only in the age group 55–59 years and 60–69 years, especially in the case of men. In this category, there has been an increase in the proportion of both males and women, manifested the most in groups aged 55–59 and 60–69 years, more significantly in the lower age category. Overall, however, the structure by marital status for both sexes is fairly stable and with no significant change between periods. Considering the Life Course Hypothesis, it seems that some reasons of migration are connected to certain marital status. Approximately 70% of health reasons were stated by widowed migrants. With respect to fact that widowed senior migrant belong to older seniors this should be not surprising. Housing reasons are very common among married migrants as well as among widowed ones. We postulate different reasons for occurrence of housing reasons among these two different groups. In case of married seniors we expect the effects of getting retired which is connected with change of financial situation. Widowed seniors are perhaps more prone to factors connected with change of family structure (spouse's death) or special requirements for housing equipment considering the health condition (in this section we have to remind the problematic methodology of identifying of migration reasons). Factors affecting both groups of seniors are creating the same gap between current and desired housing. In case of younger married seniors we can assume the migratory factor of "consumption" while in case of older widowed seniors we can rather presuppose a factor of "need".

4.4 Education

Like in the case of marital status of migrants, the current educational structure of seniors reflects the education being performed several decades ago. It should be taken into account that the present seniors studied at different times, with different educational methods as compared to those in the contemporary educational system.

As the first period being analysed are the years 1996–1998 and as the minimum age of our cohort we selected is 55 years, many of these migrants were educated even during the inter-war period. Later generations that joined the seniors in the 2011–2013 period were educated in the post-war period, in which there was a change in the organization of schooling. Unlike the inter-war period, when mainly the number of primary schools increased and Slovak education only began to take shape, in the post-war period also middle and high schools expanded (Marenčáková 2006). School policy with regard to the nature of the socialist economy tried to cover most of its needs for graduates oriented directly into the labour market (Šprocha 2012).

Changes in education were reflected also in the case of migrants. In the given periods females acquired lower education. In the period 1996–1998 the category of primary education dominates is in all age groups of seniors and for both sexes. After 15 years, in the period of 2011–2013, the massive decrease in frequency of this category was recorded. In case of men, there was an increase in particular in the category of secondary education without general certificate, for females to a greater extent in the category with general certificate. For persons who completed their education during the previous political regime, it was characteristic that males most often acquired vocational education in fields without certificate and females had a completed secondary education (with certificate) (Šprocha 2012).

The proportion of migrants with university education is interesting, especially for men. Already in the years 1996–1998 18.98% of migrants, males aged 55–59 (generation of the late 30s and early 40s of the 20th century) had university education, for males aged 60–69 years (generations from the late 20th and mid-30s of the 20th century) it was completed by 16.13%. In the overall population, tertiary educated males accounted for around 10% of the above generations (Šprocha 2012). Migrant females currently achieve a higher proportion of tertiary education than in the past in the lower age categories, but in comparison with men, this proportion is lower. Until the mid-50s only a very small proportion of females completed university studies. The first change occurred in the second half of the 50s, when there was a relatively sharp increase of the share of females in the total number of university students (Šprocha 2011).

Therefore it appears that senior's selectivity by education demonstrates in migration as in the productive ages does. This is well documented by the higher proportion of university-educated senior migrants whereas less educated senior migrants do not migrate in such a large extent.

4.5 Regression analysis

The dependent variable of regression model is the mobility rate; independent (explanatory) variables are: gender, marital status, education, reason of migration, type of municipality before and after migration and variable "x/Ex" which is share of migrants' age and his or her average life expectancy. In last variable lower values can be considered as better since they mean that in average these people still have relatively longer life to live in comparison to people with higher values of this variable. Reason to calculate such a variable was due to high VIF values (variance inflation factor – quantifies the severity of multicollinearity) of age and average life expectancy.

All independent variables except "x/Ex" were transformed into dummy variables; the omitted categories are the following:

Tab. 5 Results of regression analysis.

variables		1996–1998		2003–2005		2011–2013	
		parameter estimate	p value	parameter estimate	p value	parameter estimate	p value
intercept		3.838	<0.0001	6.477	<0.0001	6.015	<0.0001
gender		0.377	<0.0001	0.258	<0.0001	0.098	<0.0001
marital status	married	–0.017	0.7450	0.099	0.0400	0.068	0.0330
	divorced	–0.028	0.6710	0.062	0.2710	0.160	<0.0001
	widower/widow	0.488	<0.0001	0.358	<0.0001	–0.214	<0.0001
education	secondary without grad.	–0.216	<0.0001	–0.243	<0.0001	–0.025	0.3010
	secondary with grad.	–0.122	0.0100	–0.114	0.0030	0.056	0.0320
	college	–0.145	0.0180	–0.142	0.0040	–0.006	0.8490
municipality before migration		–0.112	0.0002	0.048	0.0940	0.060	0.0020
municipality after migration		–0.141	<0.0001	–0.103	<0.0001	–0.191	<0.0001
stated reason	better approach to the employment	–0.047	0.8500	–0.077	0.7740	0.147	0.3420
	health reasons	0.225	0.1880	–0.140	0.4700	–0.476	<0.0001
	marriage	–0.060	0.7990	–0.350	0.1710	–0.350	0.0330
	divorce	0.049	0.8500	–0.237	0.3410	–0.005	0.9710
	household reasons	–0.204	0.2330	–0.638	0.0009	–0.395	0.0008
	follow of the family	–0.076	0.6690	–0.531	0.0070	–0.575	<0.0001
	other reasons	0.036	0.8310	–0.447	0.0210	–0.458	<0.0001
x/Ex		0.604	<0.0001	0.290	<0.0001	0.116	<0.0001
coefficient of determination – R^2		80.09%		58.84%		30.8%	

– Gender – men;
– Marital status – single;
– Education – elementary;
– Reason for migration – change of workplace;
– Type of municipality before migration – rural municipality;
– Type of municipality after migration – rural municipality.

In all three periods we had to exclude two variables from the regression analysis – the age of the migrant and the categorical variable "reasons for migration". These two variables reached high multicollinearity. It was mainly due to the fact that some (e.g. health) reasons were, in the vast majority, reported by older seniors and, conversely, others were typical of young seniors or for those in late middle age.

The results (Table 5) show evidently that there has been a significant change in the migration of seniors. The main manifestation of this change is that while in the period 1996–1998 our used data was able to explain up to 80.09% of the variability of values of mobility rates of seniors, in the period 2003–2005 it was only 58.84%, and at present it explains only 30.80% of variability.

We would like to point out p-values of single variables. As we can see from table 3, most of variables are not statistically significant. We consider that this is due to low share of these categories in the cohort of migrating seniors. They do not necessary mean that they are not substantively significant. In fact our hypothesis is that some of them should be considered as specifics that when they appear we can expect that there will be higher or lower prevalence of migration among certain groups of seniors. Good example is migrations due to health reasons. In first two periods this reason was not statistically significant however we suppose that even in these periods seniors who have reached a certain level of health problems were more likely migratory active than those with relatively good health.

To sum up, we can see that even among single variables there is substantively significant change within analysed time period. Based on coefficients of explanatory variables, as the most important life experiences influencing decision to migrate can be considered:

(1) Gender – Especially in first two periods were women much more likely to migrate. Partially this was caused by big differences in mortality rates of men and women which resulted in high values of femininity among seniors. Nowadays, these differences are shrinking, but as we can see there is still a little higher mobility rate among women.

(2) Being a widower – Death of spouse is a life course event which changes lot of attitudes and increases the probability of migration.

(3) Level of education – Since this paper is case study, this factor is very specific and has to be considered in context of Slovak educational process and its history which was strongly connected with markets demand for labour force and its quality. In first two periods seniors had lower education then contemporary cohort seniors and therefore we can assume that those people had different views and opinions resulting into some differences in their migration decisions (some of those can be find as little changes in coefficients certain variables). To sum up, we are awaiting further changes in this category of variables. Question is whether seniors with college degree will migrate more than those with lower education (just like economically active people in Slovakia) or less since people with higher educational attainment have in general better health and therefore at least younger seniors will have less reasons to change their homes.

(4) Type of municipality after migration – It seems that among seniors there is a tendency to migrate into rural environment. We recorded this behaviour in all periods and we do not await any change. Probable reasons of this migration patterns are: better environment, cheaper real estates and in case of seniors who changed their home during communist urbanisation there are probably emotional connections to rural environment which they leaved.

(5) Reasons of migration – Reasons of migration of seniors in the past can be identified as "traditional" ones (health reasons, household reasons etc.). What we can see from our results is that "economic" reasons are becoming more important even among seniors. People are leaving labour market at higher age and are willing to change their place of living because of their jobs as well.

(6) Age and life expectancy – It seems like life and probable life expectancy are becoming less important in decision whether migrate or not. This is quite interesting finding especially when we consider common opinion on seniors as less flexible people who are not doing greater changes in their lives.

5. Conclusion

Ageism, the increasing weight of seniors in society, and pension security foster public debates in ageing European societies. However, one significant aspect which was not studied (in case of Slovakia) previously in connection with seniors is their migration mobility. In the Slovak Republic and neighbouring countries such studies are rare. At the same time, it can be assumed that the mobility of seniors may have more significant consequences, at least at regional and local levels.

In the beginning of this paper there were three research questions. First one, regarding the selectivity of the (internal) migration in the case of seniors was approved. Analysis of migration data confirmed that within our defined group of seniors, age and other demographic characteristics are quite distinct differentiating characteristics that influence the selectivity of migration itself. It can be assumed, that some inter-generational shifts in the patterns of migration occur. In the case of migration it applies in particular, that the data are not in any case satisfactory, in this case we also have to deal with insufficient size of the analysed group and statistical relevance. It was therefore not always possible to realize the intended analysis of cross interactions. Nevertheless, the study has brought some interesting, some more and some less expected, results. It is confirmed that, with increasing age, the structure of the main reasons for migration of seniors changes, with an increasing representation of health reasons. The educational attainment of migrant seniors definitely influences the migration patterns, as the group of migrants differs by migratory characteristics. The analysis showed that over the course of time some attributes of migration change, yet it is not always possible to see a clear and distinct developmental trajectory and a clear change of trend in the time of transformation. It is, however, quite clear that migration of seniors is selective. The migration of seniors in some aspects changes or develops more dynamically than the overall internal migration, it is more volatile. Based on regression analysis we were able to demonstrate a direct effect of the size of generations and ageing on the change of mobility and the attributes of migration of seniors.

Second research question dealt with assumptions of Life Course hypothesis. In this case we can say, that partially, internal migration of seniors can be explained by this hypothesis. On the other hand we have to mention that there is still strong impact of religiosity among Slovak population and therefore older people stay longer with their families.

Last research question was targeted on the link between mobility of seniors and their population size. Although the generational composition is still the most important factor affecting the mobility rate of seniors, its importance decreases and the importance of other characteristics of migrants increase. It is certain that also the migrant seniors responded to some general migration trends taking place in the transition countries, such as suburbanization and amenity migration, in which they engage. Overall as main determinant and characteristics of current internal migration of Slovak seniors we see an occurrence of unevenness of current and desired housing. This unevenness is result of certain events in life (Hurd 1990; Venti, Wise 2002, 2004). Therefore we approach to Life-Cycle Hypothesis as the explanatory theory of internal migration of seniors in Slovakia.

Acknowledgement

This contribution had been supported by VEGA Grant No. 1/0745/16 "Autonomy, interdependence and interactions of spatial systems".

REFERENCES

BLEHA, B., KOBAYASHI, K., OHZEKI, Y. (2011): Urban and Rural Local Population Policies in Japan and the Slovak Republic. Forum Statisticum Slovacum 7(6), 21–27.

BLEHA, B., ŠPROCHA, B., VAŇO, B. (2013): Prognóza populačného vývoja Slovenskej republiky do roku 2060 [Prognosis of population development of in Slovak republic till 2060]. Bratislava, INFOSTAT.

BRADLEY, D. E., LONGINO, CH. F., STOLLER, E. P., HAAS, W. H. (2008): Actuation of Mobility Intentions Among the Young-Old: An Event–History Analysis. The Gerontologist 48(2), 190–202. http://dx.doi.org/10.1093/geront/48.2.190

DENNEY, D. R., DENNEY, N. W. (1973): The Use of Classification for Problem Solving: A Comparison of Middle and Old Age. Developmental Psychology 9(2), 275–278. http://dx.doi.org/10.1037/h0035092

DENNEY, N. W., LENNON, M. L. (1972): Classification: A Comparison of Middle and Old Age. Developmental Psychology 7(2), 210–213. http://dx.doi.org/10.1037/h0033005

EUROSTAT (2013). Population by sex, age, citizenship and labour status. http://ec.europa.eu/eurostat/en/web/products-datasets/-/LFSA_PGANWS (Accessed: April 24, 2015).

EUROSTAT (2015). Population structure and ageing. http://ec.europa.eu/eurostat/statistics-explained/index.php/Population_structure_and_ageing (Accessed: August 18, 2015).

FLYNN, C. B. (1980): General versus Aged Interstate Migration, 1965–1970. Research on Ageing, 2, 165–176. https://doi.org/10.1177/016402758022006

FORMAN, D. E., BERMAN, A. D., MCCABE, C. H., BAIM, D. S., WIE, J. Y. (1992): PTCA in the Elderly: The "Young-Old" Versus the "Old-Old". Journal of the American Geriatrics Society 40(1), 19–22. http://dx.doi.org/10.1111/j.1532-5415.1992.tb01823.x

GOSNELL, H., ABRAMS, J. (2011): Amenity Migration: Diverse Conceptualizations of Drivers, Socioeconomic Dimensions, and Emerging Challenges. GeoJournal 76(4), 303–322. http://dx.doi.org/10.1007/s10708-009-9295-4

HAAS, W. H., BRADLEY, D. E., LONGINO, CH. F., STOLLER, E. P., SERROV, W. J. (2006): In Retirement Migration, Who Counts? A Methodological Question with Economic Policy Implications. The Gerontologist 46(6), 815–820. http://dx.doi.org/10.1093/geront/46.6.815

HAVLÍKOVÁ, J. (2007): Věk v sociologické teorii: Perspektiva životního běhu [Age in Sociological Theory: Perspective of Life Course]. Sociální studia 4(1–2), 179–200.

HOFF, A., FELDMAN, S., VIDOVIĆOVA, L. (2010): Migrant Home Care Workers Caring for Older People: Fictive Kin, Substitute and Complementary Family Caregivers in an Ethnically Diverse Environment. International Journal of Ageing and Later Life 5(2), 1–10. http://dx.doi.org/10.3384/ijal.1652-8670.10527

HOLMEROVÁ, I., JURAŠKOVÁ, B., ZIKMUNDOVÁ, K. (2007): Vybrané kapitoly z gerontologie [Selected Chapters from Gerontology]. Praha: Gerontologické centrum.

HURD, M. D. (1990): Research on the Elderly: Economic Status, Retirement, and Consumption and Saving. Journal of Economic Literature 28(2), 565–637.

KÁČEROVÁ, M., ONDAČKOVÁ, J., MLÁDEK, J. (2013a): Contribution of Population Processes to Population Ageing: a Comparison of the Czech and Slovak Republics. Geographica 44(1), pp. 27–43.

KÁČEROVÁ, M., ONDAČKOVÁ, J., MLÁDEK, J. (2013b): Sociálne služby pre seniorov, typy, veľkosť a priestorová diferencovanosť – komparácia Českej republiky a Slovenskej republiky. Regionální studia 1(7), pp. 51–66.

KINSELLA, K. G., VELKOFF, V. A. (2001): An Ageing world. U.S. Department of Commerce, Economics and Statistics Administration, U.S. Census Bureau.

KÖVEROVA, Š. (2002). Základy sociológie pre sociálnych pracovníkov. Učebné texty [Basics of Sociology for Social Workers. Teaching texts]. Bratislava: Katedra sociálnej práce PdF UK.

LESTHAEGHE, R., VAN DE KAA, D. J. (1986): Two Demographic transitions?. In R. Lesthaeghe, D. J. Van de Kaa (eds.), Bevolking: Groei en Krimp, Mens en Maatschappij (9–24). Deventer: Van Loghum-Slaterus.

LEE, E. S. (1966): A theory of migration, Demography 3(1), 147–157. https://doi.org/10.2307/2060063

LITWAK, E., LONGINO, C. F. (1987): Migration Patterns Among the Elderly: a Developmental Perspective. The Gerontologist 27(3), 266–272. http://dx.doi.org/10.1093/geront/27.3.266

LONGINO, C. F., BIGGAR, J. C. (1982): The Impact of Population Redistribution on Service Delivery. The Gerontologist 22(2), 153–159. http://dx.doi.org/10.1093/geront/22.2.153

MARENČÁKOVÁ, J. (2006): Vzdelanostná štruktúra obyvateľstva [Educational Structure of Population]. In J. Mládek et al. (eds.), Demogeografická analýza Slovenska [Demogeographic Analysis of Slovakia] (113–117). Bratislava: Univerzita Komenského.

MARENČÁKOVÁ, J., PASTOR, K. (2006): Časová diferencovanosť prirodzeného pohybu obyvateľstva [Temporal Differentiation of Natural Changes of Population]. In J. Mládek et al. (eds.), Demogeografická analýza Slovenska [Demogeographic Analysis of Slovakia] (22–46). Bratislava: Univerzita Komenského.

MURAKAMI, K., ATTERTON, J., GILROY, R., (2008): Planning for the Ageing Countryside in Britain and Japan: City-Regions and the Mobility of Older People. Newcastle: Centre for rural economy, Newcastle University.

MPSVR (Ministerstvo práce, sociálnych vecí a rodiny Slovenskej republiky – Ministri of Labor, Social Affairs and Family of the Slovak Republic) (2014a). Národný program aktívneho starnutia na roky 2014–2020. [National Active Aging Programme for 2014–2020]. Bratislava: MPSVR.

MPSVR (Ministerstvo práce, sociálnych vecí a rodiny Slovenskej republiky – Ministri of Labor, Social Affairs and Family of the Slovak Republic) (2014b). Národné priority rozvoja sociálnych služieb na roky 2015–2020. [National Priorities for Development of Social Services for the Years 2015–2020]. Bratislava: MPSVR.

NEUMAN, P., CUBANSKI, J., DAMICO, A. (2015): Medicare Per Capita Spending By Age And Service: New Data Highlights Oldest Beneficiaries. Health Affairs 34 (2), 335–339. http://dx.doi.org/10.1377/hlthaff.2014.1371

OECD (2015): Statistics on average effective age and official age of retirement in OECD countries. http://www.oecd.org/els/emp/Summary_1970+values.xls (Accessed: April 24, 2015).

PISCOVÁ, M. (2011): Starnutie – vek – veková identita alebo starnutie v teoretických konceptoch a v realite [Aging – Age – the Age Identity or the Aging in Theoretical Concepts and Realities]. In M. Piscová, Vek – migračné stratégie – trávenie voľného času [Age – Migrations Strategies – Spending Leisure Time] (9–42). Bratislava: Sociologický ústav SAV.

SJAASTAD, L. A. (1962): The Costs and Returns of Human Migration. Journal of Political Economy 70(5), 80–93. http://dx.doi.org/10.1086/258726

ŠPROCHA, B. (2011): Medzigeneračná premena vzdelanostnej štruktúry obyvateľstva Slovenska [Intergenerational Transformation of the Educational Structure of the Population of Slovakia] (nonpaged). In T. Löster, J. Langhamrová (eds.), Relik. Praha: Vysoká škola ekonomická.

ŠPROCHA, B. (2012): Transformácia vzdelanostnej štruktúry populácie Slovenska a jej možný vývoj do budúcnosti [Transformation of the Educational Structure of Population of the Slovak Republic and its Possible Development in the Future] (nonpaged). In T. Löster, J. Langhamrová (eds.), Relik. Praha: Vysoká škola ekonomická.

ŠPROCHA, B., VAŇO, B., BLEHA, B. (2013): Prognóza vývoja obyvateľstva v okresoch Slovenskej republiky do roku 2035 [Prognosis of Population Development in Districts of the Slovak Republic until 2035]. Bratislava: INFOSTAT, Prognostický ústav SAV, Prírodovedecká fakulta Univerzity Komenského.

SO SR [Statistical Office of the Slovak Republic] data obtained by personal request.

VAN DE KAA, D. J. (1987): Europe's second demographic transition. Population bulletin 42(1), 1–51.

VAN DE KAA, D. J. (1994): The Second Demographic Transition Revisited: Theories and Expectations (91–126). In G. Beets et al. (eds.), Population and Family in the Low Countries 1993. Lisse: Zwets and Zeitlinger.

VAN DE KAA, D. J. (2002): The Idea of a Second Demographic Transition in Industrialized Countries. Paper 6th Welfare Policy Seminar. Tokyo: National Institute of Population and Social Security.

VENTI, S. F., WISE, D. A. (2002): Aging and Housing Equity. In Z. Bodie, P. Hammond, O. Mitchell (eds.), Innovation in Retirement Financing. Philadelphia: University of Pennsylvania Press.

VENTI, S. F., WISE, D. A. (2004): Aging and Housing Equity: Another Look. Perspective in the Economics of Aging, Chicago: University of Chicago Press. https://doi.org/10.7208/chicago/9780226903286.003.0004

ZIZZA, C. A., ELLISON, K. J., WERNETTE, C. M. (2009): Total Water Intakes of Community-Living Middle-Old and Oldest-Old Adults. The Journals of Gerontology 64(4), 481–486. http://dx.doi.org/10.1093/gerona/gln045

RÉSUMÉ

Post-communistic transformation and population ageing versus the changing migratory patterns of seniors: the case of the Slovak Republic

Changes of demographic behaviour in post socialistic countries over the last decades are raising question about the problem of population ageing. In this paper authors analyse internal migration of Slovak seniors. Even though current seniors are often overlooked, we have to admit that their generation are much more numerous then generations born nowadays.

On the example of three periods we try to identify which seniors are more mobile and what factors do play any role in their migration decision. The issue who can be considered as senior is discussed in separate section. We use our own categories of seniors with regards to best match to social reality of Slovakia.

In empirical analysis we compare migration behaviour of single categories of senior according to their specific structural categories (e.g. age, sex, etc.). Moreover we track these differences and their development within three periods from 1996 to 2013.

Knowledge about migration behaviour of certain groups of seniors may be helpful in creating appropriate conditions for their life in destination regions. This could help with their social inclusion to local society and prevent the occurrence of pathological phenomena.

Arnold Kakaš, Branislav Bleha
Department of Human Geography and Demography
Faculty of Natural Sciences of Comenius University
in Bratislava
Slovak Republic
E-mail: kakas@fns.uniba.sk, bleha@fns.uniba.sk

THE EFFECT OF RURAL ROAD TRANSPORT INFRASTRUCTURE ON SMALLHOLDER FARMERS' AGRICULTURAL PRODUCTIVITY IN HORRO GUDURU WOLLEGA ZONE, WESTERN ETHIOPIA

SILESHI TAMENE, TEBAREK LIKA MEGENTO

Department of Geography and Environmental Studies, Addis Ababa University, Ethiopia

ABSTRACT

This study was carried out to examine access to rural road infrastructure and its effects on smallholder farmers' agricultural productivity in Horro Guduru Wollega Zone, Western Ethiopia. A three stage random sampling technique was employed to select 500 farming households in the study area and data was collected on their socio-economic and farm specific characteristics. The collected data was analyzed using descriptive statistics and stepwise multiple regression analysis. The result of multiple regression model used revealed that distance to major market is important in predicting agricultural productivity of smallholder farmers at 5% levels of probability in Abe Dongoro, Amuru and Hababo Guduru districts. Ownership of intermediate means of transport was also found to influence agricultural productivity in Horro, Amuru and Hababo Guduru districts ($p = 0.05$). Further analysis of the regression model showed a significant negative correlation between distance to nearest all weather roads and distance to zonal head quarter on one hand and agricultural productivity on the other hand in Abe Dongoro, Hababo Guduru and Amuru districts. Rural kebeles of Abe Dongoro and Amuru districts which has vast agricultural potential were found to be the most inaccessible in Horro Guduru Wollega Zone. It is therefore suggested that interventions in the transport sector should include provision of rural roads as well as measures that will help improve vehicle supply in rural areas. An attempt has to be done also to increase the use of intermediate means of transport to ease agricultural inputs and outputs mobility and farm access.

Keywords: rural road, agricultural productivity, smallholder, Horro Guduru

Received 19 November 2016; Accepted 21 February 2017; Published online 19 April 2017

1. Introduction

The overall development of agriculture depends on various supportive rural infrastructural facilities (Usman et al. 2013). Efficient and effective rural transportation serves as one of the channels for the collection and exchange of goods and services, movement of people, dissemination of information and the promotion of rural economy (Adedeji et al. 2014). It is also clear that development of rural infrastructure generally contributes significantly to the level and quality of rural development. Countries that have developed their rural infrastructure have recorded higher and better quality of rural development than those that have failed to do so (Economic Commission for Africa 2013).

The existence of accessible, acceptable, efficient transportation system is a pre-condition for linking remote farm areas located far from consumer centers with the agricultural production process (Taiwo, Kumi 2013). The transport system is fundamental to economic and social development in rural areas, and significant investment is required to ensure it is of a suitable level. Transport is considered as a key factor involved in agricultural development all over the world. It is the only means by which food produced at farm site is moved to different homes as well as markets. Market for agricultural produce is created by transport; furthermore, transport increases interaction among geographical and economic regions and opens up new areas to economic focus (Tunde, Adeniyi 2012). Road transport is the most predominant mode of transportation in all over the world and this is a confirmation of the crucial role transport plays in the socio-economic development of a nation (Ajiboye, Afolayan 2009).

In Ethiopia, studies have shown that, at national level, the agricultural sector employs, at least, 80% percent of the working population. More than 48% of the Nation's Gross Domestic Product (GDP) comes from agriculture. The smallholder sub-sector plays an important role in generating national output and livelihood systems in the predominantly agro-based economy of Ethiopia. The agricultural sector of Ethiopia accounts for more than a third of gross domestic product and generates more than 90 percent of export earnings (Worku 2011).

In Ethiopia, the issue of rural transportation development has continued to be of national importance. For instance, most of the rural roads are in poor condition, and this has imposed significant cost on the national economy especially to the agricultural activities due to increased vehicle operating costs and travel times. The Federal Government of Ethiopia has embarked on various programs like Growth and Transformation Plan (GTP) at one time or the other to ensure the provision of adequate transport facilities to meet the needs of the rural population but these programs have not been able to

https://doi.org/10.14712/23361980.2017.7
Tamene, S. – Megento, T. L. (2017): The effect of rural road transport infrastructure on smallholder farmers' agricultural productivity in Horro Guduru Wollega Zone, Western Ethiopia
AUC Geographica, 52, No. 1, pp. 89–99

achieve required successes. It is against this background that this study examines the impact of rural road transport infrastructure on agricultural productivity in Horro Guduru Wollega Zone, western Ethiopia. This study underlines the essentiality of the role and contribution of the rural road transport systems in supporting efficient rural agricultural activities, especially the productivity of small-scale producers.

In light of the above, it becomes expedient to examine rural transportation problems, so that the extent of the problems can be known, and possible solution proffered to achieving sustainable rural development. In this paper, an attempt has been made to analyze the effects of rural road infrastructure on smallholder farmer's agricultural productivity.

2. Problem statement and research objectives

Many rural Africans still suffer from poor access to markets, health, schooling, and high transport costs (Perschon, 2001). Inadequate rural roads make it hard for farmers to produce more and to transport any surpluses after harvest. Traffic on most rural roads still consists mainly of pedestrians often carrying head loads (DFID 2008; Lindsay 2015). Poor and inadequate rural roads have been the main concern by both small producers and consumers. Rural Africa has only 34% of road access covered as compared to 90% in the rest of the world (AFDB 2010).

Rural transport infrastructure is still poorly developed in Ethiopia, and therefore it is a crucial impediment for the growth of the rural as well as national economy. For instance, only 27% (Lulit 2012) of the rural population has access to all weather roads in 2011, compared to 60% in India and 61% in Pakistan (Giz 2013). The road density of Ethiopia per thousand square km was 49 km during the same period which falls far behind the average road density of lower middle income countries which is about 0.3 km/sq.km (IRF 2006; Lulit 2012). Therefore, most places in the country especially in the rural areas have still low road accesses and poor connectivity to major road networks.

Ethiopia's rural road network is one of the least developed in sub-Saharan Africa. The poor tends to live in isolated villages that can become virtually inaccessible during the rainy seasons. When there is a post-harvest marketable surplus, it is not always easy to reach the markets. Limited accessibility has also cut off small-scale farmers from sources of inputs, equipment and new technologies. Crop productivity is therefore low because farmers lack these important inputs. In particular, inadequate access to fertilizer is a real problem in many parts of Ethiopia where farmers have to cope with diminishing soil fertility (Fakayode et al. 2008). Consequently, efficient rural road transport infrastructure is central to raising agricultural productivity and increasing growth in Ethiopia. However, evidence show that a weak rural road transport infrastructural base has been one of the major factors militating against the attainment of the Ethiopia's growth and development objectives.

It is extremely difficult for most farmers who live and farm in the Horro Guduru Wollega Zone to gain access to all weather roads vehicles on which to transport their farm produce to home and market centres on time. In effect, the socio-economic wellbeing of the smallholder farmers is seriously affected due to high cost of agricultural in- puts and depressed prices of farm produce. Poor road conditions, high transport costs and distant markets have been identified as factors that hamper improved market access for smallholder farmers in Horro Guduru Wollega Zone.

Despite being the second populous country in Africa and one of the poorest, the question of how to reverse low agricultural productivity in Ethiopia is one that the research community has scarcely touched upon. To the researcher's knowledge, no attempt has been made to estimate the effects of poor rural road infrastructure on the structure of smallholder farm production in Ethiopia. This paper aims to fill that gap using cross-sectional data from the survey of 500 farming households in four districts of Horro Guduru Wollega Zone, Western Ethiopia.

The principal objective of the study was to investigate the effect of rural road transport infrastructure on agricultural productivity of smallholder farmers. Particularly, this research was undertaken to achieve the following three specific objectives: (1) identify the socio-economic characteristics of smallholder farmers in the study area, (2) identify the available and mostly used means of transportation in the study area, and (3) examine farmers' agricultural productivity level in relation to the existing road transportation infrastructure.

3. Research methodology

3.1 Study area

This study was conducted in Horro Guduru Wollega zone, Western Ethiopia. The capital town of the zone, Shambo, is located 314 km away from Addis Ababa to the Western part of Ethiopia. The zone comprises nine rural districts. According to the report of (CSA 2011), Horro Guduru Wollega zone covers a total land area of 8,097 km^2; a total population of 641,575 of which 50.09% are male and 49.91% are female. This study was conducted in four districts of Horo Guduru Wollega zone namely, Ababo Guduru, Horro, Abe Dongoro and Amuru (Figure 1).

3.2 The research design

Survey designs are the most important research designs in quantitative research (Creswell 2012). In

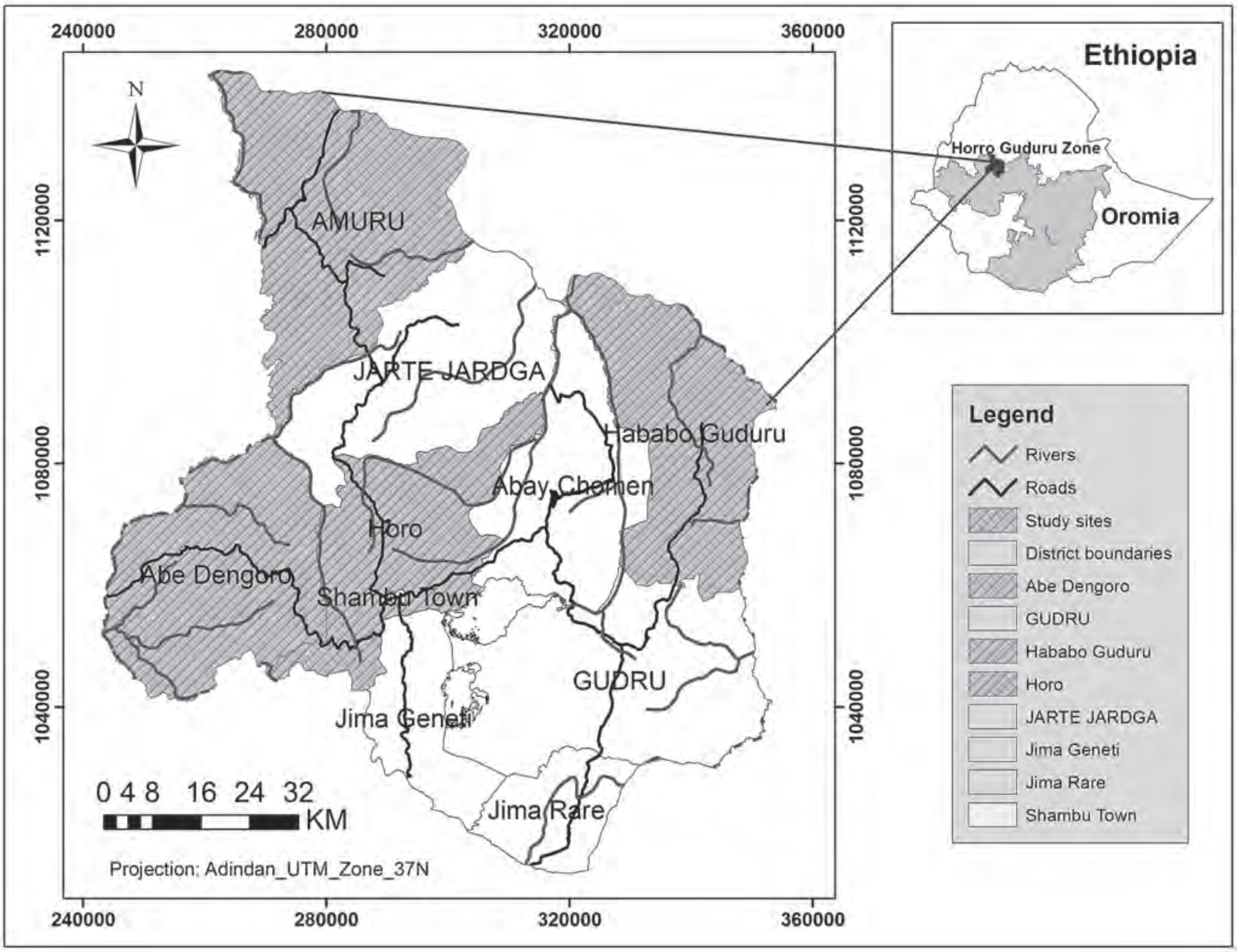

Fig. 1 Map of study area, Horro Guduru Wollega Zone by districts.
Source: Adapted Finance and Economic Development Bureau of Oromia, 2016.

explaining the effect of rural road transportation infrastructure on the agricultural productivity of smallholder farmers, survey research design was adopted and relevant data were collected through structured household questionnaire. The questionnaires are designed to collect data regarding farm-household characteristics (i.e. age, gender, education, family composition and farm size), the existing rural road transport facilities in the area, the available and mostly used means of transportation, quality of rural roads and status of smallholder farmers' agricultural productivity. Thus, for this specific research a cross-sectional survey method was employed as it is comparatively less costly, less time consuming, easier to employ, and most appropriate for data collection from smallholder farmers (Brown, Suter 2012; Saunders et al. 2007).

3.3 Sampling technique and sample size determination

Horro Guduru Wollega Zone was identified as one of the potential cereal crop producing corridors of Ethiopia. On the contrary, the existing rural road transport infrastructure in the zone is not satisfactory to support the existing agricultural potential of the area. Keeping this in view, HGWZ was purposively selected by the researcher. A Multistage simple random sampling procedure was used to derive a sample size of 500 respondents in 16 rural kebeles of the four districts of the study area. The first stage involves a random selection of four districts from the nine districts of HGWZ. Alternatively, the names of all districts of HGWZ were written on pieces of paper and the desired sample (four districts) were selected by picking the required number of papers. In such simple random sampling method, the selection of one district is independent of the selection of another district. As a result, four districts (Hababo Guduru, Horro, Amuru and Abe Dondoro) were selected. The second stage involves the random selection of four rural kebeles (RKs) from each of the four districts making a total of 16 RKs. The same simple random sampling procedure was used in the selection of RKs in each district.

The third and final stage was the random selection of farm households from each RK. The list of farm households in each RK was compiled with the assistance of the extension agents and RK manager. This list of farm households will form the sampling frame for this particular research. According to Gray et al. (2007) suggestion, the researcher used 95% confidence level (plus or minus 5 percentage points as a reasonable margin of error) to determine the sample size for this specific study. Accordingly, there will be only a 5 per cent chance that the actual coverage in this population is outside the margin of error determined by the survey. In other words, we can be confident that in 95 out of 100 surveys the true rate in the population would lie within this margin. These calculations must be repeated for each of the sample RKs in the respective sample districts. It is usual that RKs may vary considerably in the number of smallholder farmers they contain and hence to avoid bias, probability proportional to size (PPS) was employed (Table 1). RKs with larger size of smallholder farmers would have a proportionately greater chance of being included in the sample than those with small size of smallholder farmers. Thus, 500 smallholder farmers from the four districts were sampled for the study (Table 1).

Tab. 1 Sample design outlay for selecting study respondents.

Sample Districts	RK	Total farm household size	Sample size at 95% confidence level
Hababo Guduru	Moti Kawo	713	37
	Lalistu Loya	717	39
	Koticha Melole	260	15
	Sirba Loya	416	22
Horro	Odaa Buluk	549	25
	Haro Aga	1117	57
	Tokuma Alshaya	789	39
	Abe Dulacha	692	30
Amuru	Jawi Migir	516	29
	Gobu Sirba	476	25
	Haro Gudina	418	23
	Warabera	236	19
Abe Dongoro	Lomicha	978	47
	Oda Boti	433	24
	Botora Bora	469	28
	Mender 25	873	41
Total		**9652**	**500**

Source: Own sample design by using data obtained from kebele, 2016.

3.4 Methods of data collection

Both primary and secondary information were obtained for the study. The primary data were gathered through a structured household questionnaire administered by trained enumerators to the selected household heads of smallholder farmers. The study questionnaire was first pre-tested for reliability and validity. Essentially, the data was cross-sectional in nature. These data were collected between February 2016 and June 2016. The primary data include: the socio-economic characteristics of smallholder farmers such as marital status, gender, household size, farming experience, farmland size, level of education, mode of transportation often used for transporting agricultural produce from farm to home and from home to market. Rural road transport infrastructure condition such as distance to major market, distance to the nearest all weather road, ownership of intermediate means of transport in household, road distance to zonal headquarter, travel time on foot to nearest major city are among the primary data included in the household survey.

A pre-tested structured questionnaire for sample household farmers was used for primary data collection. A total of 500 copies of structured questionnaire were directly administered to the selected 500 smallholder farmers across the 16 selected samples RKs. Sample household farmers generally agreed to answer the questions willingly, and non response was almost zero. The data collection exercise took five months and involved the researcher and trained data collectors in each selected sample RKs.

The primary data obtained from the study respondents was augmented with secondary data sources. The secondary data was collected from books, journals, bulletins, magazines, internet and other literature materials. Production and productivity of major agricultural crops and related information of the study area was collected from CSA abstracts and statistical handbooks as well as from regional, zonal and district level agriculture and rural development offices.

3.5 Data processing and analysis

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) software version 20. Data gathered from respondents was subjected to different statistical techniques. These were including the descriptive statistics (mean, percentage, frequency, coefficient of variation). Inferential statistics such as simple correlation, stepwise multiple regression methods was employed to examine and establish statistical relationship between agricultural productivity as dependent variable and rural road transport infrastructure as various independent variables. A multiple regression analysis provides a means for objectively assessing the degree and nature of the relationship between dependent and independent variables. The multiple regression analysis for examining the relationships between rural road transport variables and smallholder farmers' agricultural productivity level was carried out in a stepwise method because it takes into account the issue of collinearity, the identification of outliers and the significance of linear regression coefficients. The stepwise method is sequential in approach, starting the analysis by selecting the best predictor of the dependent variable. Additional independent variables are selected in terms of the incremental explanatory power they can add to the regression model. Independent variables are added as long as their partial correlation coefficients are statistically significant.

In order to check whether there is a problem of multicollinearity, the rule of thumb, according to Gujarati (2004), is a value ≥ 0.8 in correlation coefficients between variables. As a result, Variance Inflation Factor (VIF) was computed for the variables used in regressions and no problem of multicollinearity was detected. Similarly, to check for model fit, the Hosmer and Lemeshow Test was used, which correctly predicted more than 80% of the variables.

3.6 Analytical model

The dependent variable, smallholder farmers' agricultural productivity level (yield), was measured in quintals per hectare (q/ha) and in birr/quintal. The following analysis seeks to establish whether there is any systematic relationship between rural road transport condition and smallholder farmers' agricultural productivity level. For this purpose a multivariate regression analysis was employed. This is because the model and variables used in this analysis satisfy the following three principles of this method: (1) there is only one dependent variable, (2) this variable is a parametric number, and (3) there are several parametric independent variables. Social science researchers commonly describe the different ways they measure things numerically in terms of scales of measurement, which come in three flavors: nominal, ordinal, interval or ratio scales (Brown 2001). Each is useful in its own way for quantifying different aspects of variables. Before analyzing a data set, it is important to determine each variable's scale of measurement because certain types of statistical procedures require certain scales of measurement. In this research, the variables used to explain the socio-economic characteristics of smallholder farmers are measured at nominal and ordinal level of measurement. Whereas, many of the dependent and independent variables used in the regression analysis in this research are measured at an interval or ratio level of measurement. A multiple regression analysis provides a means for objectively assessing the degree and nature of the relationship between dependent and independent variables. The regression model for this specific case is of the form:

$$Y = a + b_1x_1 + b_2x_2 + b_3x + \ldots + b_{27}x_{27} + U_i$$

In which:

Y = the agricultural productivity level (the dependent variable), measured by the monetary value of the total annual yield from farm in birr comprising all crops grown on the farms and their market prices;

a = intercept;

$b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8 \ldots b_{27}$ = change (coefficient) in agricultural productivity levels associated with a unit change in the farmers socio-economic variables and rural road transport variable (the independent variable) considered.

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 \ldots\ldots\ldots\ldots b_{27}x_{27} + U_i,$$

where:

Y = total annual yield from farm (monetary value in birr);

x_1 = farming experience (years);

x_2 = age of respondent (years);

x_3 = marital status (married, single and widow);

x_4 = distance to the nearest all weather road (km);

x_5 = education level of household head (no formal education, primary, secondary and tertiary education);

x_6 = ownership of intermediate means of transport in household (IMT) (number of IMTs in the household);

x_7 = vocational skill of household head (no = 1, yes =2);

x_8 = distance to Major Market (DSMM) (km);

x_9 = sex of household head (SEX) 1, if male; 0, if female;

x_{10} = road distance to zonal headquarter (km);

x_{11} = travel time on foot to nearest major city (min);

x_{12} = frequency of visits to the nearest town (daily, weekly, fortnightly, monthly and occasionally);

x_{13} = category of road access (asphalt concrete road, gravel road and earth road);

x_{14} = road surface condition (good, fair and bad);

x_{15} = road access condition (no vehicular access, dry season only access and all weather access);

x_{16} = road reliability in raining season (reliable and not reliable);

x_{17} = major means of transportation (head loading/human portage, animal drawn carts, pack animals and truck/car);

x_{18} = farm inputs (none, one input, two inputs and three inputs);

x_{19} = household size (number of household members);

x_{20} = farm size (hectares);

x_{21} = transport cost to the farm (in birr);

x_{22} = waiting time at the road side before accessing commercial vehicles (min);

x_{23} = distance to agricultural extension offices (km);

x_{24} = distance to agricultural farmer training centers (km);

x_{25} = distance to agricultural cooperatives (km);

x_{26} = distance to microfinance institutions (km);

x_{27} = distance to the farm (km);

U_i = error term assumed to have a zero mean and constant variance.

4. Results and Discussion

4.1 Socioeconomic characteristics of respondents

Table 2 presents the summary statistics for socioeconomic characteristics of the respondents. With respect to

Tab. 2 Socioeconomic characteristics of respondent smallholder farmers.

Sex of household head	Male	450	90
	Female	50	10
Marital status	Married	400	80
	Single	40	8
	Widow	60	12
Education level of household head	No formal education	120	24
	Primary education	260	52
	Secondary education	70	14
	Tertiary	50	10
Household size	1–3	125	25
	4–6	170	34
	7–9	130	26
	10–12	75	15
	Mean = 6		
Farming experience	1–10	40	8
	11–20	225	45
	21–30	110	22
	31–40	75	15
	41–50	50	10
	Mean = 15		
Farm size	≤ 1	50	10
	1.1–2.0	145	29
	2.1–3.0	170	34
	3.1–4.0	100	20
	>4	35	7
	Mean = 2.4		

Source: Computed from the field survey, 2016.

the first research question, it was found that the majority of the respondents are male (90.0%) and married (80%). About 24% of the respondents do not have formal education and this affects their innovation and diffusion of new ideas which might further reduce their agricultural productivity. An average household size of farming household in the study area is made of about 6 persons. The finding in this investigation was somewhat higher compared to a 4.8 persons per household at national level (CSA 2007). A possible explanation for this might be that they may be ready source of family labor on the farm. Furthermore, the rural economy is normally associated with small-scale family farms. Such units of production are characterized by labor intensive operations and limited resources.

Moreover, the study reveals that majority (45%) of the sampled farmers have between 11–20 years of farming experience. This indicates that most of the farmers sampled have enough farming experience. From Table 2, it can be seen that the mean score for farm land holding sizes per household was found to be 2.4 hectares which is above the national average of 1.14 hectares (CSA 2015). Just 10% of the respondents have farms less than 1 hectare where as the majority (34%) of the respondents cultivated between 2.1 and 3.0 hectares. This indicates that majority of the farming population in the study area are small scale farmers and were producing at subsistence level probably as result of the condition of poor rural road infrastructure that may not support large-scale and commercial production. Only 7% or 35 of the 500 respondents have farms above 4 hectares in size. This indicates that majority of the farming population in the area are small scale farmers.

4.2 Mode of transportation used by smallholder farmers

Table 3 shows that 44% of those who were interviewed indicated that they used human porterage as a means of transport to move their agricultural produce from farm to home. Likewise, Of the 500 smallholder farmers who completed the questionnaire, just 177 (30%) of them indicated that they employed the use of pack animal to transport their agricultural produce from farm to home whereas 21% use animal cart (mule, donkey or horse) for the same purpose. Surprisingly, only a minority of respondents (5%) reported that they are using motorized transport to move their agricultural produce from farm to home. Taken together, the most obvious finding to emerge from this analysis is that smallholder farmers largely depend on traditional non- motorized mode of transport to move their agricultural produce. This result is in agreement with the findings of different researchers (Usman et al. 2013; Starkey 2005; Barwell 2006) who observed that, most rural dwellers in Africa depend more on IMT than motorized transport. Surveys such as that conducted by Usman et al. (2013) have shown that owing to the very poor condition of road transport in Kwara State of Nigeria only 1.1% of the respondents own personal four wheeled vehicles and hence many people are forced to depend on motorcycle and bicycle as means of transportation. A similar work by (Porter 2013) revealed the fact that since Poor people rarely own motorized means of transport, so walking, cycling and animal traction predominates.

The higher percentage use of head porterage was observed in Abe Dongoro and Hababo Guduru which is 42% and 48% respectively as compared to the other two districts. There are several possible explanations for this result. First, these two districts are said to be far away from zone capital shambo and less attention was given to them with regard to road transport infrastructure development. Second, the physical topography of Abe Dongoro district is not welcoming the use of motorized transport. The most likely reason for the large percent (36%) of smallholder farmers in Horro district to use motorized transport (car) to move agricultural produce from home to market is due to its physical proximity to zonal capital. One possible reason behind the use of pack animals by the majority of respondents (43%) as compared to motorized transport (7%) is because of the bad condition of the rural roads from their home to markets. Another possible explanation for these results may be the lack of

Tab. 3 Mode of transportation of agricultural produce from farm to home and from home to market.

District	Mode of transport to move produce from farm to home				Total	Mode of transport to move produce from home to market				Total
	Headloading / human porterage	Pack animal	Animal cart	Car		Headloading / human porterage	Pack animal	Animal cart	Car	
Hababo Guduru	54 (48%)	33 (29%)	19 (17%)	7 (6.2%)	113 (100%)	44 (40%)	31 (27%)	7 (6%)	31 (27%)	113 (100%)
Horro	53 (35%)	57 (38%)	30 (20%)	11 (7%)	151 (100%)	30 (20%)	59 (39%)	8 (5%)	54 (36%)	151 (100%)
Amuru	38 (40%)	31 (32%)	19 (20%)	8 (8%)	96 (100%)	24 (25%)	36 (37%)	3 (3%)	33 (35%)	96 (100%)
Abe Dongoro	59 (42%)	56 (40%)	17 (12%)	8 (6%)	140 (100%)	34 (24%)	59 (42%)	5 (4%)	42 (30%)	140 (100%)
All	204 (44%)	177 (30%)	85 (21%)	34 (5%)	500 (100%)	115 (23%)	215 (43%)	35 (7%)	135 (27%)	500 (100%)

Source: Computed from the field survey, 2016.

adequate capital to pay for motorized transport. These results seem to be consistent with other research findings which revealed that bad condition of the road affects cost of transportation of agricultural produce (Moyo, Machiri 2015; Hine, Ellis 2001). It can therefore be assumed that the effect of higher percentage use of head porterage in the study area has limited the potential level of farmers' production for the reason that they can only carry certain quantity at a time.

4.3 Distance to major market and agricultural productivity

As indicated in Table 4 above, the correlations between distance to major market and agricultural productivity in

Tab. 4 Multivariate correlation analysis on rural road transport infrastructure condition and agricultural productivity using stepwise multiple regression method.

Districts	Stepwise regression method		
	Variables	**Standardized Coefficients**	**R^2**
Abe Dongoro	Distance to major market	–0.579	0.580
	Distance to the nearest all weather road	–0.670	
	The frequency of visits to the nearest town	+0.598	
	Transport cost for farm produce	–0.599	
Horro	Distance to major market	–0.328*	0.390
	Distance to the nearest all weather road	–0.279*	
	Ownership of intermediate means of transport in a household	+0.570	
	Category of road access	+0.430	
	Road access condition	+0.490	
	Transport cost for farm produce	–0.450	
Amuru	Distance to major market	–0.484	0.669
	Ownership of intermediate means of transport in a household	+0.540	
	Road distance to zonal headquarter	–0.440	
	Distance to the farm	–0. 490	
	Transport cost for farm produce	–0.450	
Hababo Guduru	Distance to major market	–0.597	0.563
	Distance to the nearest all weather road	–0.486	
	Ownership of intermediate means of transport in household	+0.520	
	Road distance to zonal headquarter	–0.620	
	frequency of visits to the nearest town	+0.480	

* Regression coefficient is not statistically significant at 0.05 levels.
Source: Computed from the field survey, 2016.

this investigation were higher for Abe Dongoro (−0.579), Amuru (−0.484) and Hababo Guduru (−0.597) districts. The regression results show that distance to major market negatively related (and statistically significant at the 5% level) to agricultural productivity. The implications for this finding is that farm households found at far distant from the market are less likely to produce crops for marketable surplus since the market price decays with physical distance, ultimately defining a threshold beyond which crop production is not economically viable.

The result thus obtained is compatible with the findings of Stifel and Minten (2003) that got statistically significant and negative correlation between agricultural productivity and distance to market center. This finding is also in agreement with Hine and Ellis' (2001) findings which showed that intensity of food production decreases as distance to market increases. In contrast to this finding, however, Goletti et al. (2001) found that distance to the nearest market does not statistically affect farmer's productivity.

4.4 Distance to the nearest all weather road and agricultural productivity

The other rural road transport related variable used in the regression analysis to estimate the effect of rural road on agricultural productivity was the distance to the nearest all weather road. The results of the correlational analysis in this research showed a significant and negative correlation (−0.67) between distance to the nearest all weather road and agricultural productivity for Abe Dongoro district. This is the indication that the presences of all-times accessible roads as the principal means of access to the farm household causes transport services to exist, which in turn is expected to increase their agricultural productivity.

A strong relationship between distance to the nearest all weather road and agricultural productivity has been reported in the literature. For instance, prior study by (Obayelu et al. 2014) has noted the importance of paved or good gravelled roads for the evacuation of agricultural produce. The observed correlation between the two variables might be explained by the fact that the growth of farm productivity is linked closely to the type and quality of rural road infrastructure in place. This means that countries that will provide adequate, affordable and accessible road infrastructure in rural areas will succeed in increasing their agricultural productivity.

4.5 Frequency of visits to the nearest town and agricultural productivity

It is apparent from Table 4 above that the frequency of visits to the nearest town correlates positively with agricultural productivity (0.598) quite revealing that the higher the frequency of visit by smallholder farmers the higher their farm productivity. Recent investigations reported by Osuolale and Ogunniyi (2015) also support the hypothesis that the frequency of visits to the nearest markets determine access to agricultural input and output markets. In a similar case in South Africa, Chaminuka et al. (2008) found that farmers who frequently visit the towns usually access different service like extension services, cooperatives, banks and post offices at a time. It can thus be suggested that investing in the growth and development of rural town centres will have positive benefits for smallholder farmers by making such services more easily accessible.

4.6 Transport cost for farm produce and agricultural productivity

It is argued that competitive rural transport is required to ensure that the advantages from reductions in transport costs are passed on to smallholder farmers. Unfortunately in Horro Guduru Wollega Zone this is far from the case. A significant negative correlation was found between transport cost for farm produce and agricultural productivity (−0.45) denoting that the higher the transport cost that farmers pay for their agricultural produce to move from farm to home or home to market the lower their farm productivity. This result provides further support for the hypothesis that reduced transport costs lower the costs and profitability of supplying modern inputs such as fertilizers, seeds, extension services and other technologies which finally increases crop productivity. This finding seems to be consistent with other researches (Jacoby, Minten 2007; Sabandar 2004) which found that differences in crop productivity among farm households are partly attributable to transport costs.

4.7 Category of road access and agricultural productivity

Category of road access correlates positively with agricultural productivity (0.43), which means as the quality of road access increases (i.e from earth road to gravel) the productivity of smallholder farmers will increase. It is encouraging to compare this finding with that found by Ashagidigbi et al. (2011) who found a significant positive correlation between category of road access and economic productivity of farmers' output. Similarly, by using time series data for 256 districts in India Narayanamoorthy, Hanjra (2006) found a strong and positive relationship between road infrastructure development and agricultural productivity. These lines of reasoning have been supported by many African and Asian studies (Kassali et al. 2012; 2014; Tunde, Adeniyi 2012; Felloni et al. 2000; Qin, Zhang 2012).

4.8 Ownership of intermediate means of transport and agricultural productivity

Closer inspection of Table 4 above shows that ownership of intermediate means of transport was highly correlated with agricultural productivity in Horro (+0.57), Amuru (+0.54), Hababo Guduru (+0.52) districts implying the higher the proportion of ownership of intermediate means of transport the higher the productivity of farm households. This result may be explained by the fact that the various intermediate means of transports complement motorized transport systems, fulfilling needs for collecting and distributing agricultural produce over relatively short distances. Another possible explanation for this result is that intermediate means of transport are appropriate to transport small and medium loads as compared to motorized means of transport. These results are in line with the work of Sabandar (2004), who argued that local market and intermediate means of transport are critical in relation to rural welfare. This finding corroborates the ideas of Stifel et al. (2013), who found a 50 percent reduction in transport costs when using IMT as opposed to motorized means of transport. Similar conclusions were raised by World Bank (1988), who argued that transporting crops to village markets and collection points often involves intermediate means of transport, to connect to the larger, motorized transport services needed to move produce to distant markets.

4.9 Road distance to zonal headquarter and agricultural productivity

As indicated in Table 4, the correlations between road distance to zonal headquarter and agricultural productivity were higher for Amuru (−0.44) and Hababo Guduru (−0.62) districts compared to those of other two districts. This higher correlation for Amuru and Hababo Guduru districts might be attributed to their relative remoteness from zonal center. This finding indicates that since zonal center is considered to be the hub for input and produce markets, as proximity to zonal center decreases farm productivity of farming household is found to decrease. In the literature, a well-established inverse relationship between these two variables was found by many studies. An example of this is the study carried out by Philemon (2014) that strongly emphasized remoteness and consequent poor access to social-services and opportunities as a key factor in low farm productivity. In another major study, Stifel and Minten (2007) found that rice prices are 13 percent more variable in the most remote areas compared to the least remote.

There are some empirical evidences that support these general arguments in Ethiopia as well. For example, Arethun and Bhatta (2012) conducted on contribution of rural roads to access to and participation in markets in Ethiopia and they come up with the conclusion that road accessibility as one of the major factors influencing the productivity of rural household. Likewise, Kifle (2010), in his dissertation work entitled 'Road Infrastructure and Rural Poverty in Ethiopia' found the fact that remoteness from the market forced smallholder farmers either to accept low prices for agricultural produce they market or consume it at farm level although they prefer to sell.

4.10 Distance to the farm and agricultural productivity

Finally, the other rural road transport related variable assumed to influence smallholder farmers' agricultural productivity was the distance to farm plot. Thus, in Amuru district there was a significant negative correlation (−0.49) between distance to the farm and agricultural productivity. Preliminary results from stepwise regressions indicate that distance to farm contribute to explain farm performance by correlating negatively, and statistically significant to agricultural productivity. Therefore, farmers in Amuru district covered long distances before getting to their farm plots and this is expected to influence the productivity and production performance of farmers. This result may be explained by the fact that when the farm land of smallholders is far apart from their home the greater was the cost of: transportation, farm management and supervision. This in turn hindered the optimal application of modern agricultural inputs and led to low productivity. It is encouraging to compare this finding with that found by Ojo and Afolabi (2003). In their study on 'Effects of farm distance on productivity of farms in Nigeria', Ojo and Afolabi found that farm distance to key infrastructure such as road correlate negatively with agricultural productivity. Similarly, further studies by (Ekbom 1998; Ojo 2008) also observed statistically significant effects of farm distance on agricultural performance of smallholder farmers.

5. Conclusion

The main goal of the current study was to explain the effect of rural road transport infrastructure on smallholder farmers' agricultural productivity in Horro Guduru Wollega Zone, Western Ethiopia. One of the more significant findings to emerge from this study is that distance to major market, category of road access, road access condition, ownership of intermediate means of transport, transport cost for farm produce, distance to the nearest all weather road and the frequency of visits to the nearest town, road distance to zonal headquarter were found to be important in predicting agricultural productivity in the study area. Spatial vulnerability in road quality and availability was observed among the four selected districts of Horro Guduru Wollega Zone. The quality of rural road infrastructure in Horro Guduru Wollega Zone indicates that the zone is still backward in terms of rural road infrastructure development despite its huge agricultural potential. A large proportion of the total length of all the roads in the study area is not paved. Due to the high agricultural potential of the area, these roads nevertheless, carry considerable volume of traffic in rural areas. The ability to carry traffic can be enhanced if these rural roads are properly maintained. There is urgent need to rehabilitate the roads in order to improve rural road accessibility which further increases smallholder farmers' agricultural productivity in rural areas.

Acknowledgements

This research was financially supported by the Ministry of Education of the Ethiopian Democratic Republic, Addis Ababa University and Wollega University. Authors would like to thank the executive editor Eva Štefanová as well as the two anonymous reviewers for their constructive comments and recommendations.

REFERENCES

ADEDEJI, O. A., OLAFIAJI, E. M., OMOLE, F. K., OLANIBI, J. A., LUKMAN, Y. (2014): An Assessment of the Impact of Road Transport on Rural Development: A case Study of Obokun Local Government Area of Osun State, Nigeria. British Journal of Environmental Sciences 2(1), 34–48.

AFDB (2010): Infrastructure – African Development Bank. Retrieved on 22 August 2011 from http://www.afdb.org/en/topics-sectors/sectors/infrastructure.

AJIBOYE, A. O., AFOLAYAN, O. (2009): The Impact of Transportation on Agricultural Production in a Developing Country: A case of Kolanut Production in Nigeria. International Journal of Agricultural Economics and Rural Development 2(2), 49–57.

ARETHUN, T., BHATTA, B. P. (2012): Contribution of Rural Roads to Access to- and Participation in Markets: Theory and Results from Northern Ethiopia. Journal of Transportation Technologies 2, 165–174. https://doi.org/10.4236/jtts.2012.22018

ASHAGIDIGBI, W. M., ABIODUN, O. F., SAMSON, O. A. (2011): The Effects of Rural Infrastructure Development on Crop Farmer's Productivity in Osun State. World Rural Observations 3(1), 48–58.

BARWELL, I. (1996): Transport and the Village: Findings from African Village Level Travel and Transport Surveys and Related Studies. World Bank Discussion Paper, no. 344. The World Bank. Washington, DC.

BROWN, J. D. (2001): Using Surveys in Language Programs. Cambridge: Cambridge University Press.

BROWN, T., & SUTER, T. (2012). Marketing Research. 8th ed. Mason, OH: South-Western Publishing.

CHAMINUKA, P., SENYOLO, G. M., MAKHURA, M. N., BELETE, A. (2008): A factor analysis of access to and use of service infrastructure amongst emerging farmers in South Africa. Agrekon 47(3), 365–378. https://doi.org/10.1080/03031853.2008.9523805

CRESWELL, J. W. (2012): Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research. 4th ed. SAGE publications: London.

CSA (2007): The 2007 Population and Housing Census of Ethiopia: Statistical Report for Oromiya.

CSA (2011): Federal Democratic Republic of Ethiopia Central statistical Agency Statistical Abstract. Addis Ababa, Ethiopia.

CSA (2015): Key Findings of the 2014/2015 (2007 E.C.) Agricultural Sample Surveys. The Federal Democratic Republic of Ethiopia Central Statistical Agency. Addis Ababa, Ethiopia.

DFID (2008): Better roads for Africa, Research News Research for Development. Retrieved on 19 August 2011 from http://www.dfid.gov.uk/r4d/news.asp?ArticleID=50292.

ECONOMIC COMMISSION FOR AFRICA (2013): Infrastructural Development and Rural Transformation.

EKBOM, A. (1998): Some Determinants to Agricultural Productivity – An Application to the Kenyan Highlands. Presented at the World Conference of Environmental Economics, Venice, Italy, 25–27 June, 1998.

FELLONI, F., WAHL, T., WANDSCHNEIDER, P. (2000): Evidence of the effect of infrastructure on agricultural production and productivity: Implications for China. Department of Agricultural Economics, Washington State University, Pullman, WA.

GRAY, P. S., WILLIAMSON, J. B., KARP, D. A., DALPHIN, J. R. (2007): The Research Imagination: An Introduction to Qualitative and Quantitative Methods. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511819391

GIZ (2014): Improving Rural Transport Infrastructure: Experience from Bangladesh. An overview on the Rural Infrastructure Improvement Project (RIIP-1). WAGNER, A., SCHMID, D (eds.). Federal Ministry for Economic Cooperation and Development (BMZ). https://www.researchgate.net

GOLETTI, F., GRUHN, P., BHATTA, A. (2001). Farmer productivity in Nepal. Discussion paper No. 17. Agricultural Sector Performance Review TA3536-NEP, Kathmandu, Nepal.

GUJARATI, D. N. (2004): Basic Econometrics. 4th ed. New Delhi: Tata McGraw-Hill.

HINE, J. L., ELLIS, S. D. (2001): Agricultural Marketing and Access to Transport Services. Rural Transport Knowledge Base; Rural Travel and Transport Program 2001.

INTERNATIONAL ROAD FEDERATION (2006): 'World Road Statistics', Statistical Report.

JACOBY, H., MINTEN, B. (2007). On Measuring the Benefits of Lower Transport Costs. World Bank, Washington, DC, Mimeo.

KASSALI, R., AYANWALE, A. B., IDOWU, E. O., WILLIAMS, S. B. (2012): Effect of Rural Transportation System on Agricultural Productivity in Oyo State, Nigeria. Journal of Agriculture and Rural Development in the Tropics and Subtropics 113(1), 13–19.

KIFLE, A. W. (2010): Road Infrastructure and Rural Poverty in Ethiopia. PhD dissertation. Department of Development and Economic Studies. University of Bradford.

LINDSAY, A. K. (2015): Rural Roads and Agricultural Development in Swaziland. Journal of Social Science Studies 2(1), 431–438.

LULIT, A. (2012): Impact of Road on Rural Poverty Evidence Form Fifteen Rural Villages in Ethiopia. MA thesis. Erasmus University Rotterdam, Institute of Social Studies (ISS), The Hague, the Netherlands.

MOYO, W., MACHIRI, A. (2015): An Assessment of the Contribution of Road Transport Systems to Smallholder Agricultural Production in Bubi District. International Journal for Research in Applied Sciences 1(1), 1–14.

NARAYANAMOORTHY, A., HANJRA, M. A. (2006): Rural Infrastructure and Agricultural Output Linkages: A Study of 256 Indian Districts. Indian Journal of Agricultural Economics 61(3), 444–459.

OBAYELU, A. E., OLAREWAJU, T. O., NURUDEEN LEKE OYELAMI, N. L. (2014): Effect of Rural Infrastructure on Profitability and Productivity of Cassava-Based Farms in Odogbolu Local Government Area, Ogun State, Nigeria. Journal of Agricultural Sciences 59(2), 187–200. https://doi.org/10.2298/JAS1402187O.

OJO, S. O. (2008): Effects of Land Acquisition for Large Scale Farming on the Performance of Small Scale Farming in Nigeria. Journal of Human Ecology 24(1), 35–40.

OJO, S. O., AFOLABI J. A. (2003): Effects of Farm Distance on Productivity of Farms in Nigeria. Journal of Applied Science 6(1), 3331–3341.

OSUOLALE, T. O., OGUNNIYI, G. (2015): Promoting Food Production Through Input Services and Rural Infrastructures. Academic Research Journal of Agricultural Sciences and Research 3(8), 224–230. https://doi.org/10.14662/ARJASR 2015.043

HEYEN-PERSCHON, J. (2001): Non-Motorized Transport and its socio-economic impact on poor households in Africa: Cost-benefit analysis of bicycle ownership in rural Uganda. Results of an empirical case study in cooperation with FABIO /BSPW. Hamburg.

PHILEMON, K. (2014): Roads and rural development: evidence from a longitudinal household survey in Kenya. PhD dissertation. Faculty of Economics at the National Graduate Institute for Policy Studies (GRIPS), Kyoto University, Kyoto, Japan.

PORTER, G. (2013): Transport Services and their Impact on Poverty and Growth in Rural Sub-Saharan Africa. AFCAP/Durham University.

QIN, Y., ZHANG, X. (2012). The Road to Specialization in Agricultural Production: Evidence from Rural China. International Food Policy Research Institute (IFPRI) Discussion Paper 01221. October 2012. Development Strategy and Governance Division. https://doi.org/10.2139/ssrn.2198039

SABANDAR, W. P. (2004): Transport development and the rural economy: Insights from Indonesia. PhD dissertation. University of Canterbury.

SAUNDERS, M., LEWIS, P., THORNHILL, A. (2007). Research methods for business students. 4th ed. Harlow, England: Financial Times/Prentice Hall.

STARKEY, P. (2005): Methodology for the Rapid Assessment of Rural Transport Services. Seminar on Sustainable Access and Local Resource Solution, 28–30 November, 2005, Bangkok. http://www.docstoc.com/doc/43488005/26-paul-starkey

STIFEL, D., MINTEN, B. (2003): Transactions Costs and Agricultural Productivity: Implications of Isolation for Rural Poverty in Madagascar. Cornell University. Discussion Paper No 56. http://www.cgiar.org/ifpri/divs/mssd/dp.htm

STIFEL, D., MINTEN, B. (2008): Isolation and agricultural productivity. Agricultural Economics 39(1), 1–15. https://doi.org/10.1111/j.1574-0862.2008.00310.x

STIFEL, D., MINTEN, B., KORO, B. (2013): Economic Benefits and Returns to Rural Feeder Roads: Evidence from a Quasi-Experimental Setting in Ethiopia. International Food Policy Research Institute (IFPRI) / The Ethiopian Development Research Institute (EDRI), Addis Ababa, Ethiopia. https://economics.lafayette.edu

TAIWO, A., KUMI, F. (2013): An Appraisal of Road Condition Effect on Rural Transportation in Sekyere Central District of the Ashanti Region of Ghana. Journal of Transportation Technologies 3, 266–271. https://doi.org/10.4236/jtts.2013.34028

TUNDE, A. M., ADENIYI, E. E. (2012): Impact of road transport on agricultural development: a Nigerian example. Ethiopian Journal of Environmental Studies and Management (EJESM) 5(3), 232–238. https://doi.org/10.4314/ejesm.v5i3.3

USMAN, B. A., ADEFILA, J. O., MUSA, I. J. (2013): Impact of rural road transport on agricultural production in Kwara State, Nigeria. Nigerian Journal of Agriculture, Food and Environment 9(2), 20–25.

WORKU, I. (2011): Road Sector Development and Economic Growth in Ethiopia. EDRI Working Paper 4. Addis Ababa, Ethiopia: Ethiopian Development Research Institute.

WORLD BANK (1988): Road Deterioration in Developing Countries: Causes and Remedies, Washington DC, World Bank.

RÉSUMÉ

The effect of rural road transport infrastructure on smallholder farmers' agricultural productivity in Horro Guduru Wollega Zone, Western Ethiopia

The aims of this study are detailed analysis of the effects of rural road transport infrastructure on smallholder farmers' agricultural productivity in Horro Guduru Wollega Zone, Western Ethiopia. Rural transport connectivity increases smallholder farmers' crop productivity after controlling for other factors. The effects of this connectivity are assumed to take place through a decline in the transport costs of agricultural outputs, which raises the producer prices of agricultural produce. Reduced transport costs in rural areas also lower the costs and profitability of supplying modern agricultural inputs such as improved seeds, chemical fertilizers, extension services, and other technologies. Distance to major market, category of road access, ownership of intermediate means of transport, transport cost for farm produce, distance to the nearest all weather road and the frequency of visits to the nearest town were found to be important in predicting agricultural productivity in the study area. Results indicate that the quality of rural road infrastructure development in the study area is poor based on the proportion of asphalt concrete and graveled road per kilometer square. Spatial vulnerability in road quality and availability was observed among the four selected districts of Horro Guduru Wollega Zone. Therefore, there is urgent need to rehabilitate the roads in order to improve rural road accessibility which further increases smallholder farmers' agricultural productivity in rural areas.

Sileshi Tamene
Department of Geography and Environmental Studies
Addis Ababa University
Ethiopia
E-mail: sileshitamene@gmail.com
Tel.: +251917819331

Tebarek Lika Megento
Department of Geography and Environmental Studies
Addis Ababa University
Ethiopia
E-mail: tebarek.lika@aau.edu.et
Tel.: +251911166385

IDEOLOGY, CLEAVAGES, AND VOTING BEHAVIOUR IN 2009 AND 2013 REGIONAL ELECTIONS IN SLOVAKIA

MARTIN PLEŠIVČÁK

Department of Human Geography and Demography, Faculty of Natural Sciences, Comenius University in Bratislava, Slovakia

ABSTRACT

When explaining electoral behaviour, cleavage theory with its practical consequences constitutes a traditional question in established Western democracies, but is just emerging in post-socialist countries of Central and Eastern Europe. The general objective of this study is to identify the spatial patterns of election results and inter-electoral shifts in support of politico-ideological blocs (measured by distribution of mandates, gained by parties at 2009 and 2013 regional elections) at the level of self-governing regions of Slovakia, and evaluate the impact of socio-political cleavages that these territorial discrepancies within the country are caused by. Elections for regional self-government held in Slovakia in 2013 are properly evaluated, when a total of 408 regional MPs were delegated to parliaments of eight NUTS3 level regions. Spatial patterns of numbers and inter-electoral changes of the mandates gained by individual political blocs representing the right wing, etatist stream, parties of ethnic orientation, so-called *'Slovak coalition'* and independent candidates are displayed not only at the regional scale, but also at the hierarchically lower level of election districts (with 90 territorial units). For regional elections, socio-economic and ethnic cleavages are considered the most important determinants of spatial differentiation related to the voting behaviour of the electorate, and then distribution of power in regional politics, but the phenomenon of independent candidates has the potential to compete with their explanatory value increasingly.

Keywords: region, regional self-government, politico-ideological bloc, election outcome, socio-political cleavage

Received 8 February 2017; Accepted 27 March 2017; Published online 19 April 2017

1. Introduction

The persistent lack of interest in the use of suffrage is a society-wide phenomenon that blurs the lines between the voting behaviour of Western countries and the post-socialist part of Europe, having a relatively brief experience with democratic election for their political representatives. Electoral lethargy can be understood as a manifestation of the natural reluctance of some citizens in the political situation of the country, region, city, town or commune where they live in, but this can also be the result of disappointment in tenure governed by more consecutive garnitures of different politico-ideological orientation. To many of them, a protest voting is not a solution or sufficient motivation to cast their vote on Election Day, which is also related to the slim chance of success for lesser-known candidates with a discreet election campaign of low budget. In the case of elections for regional and local self-government, low public awareness of powers delegated into the appropriate region, city, town or village is also very often the cause of a low turnout. In the former Eastern Bloc countries, this is associated with a very short experience of the electorate with the presence of self-government in the public space, and then the option to elect representatives having the powers just at the finer regional or local level.

The above mentioned facts are the reason that interest in elections at other than the general level is not sufficient. Historical heritage of the former regime prior to 1989 caused people of post-socialist countries to not act in the regional and transnational context yet. Just these types of elections are often perceived by them as either a vote of the second order or referendum on socio-economic themes rigidly present at the national level, ignoring the peculiarities of regional and European issues, which should be their main topic naturally.

The aim of this contribution is not to verify the validity of the second-order election concept, however. We are interested in current regional and intra-regional patterns related to politico-ideological and cleavage concepts of electoral behaviour, what their geographical and socio-political context is and what level of volatility is shaped over time. We will map the election results (measured by seats won) of different value and ideological blocs of parties whose electorate is either similar each other or very distinct from inherent political rivals representing the opinion counterbalance as a consequence of differences in voting behaviour that reflects dominant socio-political contradictions as left-right and ethnic. However, a central research question of the present contribution is what kind of socio-political cleavages affect the final election results at regional level (traced via distribution of mandates) and to what extent they do so (percentage of seats for political-ideological blocks aligned along the same kind of contradiction). This stems from the analysis of both pre-election political agreements between the parties

https://doi.org/10.14712/23361980.2017.8
Plešivčák, M. (2017): Ideology, cleavages, and voting behaviour in 2009 and 2013 regional elections in Slovakia
AUC Geographica, 52, No. 1, pp. 100–115

and the electoral success of particular politico-ideological alternatives actually affecting the regional dimension of the politics. Use the concept of dividing lines would require a more systematic assessment of the factors that influenced the distribution of seats in regional elections, mainly in terms of socio-economic stratification of territorial units under study. In such a case a deeper analysis would be required, reflecting the relationship between electoral preferences and socio-economic characteristics of the territory, for example through the use of tools of spatial econometrics (e.g. Durbin model of spatial regression). This was not ambition of this contribution. It focuses more on the relationship between political agreement (value-ideological profile, partisan, coalition affiliation of candidates) and their successfulness (representation) in particular regional parliaments.

2. Theoretical background

The assumption that citizens' voting behaviour is mainly due to their position within the social structure is a major element of political-sociological approach examining elections, usually associated with Berelson and Lazarsfeld's Columbia School. In the case of European literature, the original study *'Party Systems and Voter Alignments'* by Lipset and Rokkan (1967) is generally regarded as the theoretical framework for the politico-sociological standpoint to research this issue. Under this approach, the structure of social cleavage is reflected by the divergence in value orientation. The central position of the party identification concept as the main determinant of voters' political attitudes, his perceptions and political behaviour constitutes an essential element for the political-psychological school of Michigan, while the idea of an ideological continuum, i.e. left-right dimension in the meaning of the concept aimed at conservation of values and information for voters and political parties, is viewed as a cornerstone of the economic theory of democracy established by Downs (1957). Assessment of political parties and candidates in relation to political issues and government performance is a key component for any explanatory model presuming the behaviour of voters based on their own interest (Carmines and Huckfeldt 1996).

As mentioned earlier, the political and sociological approach taken in Europe (the idea related to electoral choice on the basis of a limited number of social cleavages) is based on the well-known Lipset and Rokkan's claim that the party systems of the sixties of the 20th century (with few, but all the more significant exceptions) reflect the social structure of the twenties (Lipset and Rokkan 1967). They argue that the party systems originated in Western Europe at the time when universal suffrage was established reflect four historical cleavages as follows: between centre and periphery, church and state, agriculture and industry, and employers and workers, while these party systems almost without exception have withstood all the turbulent political events experienced in the first half of the last century. Of these four dividing lines just social class (employers and workers) and religion (church and state) have become the most important and durable at the same time in most Western countries.

In the past, scholars interested in the voting behaviour of the electorate paid attention to its regional context sporadically. However, analyses focused on a wide scale of the individual aspects of either crucial political parties or smaller, autonomist ones, as well as the electoral behaviour of citizens at elections for self-governing regions, thanks to a multidisciplinary study approach explicitly applied to socio-political phenomenon of regional election have gradually found their place (Jeffery and Hough 2003; Pallarés and Keating 2003; Wyn Jones and Scully 2006). The volatility of electoral support for political parties at regional elections on one hand or its stability on the other can be seen as one of the traditional topics being studied by academics. In this context, there has been an attempt to answer the question concerning the importance of internal factors such as the organizational structure of the party, its election program or the local and regional political climate (Hopkin 2003; van Biezen and Hopkin 2006; Hopkin and Bradbury 2006; Roller and van Houten 2003; Fabre et al. 2005). In this respect, expertise of the party is important as well, which determines its ability to solve upcoming problems (Fiorina 1981; Petrocik 1996). Moreover, a significant part of the electorate is interested in the personality of party leader and his preconditions for holding high public office (Clark et al. 2009).

In general, the importance of elections at the regional level has been growing not only in established countries of the Western type, but also within territory beyond the former Iron Curtain, the post-socialist countries of Central and Eastern Europe (Schakel 2013). As Schakel (2011) concludes, in this geopolitical space, a number of countries gained experience with elections at this spatial level during the 1990s already, just after the fall of communism (e.g. Bosnia and Herzegovina, Croatia, Romania, Russia, Serbia and Montenegro, Poland or Hungary), about a decade later in the Czech Republic and Slovakia – the countries which for nearly seven decades constituted a common state (with the exception of the short period during World War II).

However, interest from the academic community in the regional elections of Central and Eastern European countries has been minimal. Political science and electoral geography studies have been almost exclusively concentrated on various aspects of general elections, which have traditionally enjoyed the greatest focus of the citizens as well. These issues have been discussed systematically by Tucker (2002), who found out that only about one-tenth of academic works devoted to the election of a particular type had closer analysed regional or local elections. This lethargy of both academia and the public can be explained that, in terms of area, most post-socialist countries belong to territorially smaller ones, often without further internal division of the territory considering the delegation of administrative functions and decision-making powers to the territorial units of a lower hierarchical level (Hooghe et al. 2010). Several authors, such as Soós and Kálmán (2002), Pop (2002), and Buček (2002), agree that turnout for this type of election moves below 50%, in some cases even at a level of a third or quarter of eligible voters (e.g. Slovakia) can be considered the main evidence of generally little interest in regional elections. The low level of party competition at the regional election constitutes another reason for the political apathy, since formation of electoral coalitions grouping several parties usually led by one dominant party is very common there (Ivaniševič et al. 2001). In some cases, parties at the regional level are even able to form a coalition with such political rivals, which are located on the opposite side of the value and ideological spectrum (Buček 2002). Reif and Schmitt (1980) found that the party result at elections to the European Parliament does not take into account the relevance of European issues and degree of their support by the electorate of member states properly, but they are primarily a reflection on national political issues and debates present on the domestic political scene. Reif (1985) concluded identical statements on the occasion of other directly run elections to the European Parliament five years later. Similar conclusions on the voting behaviour of the electorate in countries of the Anglo-Saxon world (Canada, United Kingdom, Belgium, Germany, Austria, Italy, Spain, etc.) can be pronounced also for regional elections, when national policy issues play a crucial role again. The degree of general topics relevance may differ from place to place significantly (Jeffery and Hough 2006).

For the countries of Central and Eastern Europe, Schakel (2011) comes to the conclusion that the traditional concept of a second-order election is affected by the quality of the party system present in this area, mainly by the number of parties seeking support of the electorate, which is several times higher than in countries with a system of few parties. Individual political orientation is not created without reference to the environment where the individual lives (Kostelecký 2003, 2012; Bernard and Kostelecký 2014). Therefore, prediction of the regional election results is still quite difficult even if we comprehend the phenomenon of second-order election, especially in the former Eastern bloc countries with a lack of experience with the democratic election of representatives to public office. In general, the ruling parties are less successful at regional elections, while opposition or regional ones usually gain more votes compared to general ballots. These findings were also confirmed by Voženílek et al. (2010), who decided to evaluate the electoral results of the main political parties acting on the Czech political scene in the context of peculiarities concerning elections for regional self-government held in the communities of Olomouc region during the first decade of the new millennium. However, the party's likelihood to succeed at elections for regional self-government must be seen in a more complex way respecting the election commitment of voters, the presence of (relatively wide) electoral coalitions, the state of the national (regional) economy, etc. The effect of the general election cycle can contribute to the final form of the election mosaic as well.

Mesežnikov et al. (2006) provide a detailed analytical interpretation of the results concerning elections for regional self-government – both parliaments of *'higher territorial units'* and the chairmen of self-governing regions. The authors offer an analytical perspective on the election results in the context of the overall political impact of fundamental changes made under the decentralization of public administration. They examine the regional aspect of public administration reform, experience of local government operation in the very first term, public opinions on regional self-government, activities of political parties and their mutual electoral competition as well as the actual election results.

All sorts of aspects concerning regional politics and public administration, elections to the regional self-government in relation to the representation of the Hungarian minority included are described by Kling (2008). The electoral behaviour of the population in southern Slovakia is largely influenced by its ethnic composition. In this part of the country it is essentially being elected according to the ethnic principle – a territory with a significant representation of the Hungarian minority overwhelmingly supports political parties developed under the ethnic contradiction, which regularly gain electoral support of ten percent at the national elections. In general, the local level is more sensitive to the needs of ethnic minorities than the central one is (Buček 2001).

The phenomenon of *'ethnic mobilization'*, i.e. activation of *'non-Hungarian'* candidate voters is more pronounced by Dostál (2002) and Krivý (2002). Based on electoral participation at ballots, Krivý (2002) formulated a hypothesis on the dominant influence of the *'Hungarian factor'* affecting polls and their outcomes. Investigating the relationship between the election results of the *'right-wing bloc'*, which the SMK (Party of Hungarian Coalition) was a coherent part of, and the level of voter participation in both all municipalities and municipalities with a territorial share of Hungarian nationality under five percent, he figured out that municipalities with a higher turnout support mostly the right-wing bloc mainly due to the SMK and its electorate.

In addition to above-mentioned ethnic cleavage of the electorate, Madleňák (2012) speaks of five other socio-political conflicts simultaneously operating, which have formed the electoral behaviour of voters in the history of independent Slovakia and whose validity can be considerably different when regarding their temporal and spatial context – centre vs. periphery, *mečiarism vs. antimečiarism*, conservative-liberal cleavage, socio-economic (left-right) cleavage, urban-rural cleavages and ethnic cleavage.

Stressing the role of a geographical approach in solving a wide variety of issues related to the phenomenon of elections, their organizations, political parties, or the behaviour of voters at the ballots has found a firm place also in several works of Czech, Polish and Slovak authors (Blažek and Kostelecký 1991; Jehlička and Sýkora 1991; Jehlička, Kostelecký and Sýkora 1993; Kostelecký 1993, 2000 and 2002; Zarycki 2000; Zarycki and Nowak 2000; Čmejrek 2008; Kostelecký and Krivý 2015; Zyricki 2015; Mikuš et al. 2016) during the last three decades.

3. Methodological issues

By present study, we want to take a closer look at the representation (potential to enforce certain perception of politics, based on election results, mandates won) of individual value-ideological blocs in the political decision-making during the term of regional self-government – i.e. through the analysis of the election results we want to catch potential dividing lines in political decision-making process that could emerge during tenure (based on division of power via candidates elected), and not directly in the voting behaviour of electorate prior election.

Electing both deputies and chairman (president) of the self-governing region (regional parliament), one-round elections of the deputies and two-round elections of the president are defined by the law. The second round of presidential election is held when no candidate gains more than 50 per cent of all votes cast in the first round. The second round is featured by two most successful candidates of the first round. The mandate is secured by the candidate who gains most valid votes in the second round. Tenure of both chairman and regional deputies is four years long. The first elections to regional parliaments took place in Slovakia in 2001, after the setting up the regional self-government by the Slovak legislation.

In total, there are 408 deputies of eight regional self-governments elected in Slovakia occupying the office for four-year period of time, most in Prešov (62) and least in Trnava region (40), which is determined by their population size. At regional elections, the territory of the Slovak Republic is divided into election districts. In the case of regional chairman election, the country consists of eight election districts, one for each self-governing region. For the members of regional parliament elections, the territory of Slovakia is divided into 90 electoral districts (see Fig. 1), oscillating from 18 (Bratislava region) to seven (in the case of Trnava region) depending on individual region.

The main analytical goal of the presented paper is to evaluate the territorial differentiation of election results

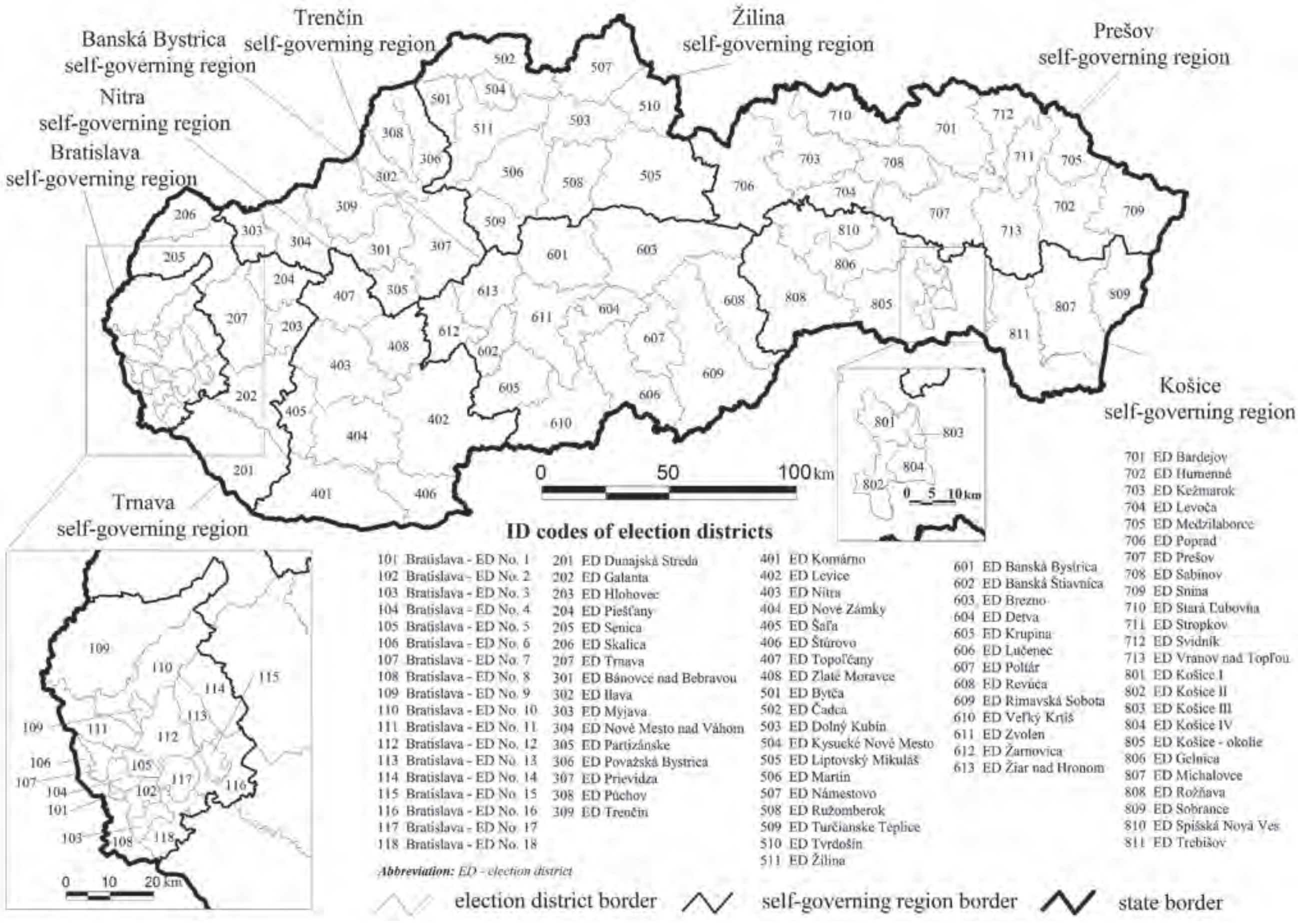

Fig. 1 Territorial composition of self-governing regions and election districts at regional elections in Slovakia.
Data source: Act No 180/2014 Coll. on Conditions of the Exercise of Voting Rights and on amendments to certain laws, author's processing.

concerning the ballots to the regional self-government on the basis of the seats won by political blocs representing the opinion alternatives in the struggle for political power, not only at national but also regional level. This enables the definition of both the geographical distribution of political power within the regional parliament on the basis of left-right or ethnic contradictions (socio-political cleavages), and the spatial differentiation in the success of independent candidates, not only in the Slovak Republic as a whole, but also the partial regions and their

Tab. 1 Basic outcomes of 2009 and 2013 regional elections in self-governing regions of Slovakia.

					Absolute numbers					**Relative numbers**				
Self-governing region	**D**	**T**	**OCH**	**OP**	**R**	**ET**	**EM**	**SC**	**I**	**R**	**ET**	**EM**	**SC**	**I**
2009														
Bratislava	44	19.46	R	R	28	14	1	0	1	63.64	31.82	2.27	0.00	2.27
Trnava	40	20.46	I	F	11	11	12	0	6	27.50	27.50	30.00	0.00	15.00
Trenčín	45	20.59	ET	ET	8	27	0	0	10	17.78	60.00	0.00	0.00	22.22
Nitra	54	21.81	SC	SC	0	0	13	38	3	0.00	0.00	24.07	70.37	5.56
Žilina	57	23.68	ET	F	18	28	0	0	11	32.46	48.25	0.00	0.00	19.30
Banská Bystrica	49	27.06	ET	ET	7	30	7	0	5	14.29	61.22	14.29	0.00	10.20
Prešov	62	26.31	ET	F	27	28	1	0	6	43.55	45.16	1.61	0.00	9.68
Košice	57	22.93	ET + EM	ET	10	30	4	0	13	17.54	52.63	7.02	0.00	22.81
Slovak Republic	**408**	**22.90**	**–**	**F**	**109**	168	38	38	55	26.72	41.18	9.31	9.31	13.48
2013														
Bratislava	44	21.65	R + EM	R + EM	36	2	0	0	6	81.82	4.55	0.00	0.00	13.64
Trnava	40	17.46	I	F	7	12	15	0	6	17.50	30.00	37.50	0.00	15.00
Trenčín	45	17.37	ET	ET	9	25	0	0	11	20.00	55.56	0.00	0.00	24.44
Nitra	54	17.90	ET	SC	3	1	14	32	4	5.56	1.85	25.93	59.26	7.41
Žilina	57	21.57	ET	F	17	24	0	0	16	29.82	42.11	0.00	0.00	28.07
Banská Bystrica	49	24.59	UN	SC	3	3	5	25	13	6.12	6.12	10.20	51.02	26.53
Prešov	62	22.13	ET	ET	20	36	0	0	6	32.26	58.06	0.00	0.00	9.68
Košice	57	17.77	ET + EM	F	16	26	4	0	11	28.07	45.61	7.02	0.00	19.30
Slovak Republic	**408**	**20.11**	**–**	**F**	**111**	**129**	**38**	**57**	73	27.21	31.62	9.31	13.97	17.89
Difference 2013–2009														
					Absolute numbers					**Relative numbers**				
Self-governing region	**T**	**SOCH**	**SOP**		**R**	**ET**	**EM**	**SC**	**I**	**R**	**ET**	**EM**	**SC**	**I**
Bratislava	2.19	R > R+EM	no		8	−12	−1	0	5	18.18	−27.27	−2.27	0.00	11.36
Trnava	−3.00	no	no		−4	1	3	0	0	−10.00	2.50	7.50	0.00	0.00
Trenčín	−3.20	no	no		1	−2	0	0	1	2.22	−4.44	0.00	0.00	2.22
Nitra	−3.90	SC > ET	no		3	1	1	−6	1	5.56	1.85	1.85	−11.11	1.85
Žilina	−2.10	no	no		−1	−4	0	0	5	−2.63	−6.14	0.00	0.00	8.77
Banská Bystrica	−2.50	ET > UN	ET > SC		−4	−27	−2	25	8	−8.16	−55.10	−4.08	51.02	16.33
Prešov	−4.20	no	F > ET		−7	8	−1	0	0	−11.29	12.90	−1.61	0.00	0.00
Košice	−5.20	no	ET > F		6	−4	0	0	−2	10.53	−7.02	0.00	0.00	−3.51
Slovak Republic	−2.79	–	no		2	−39	0	19	18	0.49	−9.56	0.00	4.66	4.41

Abbreviations: D – number of deputies, T – turnout, OCH – political orientation of regional chairman, OP – political orientation of regional parliament, R – right-wing parties, ET – etatis parties, EM – ethnic minority parties, SC – Slovak coalition, I – independent, F – fragmented, UN – ultranationalist, SOCH – political orientation shift of regional chairman, SOP – political orientation shift of regional parliament.

Data source: Statistical Office of the Slovak Republic 2014, author's calculations and processing.

respective election districts. For this purpose, we notice the results of the first leg of elections particularly, which are crucial towards the occupation of seats in representative bodies of individual self-governing regions. However, we will not only take into account the results of recent elections to the regional self-government (2013) and their spatial peculiarities, but also consider the territorial shifts in support of individual political blocs at regional level comparing election results between 2009 and 2013. We will identify the degree of either stability or volatility concerning the politico-ideological orientation of the given self-governing region not only as a whole but also its partial territories. In practical terms, we will draw attention to the election score gained by candidates of right-wing parties, leftist and national-conservative parties, the political representatives of the Hungarian minority living in Slovakia, the so called *'Slovak coalition'*, as well as independent candidates, not just for elections held in 2013, but in the context of evaluating their inter-electoral gains and losses in the proportion of votes cast in the last two ballots. In achieving this objective, we will deal with the value of both percentage share and its inter-electoral difference expressed by percentage point change (hereinafter referred to as *'p.p.'*). We will also assess the degree of regional parliament fragmentation in terms of occupancy of seats by the above mentioned blocs of political parties (see Table 1).

Elections to regional self-government as one of the practical consequences emerging from the process concerning the decentralization of public administration in Slovakia have been taking place since 2001, in a four-year periodicity. As a part of our research, we will concentrate on the last two polls, in which twenty-two (2009) and twenty (2013) parties participated. Although the main goal of this paper is to evaluate the inter-electoral spatial and temporal shifts in voter support gained by political blocs (and thus not primarily by the single parties), in this context it is also necessary to outline the mosaic of parties that constitute them from a politico-ideological point of view. For the 2009 election, we grouped the parties as follows:

– **right-wing parties** (of both conservative and liberal orientation) – Democratic Party (DS), Conservative Democrats of Slovakia (KDS), Christian Democratic Movement (KDH), LIGA – Civil Liberal Party (LIGA), Civic Conservative Party (OKS), Civil Candidates (OK), Freedom and Solidarity (SaS), Free Forum (SF), Slovak Democratic and Christian Union – Democratic Party (SDKÚ-DS), Green Party (SZ) and the Green Party of Slovakia (SZS) – a total of 11 political parties;
– **etatist parties** (of both leftist and national-conservative orientation) – Movement for Democracy (HZD), People's Party – Movement for a Democratic Slovakia (ĽS-HZDS), New Democracy (ND), Smer – Social Democracy (Smer-SD), Civil Solidarity Party (SOS), Dawn (ÚSVIT) and the Slovak National Party (SNS) – a total of 7 political parties;
– **parties of ethnic minorities** – Bridge-Bridge (Most-Hid), Hungarian Coalition Party – Magyar Koalíció Pártja (SMK-MKP) and the Party of the Roma Coalition (SRK) – 3 parties in total;
– **so-called 'Slovak coalition'** (standing for the seats in Nitra region only) – Smer-SD, SDKÚ-DS, ĽS-HZDS and KDH.
– **independent candidates**.

The next elections for regional self-government held in 2013 were attended by 20 political parties we grouped as follows:

– **right-wing parties** (of both conservative and liberal orientation) – Democratic Union (DÚ), KDS, KDH, Independent Forum (NF), New Majority (NOVA), OKS, SaS, SDKÚ-DS, SZ and the Change from the Bottom (ZZ) – a total of 10 political parties;
– **etatist parties** (of both leftist and national-conservative orientation) – HZD, ĽS-HZDS, Smer-SD, ÚSVIT, People's Party – Our Slovakia (ĽS-NS), Nation and Justice – our party (NaS-ns) and SNS – a total of 7 political parties;
– **parties of ethnic minorities** – Most-Hid and the Party of the Hungarian community – Magyar Közösség Pártja (SMK-MKP) – 2 parties altogether.
– **so-called 'Slovak coalition'** (standing for the seats in the regions of Nitra and Banská Bystrica only) – Smer-SD and KDH;
– **independent candidates**.

Considering political and ideological values, each electoral coalition clearly tended to protect either pro-reform ideas, etatist values, minority rights, nationalism (so-called Slovak Coalition), or candidates were agents of independent politics. Mandates gained by candidates coming from the same politico-ideological block were summed up within the given electoral district as well as entire region and then were converted into the relative number of seats.

Combining leftist and national-conservative parties into a single block, we wanted to emphasize the uniqueness of Slovak political scene: willingness of these two ideologies to cooperate not only regional but also national level. As an evidence the ruling coalition (state government) 2006–2010, when, despite strong criticism from Brussels, leftist Smer-SD formed a government with the ĽS-HZDS and the nationalist SNS (in government with Smer-SD also today). Cleavage of Slovak party system into the centre-right politics represented by pro-reform, quite liberal oriented parties on the one hand, and those emphasizing values of etatism and egalitarianism on the other are a typical feature of the Slovak party system in effect since the beginning of the 90s.

In this context, it is necessary to stress that we are aware of the interpretative limits resulting from such a grouping of parties selected, as the introduced concept of political blocs is not able to cover adequately all the real existing socio-political cleavages affecting the voting behaviour of the Slovakian electorate (leftist-rightist and ethnic dimension of the politico-preferential contradiction are regarded but, for example, conservative – liberal not). Division into socio-economic (left-right) and ethnic cleavage respects the result of pre-election consensus between parties running for regional office in 2009 and 2013. The weight of the first mentioned contradiction is calculated as a sum of the electoral score gained by rightist and etatist parties; for the latter we consider votes cast to both ethnic minority parties and the so-called *'Slovak coalition'*. Likewise, we must draw attention to the fact that, in some cases, there was a political agreement on the establishment of an election coalition between parties from quite different sides of the political spectrum that complicates the perception of an ambiguous and clearly recognizable struggle between traditional blocks of political parties (e.g. conservative-liberal cleavage).

4. Results: Politico-ideological orientation

Revealing the territorial patterns in electoral outcomes of individual political (party) blocs measured by seats won is the first of our main objectives. Findings of this kind can be considered the key to understanding the problems of political power distribution in a spatial context, which means in practical terms familiarity with the nature of the current value and politico-ideological orientation of regional parliaments affecting the performance of government at a sub-national scale. The first of the monitored party blocs is entrenched on the right side of the political spectrum. In the 2013 elections, right-wing parties (either on their own or in coalition) were extremely successful especially in the Bratislava region (see Fig. 2, 3 and 4) where their candidates gained more than 80% of all seats in the parliament (36 of 44 overall). Compared to its nationwide result (27.21%), they enjoyed slightly stronger support in the regions of Prešov (32.26%), Žilina (29.82%) and Košice (28.07%) as well. This confirmed the territorial pattern of both liberal (*'metropolitan environment'*) and conservative voter (northern Slovakia as representative of religious values) from the right side of the political spectrum. With only a few remarkable difficulties in contrast, right-wing parties succeeded in attracting the electorate in the regions of Nitra (5.56%) and Banská Bystrica (6.12%), but also in Trnava (17.50%) and Trenčín (20.00%). To some extent it is a consequence related to the establishment of the so-called *'Slovak coalition'* in the case of the first two mentioned regions embodying the border with Hungary, when right-wing

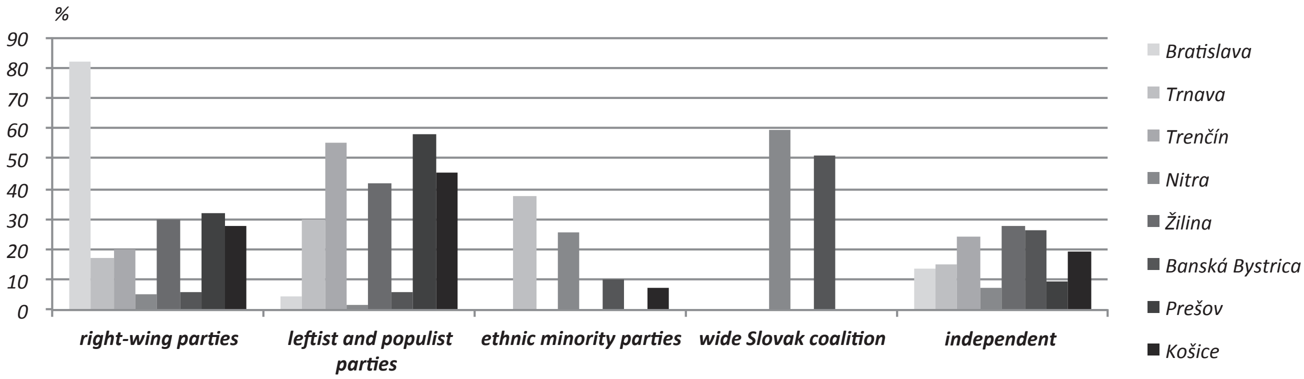

Fig. 2 Seats won by politico-ideological blocs at the 2013 regional elections in self-governing regions of Slovakia (according to blocs). Data source: Statistical Office of the Slovak Republic 2014, author's calculations and processing.

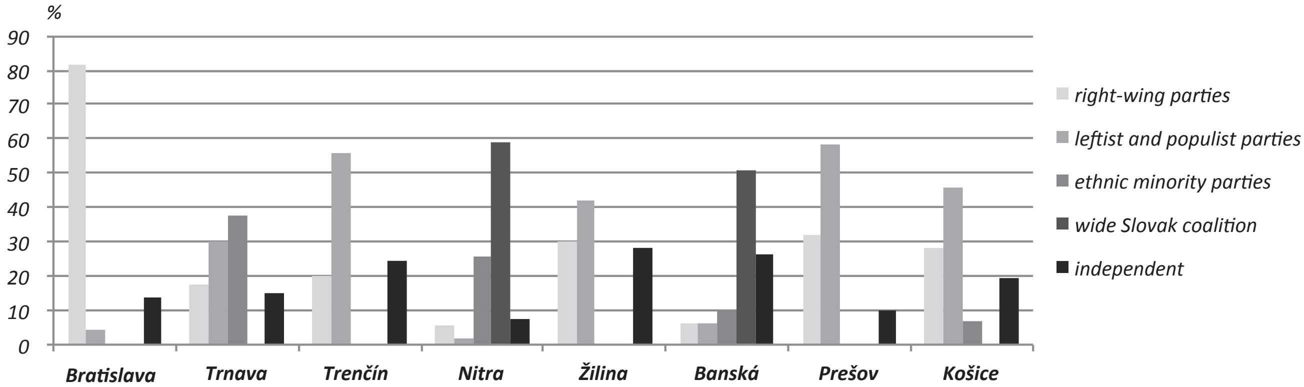

Fig. 3 Seats won by politico-ideological blocs at the 2013 regional elections in self-governing regions of Slovakia (according to regions). Data source: Statistical Office of the Slovak Republic 2014, author's calculations and processing.

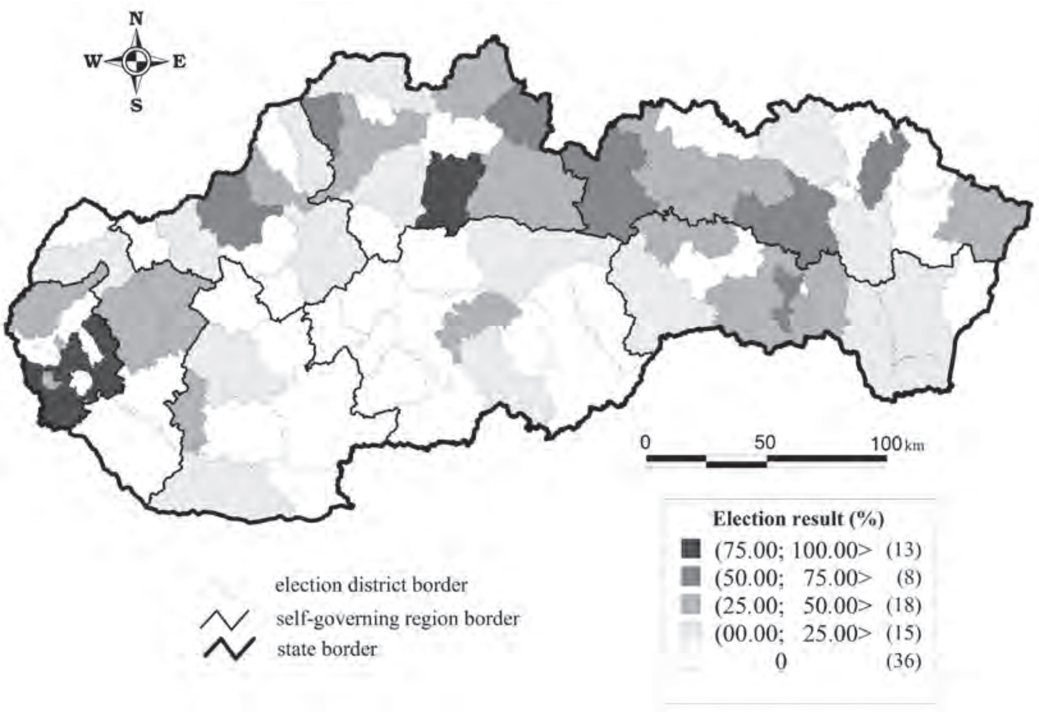

Fig. 4 Seats won by right-wing parties at the 2013 regional elections in election districts of Slovakia.
Data source: Statistical Office of the Slovak Republic 2014, author's calculations and processing.

conservative KDH joined forces with leftist Smer-SD and for these two regions this party does not primarily hold a position advocating classic right-wing politico-ideological values (in terms of socio-economic cleavage), but rather national with the mutual goal of obtaining seats in regional parliament at the expense of the Hungarian minority parties. In Trnava region, ethnic minority parties as well as the leftist and national-conservative ones are traditionally more successful than right-wing forces, promoting the values of egalitarianism and etatism for a long-term perspective. In the Trenčín region as a former stronghold of the ĽS-HZDS and currently Smer-SD, electoral support for right-wing parties are traditionally at a low level. Thus, typical right-wing parties did not succeed within an environment characterized by wide ethnic cleavage (the regions of Nitra and Banská Bystrica, south of the Trnava region), in some cases, even in those parts of Slovakia which traditionally support either leftist and national-conservative politics (the regions of Trenčín and Prešov region) or independent candidates (the regions of Žilina, Banská Bystrica and Trenčín).

In the following section of the paper we will focus one's attention on the spatial context of the regional voting score by block of etatist parties (leftist and national-conservative), whose voter profile is very similar in Slovakian politics. They establish an electoral coalition very often not only in the case of regional elections, but general ones as well. Recently, ruling Smer-SD as the most popular party in Slovakia for the recent decade has received a significant part of the electorate from national-conservative ĽS-HZDS gradually, but also the nationalist SNS. Parties of this politico-ideological and value orientation have confirmed both agenda proximity and the ability to cooperate also at a national level, when after the 2006 general elections they managed to conclude a political agreement and form a common ruling coalition (in this case consisting of Smer-SD, SNS and ĽS-HZDS).

The bloc of leftist and national-conservative parties does not rely on the electoral support coming from one or few centres to such a significant extent, as we can see in the case of right-wing parties controlling regional government in the Bratislava region by more than 4/5ths majority. Therefore, the etatist stream exceeds its most serious politico-ideological and program opponent in seats of the regional parliament in the nationwide sum (129 to 111). More than 50% of positions are occupied by candidates grouped in this block within two regions, namely Prešov (58.06%) and Trenčín (55.56%), which can be considered the traditional strongholds of political groups promoting the values of egalitarianism and etatism. The national average in share of seats (31.62%) is significantly stepped over also in the regions of Košice (45.61%) and Žilina (42.11%). The proportion of mandates for leftist and national-conservative parties is very close to the national mean in the parliament of the Trnava region (30.00%). As mentioned earlier, leftist Smer-SD as the most significant representative of this bloc constituted the so-called *'Slovak coalition'* with the right-wing conservative KDH in the case of both Banská Bystrica region and Nitra region. Therefore, the voting results of the etatist bloc were (statistically) low in these two regions (Banská Bystrica region – 6.12% and Nitra region – 1.85%), influenced by specific political agreements concluded by the above mentioned parties. Following the results of the 2013 regional elections held in Slovakia, a bloc of left-wing and national-conservative parties has occupied a significantly marginal position only in the Bratislava region, where its candidates took only two out of 44 seats (4.55%). Leaving aside the specific position related to the regions of Nitra and Banská Bystrica, a stream of right-wing parties managed to beat the etatist ones only in the region of the Slovakian capital for the 2013 elections for regional self-government.

Current leftist and national-conservative political formations won all seats in only six out of 90 electoral districts located mainly in the north-east of the country (see Fig. 5). Conversely, parties of this block succeeded in the struggle for parliamentary posts only in a few electoral districts in the regions of Bratislava as well as Nitra and Banská Bystrica (the last two being a result of the regional electoral strategy of Smer-SD, whose candidates competed for an office on a common slate with nominees of KDH, constituting the so-called *'Slovak coalition',* that intended to eliminate the number of mandates for parties of the Hungarian minority in this part of Slovakia). The bloc of etatist and egalitarian political forces did not succeed in the strongly religious region of upper Orava (north corner of Slovakia).

However, the left-right dimension of the socio-political contradiction is not the only cleavage present in the voting behaviour of the electorate. In Slovakia, the electoral decision of voters has been traditionally influenced by ethnic contradiction, which is even more intense when you think along the lines related to the delegation of representatives elected to the governments of individual regions. The SMK-MKP and the Most-Hid constitute the two main parties of ethnic orientation strictly advocating political, civil and cultural rights, and also the general status of ethnic minorities (explicitly the Hungarian one). The latter forms a regional election bloc of right-wing parties along with other representatives of right-wing politics very often, especially in regions inhabited by only a minimal number of Hungarians. In 2009, when the fourth elections to the regional government in order ran, the Party of the Roma Coalition (SRK), also with an election program of an ethnic manifesto took part, but did not succeed. In the 2013 elections for regional self-government, ethnic minority parties gained 38 seats in the regional parliaments throughout the Slovak Republic, mostly in the regions of Trnava (15 out of 40) and Nitra (14 out of 54), but their nominees were elected also in the regions of Banská Bystrica (5) and Košice (4), i.e. territories bordering Hungary characterized by a high geographical concentration of Hungarians. However, their political influence is not restricted only to the aforementioned frontier belt, since as a part of the wide right-wing coalition they scored well in other parts of Slovakia (Most-Hid in particular) as well. However, SMK-MKP compiled neither its own nor a common candidate list in several regions. For the Slovak Republic as a whole, the proportion of seats obtained by candidates nominated by parties of ethnic minorities (9.31%) almost perfectly corresponds to the territorial representation of Hungarians living in Slovakia, which just confirms the importance of ethnic cleavage in the voting decision of the electorate in the southern parts of Slovakia. These parties registered an above average share of seats in the regions of Trnava (37.50%), Nitra (25.93%) and Banská Bystrica (10.20%),

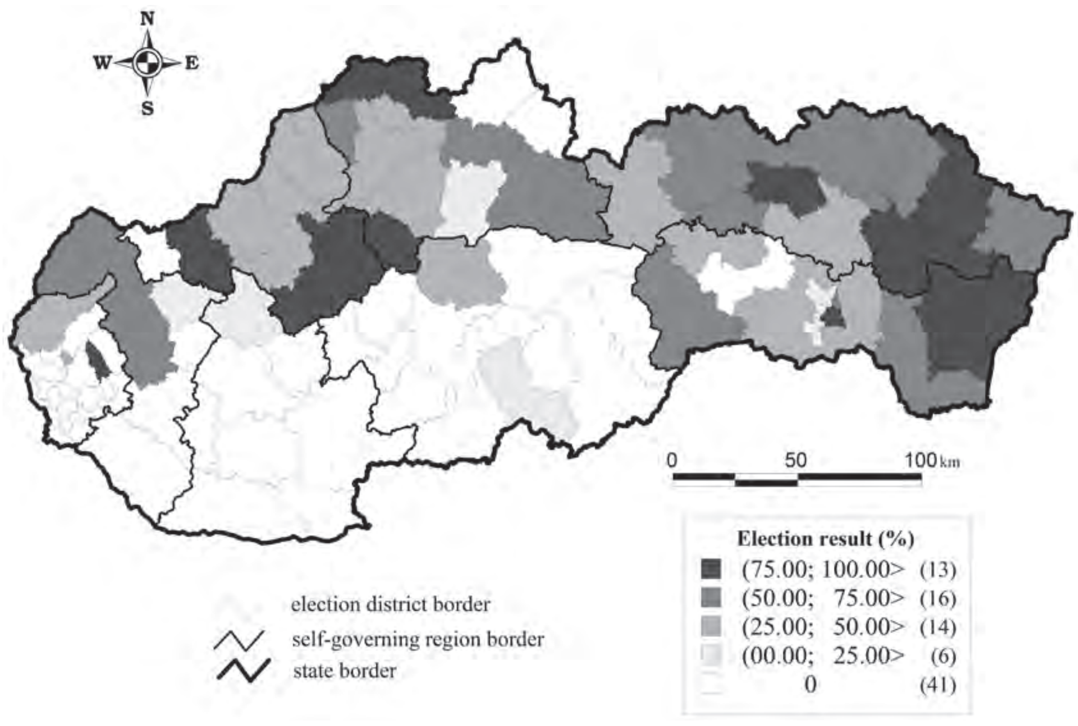

Fig. 5 Seats won by etatist parties at the 2013 regional elections in election districts of Slovakia.
Data source: Statistical Office of the Slovak Republic 2014, author's calculations and processing.

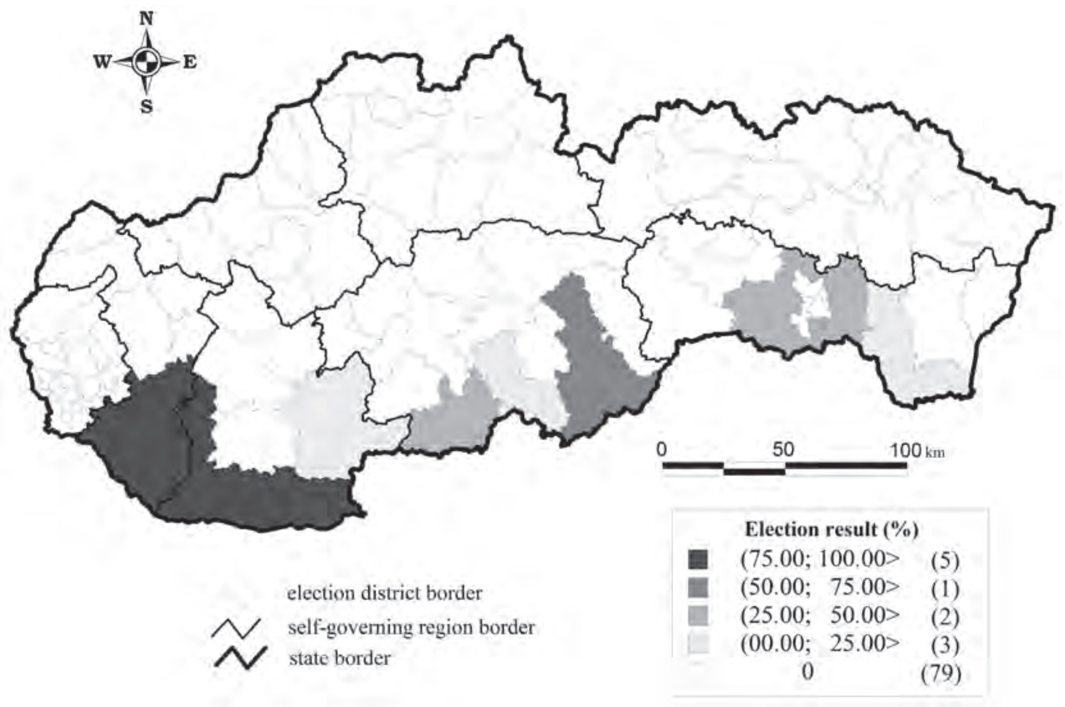

Fig. 6 Seats won by ethnic minority parties in the 2013 regional elections in election districts of Slovakia.
Data source: Statistical Office of the Slovak Republic 2014, author's calculations and processing.

with slightly lagging Košice (7.02%). Candidates nominated by them on their own (not within a wide right-wing coalition) failed in other regions of Slovakia, however.

SMK-MKP and Most-Hid were able to cooperate within a broad right-wing coalition in the Bratislava region only. In other parts of Slovakia, they acted as political competitors trying to attract the same electorate, which is related to the former disruption of SMK-MKP, leaving a large part of its members and the subsequent formation of Most-Hid in 2009. All seats for candidates of ethnic minority parties were delegated in three of 90 election districts in total constituted in Slovakia (Dunajská Streda, Galanta and Štúrovo), at least one post in 11 of them (see Fig. 6). In the remaining 79 districts, there was no deputy elected purely with the support of either SMK-MKP or Most-Hid.

In the regions of southern Slovakia, the politico-ideological counterweight to the alternative of ethnically orientated parties in the case of the 2013 regional elections was represented by the electoral coalition of leftist Smer-SD, recently the most popular party, and the right-wing conservative KDH. These two political forces formed a common slate only in two regions, namely Nitra and Banská Bystrica, while they did not stand for office in other regions jointly (see Fig. 7). This coalition acquired a majority position in the regional parliaments in both cases, since it occupied 32 out of 54 seats (59.26%) delegated in the Nitra region and 25 out of 49 (51.02%) elected in the Banská Bystrica region. Overall, the so-called *'Slovak coalition'* gained 57 of the 408 mandates (13.97%) designed for regional self-government in the Slovak Republic, which is above the previously mentioned election result of parties profiled on ethnic principle (28 seats / 9.31%).

Formation of the so-called *'Slovak coalition'* also for the region of Banská Bystrica was a specific feature of the 2013 elections for regional self-government. Until then, such an initiative had worked only in the Nitra region. On the occasion of the regional elections held in 2009, the so-called *'wide Slovak coalition'* running for office in the mentioned region was composed not only of Smer-SD and KDH, but also SDKÚ-DS and ĽS-HZDS. There was no such political agreement concluded in other regions of Slovakia. Its absence can be considered quite interesting, especially in the case of the Trnava region characterized by a relatively high territorial share of Hungarians, but its long-term chairman had been promoting the policy of cooperation within the regional parliament across the entire spectrum of political parties.

The last group of candidates whose regional election result will be studied in this paper consists of those who were not nominated by any political parties and thus can be considered as civic or independent candidates. Regarding the nationwide sum of seats for all regional parliaments (408 seats altogether), after etatist (129) and right-wing parties (111) it is just the third most important political stream, since there were 73 independent candidates at the 2013 regional elections elected. The share of the regional seats for independent candidates is above the national average (17.89%) in the regions of Žilina (28.07%), Banská Bystrica (26.53%) and Trenčín (24.44%) located in the north-western and central area of Slovakia, and partly also in the Košice region (19.30%) in the east, where they constitute from a fifth to a quarter of all

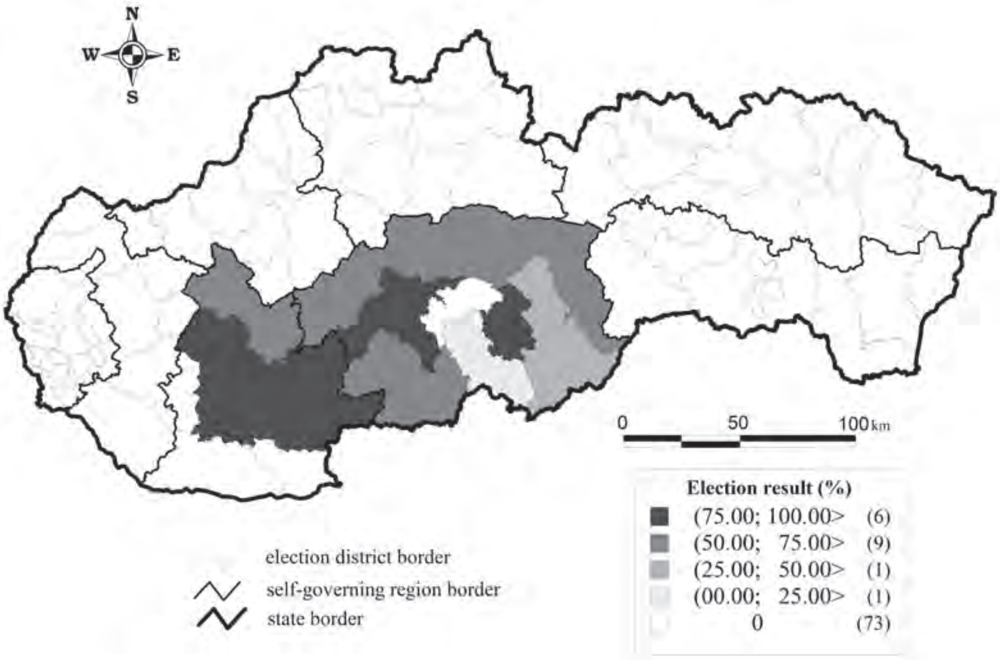

Fig. 7. Seats won by *'the Slovak coalition'* at the 2013 regional elections in election districts of Slovakia.
Data source: Statistical Office of the Slovak Republic 2014, author's calculations and processing.

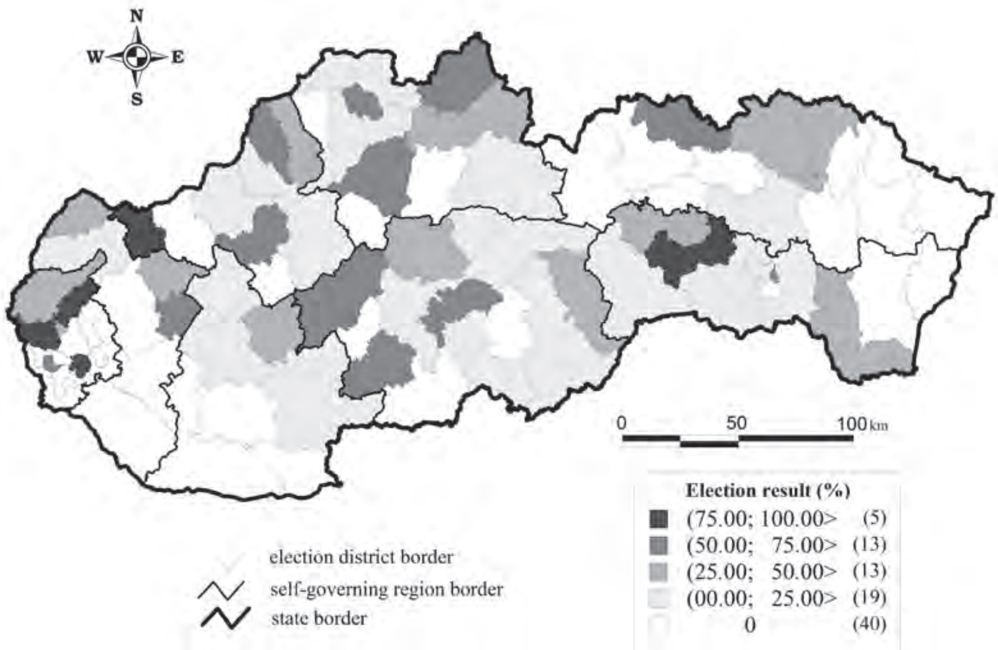

Fig. 8 Seats won by the independents at the 2013 regional elections in election districts of Slovakia.
Data source: Statistical Office of the Slovak Republic 2014, author's calculations and processing.

seats available delegated via regional elections. Conversely, the lowest support for these candidates is observed in the regions of Nitra (7.41%), Bratislava (13.64%) and Trnava (15.00%), situated in south-western Slovakia, and Prešov region (9.68%) in the north-east of the country, in which they managed to occupy from one fourteenth to one seventh of elected seats only. There is also a second question related to the successfulness of nominees for individual politico-ideological blocs, given the number of candidates they nominated for election. However, this issue is out of the objectives concerning this contribution.

As mentioned earlier, the independents represent the third largest bloc of regional MPs, since they gained almost one fifth of all seats in regional parliaments distributed via elections held in 2013. The geographical mosaic of their voting results (see Fig. 8) indicates features of spatial randomness in most regions of Slovakia, i.e. it is not formed in the shape of a spatially compact belt of either higher or lower values (perhaps with the exception of the regions of Trnava, Nitra and Prešov).

Finally, we synthesize the above mentioned findings pertaining to the spatial level of regions as well as election districts, applying a holistic approach for assessing the electoral outcomes of the mentioned politico-ideological blocks for this purpose. Right-wing parties were able to get the most delegated mandates mainly through districts localized in the regions of Bratislava and Košice (especially of their urban areas) as the biggest cities in the country, while they succeeded similarly in another four election districts situated in northern Slovakia only. The rightist bloc dominated in 18 out of 90 election districts. In this respect, the most successful bloc of parties were the left-wing and the national-conservative ones, which won a majority even in 22 districts. Relatively most of them are located in the regions of Prešov (8 of 13) and Košice (4 of 11) in eastern Slovakia, and Trnava (3 of 7) and Trenčín (3 of 9) in the west of the country. Another political bloc under study has been represented by parties of an ethnic character (in this case the Hungarian minority). They decimated other competing political forces in the regions of Trnava and Nitra, located in the south-west of Slovakia. In other parts of the country, parties based on the ethnic principle have not been able to gain a significant part of the electorate (due to the historical, ethnic and political context as well). The so-called *'Slovak coalition'*, composed of leftist Smer-SD and right-wing conservative KDH, can be considered as being a counterbalance to the stream of ethnic minority parties in the regions of Nitra and Banská Bystrica. It dominated in eleven election districts situated in the central and northern part of the Nitra region, and in a scattered form within the Banská Bystrica region. The same number of districts were dominated by independent candidates. Most of the seats available were obtained by them in four districts located in the Bratislava region and three districts situated in the Trenčín region. With regard to the political blocs' representation, the highest number of regional governments is characterized by the fragmented structure of their parliament. In practical terms, this means that no politico-ideological stream has a simple majority of seats in the given regional parliament for the 2013–2017 tenure. This is applied for the regions of Trnava, Žilina and Košice, where a political consensus across the spectrum of different political and ideological groups is needed in the prospect of ensuring the smooth operation of regional government in the coming period. For the regions of Trenčín and Prešov, as traditional strongholds of etatist forces, it is not surprising that the regional parliament is dominated by left-wing and national-conservative parties in the coming four years. The so-called *'Slovak coalition'* won a majority in the agency of the Nitra region and the Banská Bystrica as well. Right-wing forces managed to take control over the Bratislava self-governing region again, but this time also thanks to a coalition with the Hungarian minority parties. If we considered the electoral score of political blocs for all regional parliaments, we would find out that no one has a majority of votes in the Slovak Republic for the 2013–2017 period.

Comparing the politico-ideological inclination of regional parliaments concerning both contemporary and prior tenure, we come to the conclusion that no change occurred in five regions overall. The mentioned territories are located in the west and north-west of Slovakia. The centrally situated region of Banská Bystrica recorded a transformation of political and ideological structure of its representation from etatist to "more Slovak" in order to eliminate the electoral gains of ethnic minority parties. However, this transition is just on paper and can be seen as an accompanying derivative of political agreement concluded by Smer-SD and KDH, and the subsequent establishment of the *'Slovak coalition'* within the above mentioned region (in Nitra region, this concept has traditionally been used). Thus, this part of the country remains mostly etatist-minded. Development of the politico-ideological and value orientation of regional parliaments in eastern Slovakia is also quite interesting. While Prešov region is reporting a change in inclination from fragmented to leftist and national-conservative, Košice as the metropolis of the east has observed the opposite trend since 2009.

5. Results: Socio-political cleavages

Based on the results of the 2013 regional elections conducted in Slovakia, the main objective of the paper was to assess the regional context related to dominant socio-political cleavages affecting the electoral behaviour of society at a regional scale. Respecting the political agreements and ideological background of parties' candidates running for the election to the decision-making bodies of self-governing regions, we have considered the effect of two major socio-political cleavages as being socio-economic (rightist-leftist) and ethnic (nationalist) electoral-preferential contradiction. As an alternative to them, a vote for independent candidates has emerged in the case of elections for regional government.

Considering the nationwide outcome of the elections for regional parliaments, we come to the conclusion that more than half of the seats was gained by parties crucially profiled along the left-right cleavage (58.82%), whereas the ethnic contradiction was important for one quarter of mandates (23.28%) and about one fifth of seats (17.89%) was identified with the alternative of independent candidates.

However, a regional context of electoral behaviour can significantly modify the election results in different parts of Slovakia (see Fig. 9). The left-right cleavage of the electorate is most notable for the regions of the largest cities in Slovakia – namely Prešov (90.32%), Bratislava (86.36%) and Košice (73.68%), supplemented by regions

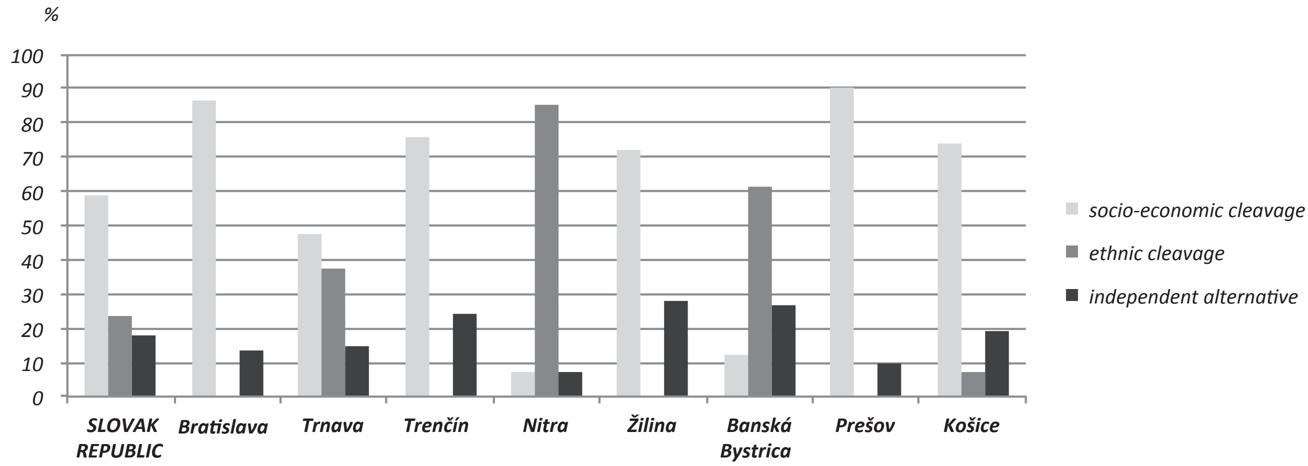

Fig. 9 Weight of analysed socio-political cleavages in the 2013 regional elections in self-governing regions of Slovakia.
Data source: Statistical Office of the Slovak Republic 2014, author's calculations and processng.

located in the north-west, such as Trenčín (75.56%) and Žilina (71.93%), where a significant differentiation of citizens' socio-economic status between centre and its hinterland can be expected. On the contrary, ethnic cleavage affecting electoral decision on representatives of the regional government is most notably profiled in the regions of Nitra (85.19%), Banská Bystrica (61.22%) and Trnava (37.50%), but the marginal position was taken in the region of Košice as the metropolis of the east (7.02%). In the Banská Bystrica region, the share for ethnic cleavage in 2009 is affected by the fact that the political agreement of the parties from different sides of the political and ideological spectrum had not existed there, however this also tells that for the period 2009-2013 public demand stressing the need to address more fundamental ethnic issues had not been formulated in this region (unlike the Nitra region). In 2013, under the context of strengthening the relevance of Roma issue in the Banská Bystrica region (especially by ĽS-NS) demand to establish a wider agreement across the political spectrum (Smer-SD and KDH) against the flowering of nationalism was legitimate and politically justifiable (relevancy visible particularly in election of regional president). In the light of final election results was showed that the coalition should be even wider (victory of M. Kotleba).

The above mentioned just confirms that the decision of the public to vote their representatives is heavily influenced by ethnic themes in the southern parts of Slovakia characterized by a mixed population of Slovak and Hungarian ethnicity. In other parts of Slovakia, no ethnic contradiction related to voting the deputies of the regional parliament was identified. To some extent, part of the electorate considers the option to elect the independent candidates as attractive in all regions of Slovakia. As mentioned before, the election score of independent candidates moves below the national average in south-western and north-eastern Slovakia. In other parts of the country, their election outputs are above the national average, mainly in the north-west and the central part.

If we took into account the temporal context of this issue (see Table 1), we would discover that even in the case of individual regions the impact of various socio-political contradictions is not invariable, although it shows a relatively high degree of inter-electoral stability at a regional level. On the national scale, the importance of ethnic socio-political cleavage has increased (+4.66 p.p.), but to a significant extent as a consequence of the so-called 'Slovak coalition' establishment that subsequently led to a decline in the perception of left-right political competition (−9.07 p.p.). However, a slight inter-electoral increase in support of independent candidates (+4.41 p.p.) is indisputable.

If we do not take into consideration a political agreement between the leftist Smer-SD and right-wing conservative KDH concluded to suppress the impact of ethnic parties in the decision-making process in the regional government of Banská Bystrica (−63.27 p.p.), the explanatory power of socio-economic cleavage significantly decreased in the western part of Slovakia inter-electorally, namely in Bratislava (−9.09 p.p.), Žilina (−8.77 p.p.) and Trnava (−7.50 p.p.), while the left-right context of electoral behaviour slightly strengthened in the region of Nitra (+7.41 p.p.) situated in the south-west, and the regions of Košice (+3.51 p.p.) and Prešov (+1.61 p.p.), located in eastern Slovakia.

Ethnic cleavage as the second socio-political contradiction related to politico-preferential attitudes of the public in two recent elections for regional self-government increased its influence especially in the regions of Banská Bystrica (+46.94 p.p. as a response to the establishment of the so-called *'Slovak coalition'*), but slightly also in the regions of Trnava (+7.50 p.p.) and Trenčín (+4.66 p.p.), in the west of the country. Ethnic contradiction in deciding on representatives of the regional self-government weakened in the Nitra region (−9.26 p.p.) of south-western Slovakia, slightly in the neighbouring region of Bratislava (−2.27 p.p.), and in Prešov region (−1.61 p.p.), located in the north-east.

When contemplating the alternative to the left-right and ethnic orientation of voting behaviour expressed by the electorate (i.e. voting for independent candidates) it can be stated that the independents managed to increase their seats most strikingly in the regions of Banská Bystrica (16.33 p.p. as option to ethnic contradiction) as well as in Bratislava and Žilina (+11.36 p.p. / +8.77 p.p. as an alternative to a left-right cleavage of the electorate). Košice region is characterized as the only one with decrease in regional representation of independent candidates (−3.51 p.p.).

6. Conclusion

Parties compete usually for political, social and cultural issues explicitly binding to a specific territory, therefore degree of devolution and delegation of administrative functions as well as extent of their politicization at the regional level (Fabre and Martínez Herrera 2009), ideological and value equipment of political parties emphasized by Petrocik (1996), Budge and Farlie (1983), and Klingemann et al. (1994), and the real performance of the ruling ones (Stokes 1963, 1992) are also conditional for the party competition. In this context, we must not forget the variety of socio-political cleavages that affect the final electoral decision of the electorate (Lipset et al. 1967).

Madleňák (2012) defines six socio-political cleavages simultaneously forming the voting behaviour of the Slovak electorate during the history of the independent Slovak Republic (since 1993), whose validity can be very different in a given temporal and space context. In this study we have ignored the centre vs. periphery conflict, which was particularly important in the era of Czechoslovakia, when there was a pronounced bipolarity between Prague (Czech) and Bratislava (Slovak). Today in this context, it refers to the socio-political contradiction between Bratislava and the rest of the country. In our opinion, this cleavage, represented by the urban vs. rural contradiction, are currently just spatial expressions of the most important political-preferential cleavages developed within Slovakian society (formed particularly along the ethnic, socio-economic and conservative-liberal issues). Therefore, we have not dealt with them in this paper as well as *'mečiarism vs. antimečiarism' phenomenon*, which was particularly dominant in the second half of the nineties and over time has lost its importance. In this work we have tried to review the affect of the most important socio-political cleavages within contemporary Slovakian society shaped along the ethnic and socio-economic cleavage, ignoring the conservative-liberal contradiction traditionally diminished in the establishment of political agreement concluded by parties prior to the regional election struggle.

The comprehensive objective of this paper was to evaluate the impact of crucial socio-political contradictions affecting the voting outcomes in the 2013 regional elections in Slovakia. For this kind of ballot, the electoral behaviour of citizens is largely determined by a left-right cleavage, which rules nearly 60% of the election results measured by distribution of mandates. Ethnic cleavage in electoral decisions of the public was transformed into one quarter of seats, nearly a fifth of them are covered by the independent candidate alternative. In an inter-electoral comparison, the significance of ethnic cleavage as well as the option to cast an independent candidate increased, whereas the socio-economic dimension of the voting act slightly declined at a national level (due to specific political arrangements concluded by parties).

However, the regional context is capable of modifying the observed relationships significantly, and thus formulates its own conclusions on the electoral behaviour of society. A left-right cleavage of the electorate and its political representation is peculiar to regions of the largest cities in Slovakia (75–90%), while ethnic contradiction is expressed almost exclusively in the southern parts of Slovakia within the mixed territory inhabited by Slovaks and Hungarians (40–85%). The option of independent candidates is increasingly used by the electorate of north-western Slovakia and its central part as well (25–30%).

In the case of elections for regional self-government (as well as elections for the European Parliament), the informative value of the findings is obviously weakened by the low level of the turnout, however. It seems that a quarter a century after the fall of the *'Iron curtain'*, the Slovakian public is accustomed to participate in the electoral decision-making process on the central political representation, partly gradually learning to decide on local matters related to its own community. Unfortunately, regional and transnational issues equally important for socio-economic development are remote from the civic interest of people in political issues so far.

The global economic crisis with its regional consequences was also being considered an opportunity to change traditional politico-ideological patterns of voting behaviour related to the electorate from Central and Eastern post-socialist Europe and its partial regions. Being aware of the uniqueness in both regional politics and elections deciding on its character, there are also other than traditional cooperation schemes between parties from the same side of the political spectrum only, with a decent chance of succeeding for independent candidates unencumbered by accountability to a political party.

Acknowledgements

This contribution had been supported by VEGA Grant No. 1/0745/16 "Autonomy, interdependance and interactions of spatial systems".

References

Act No 180/2014 Coll. on Conditions of the Exercise of Voting Rights and on amendments to certain laws.

BERNARD, J., KOSTELECKÝ, T. (2014): Prostorový kontext volebního chování – jak působí lokální a regionální prostředí na rozhodování voličů. Sociologický *časopis* / Czech Sociological Review 50(1), 3–28. https://doi.org/10.13060/00380288.2014.50.1.30

BLAŽEK, J., KOSTELECKÝ, T. (1991): Geografická analýza výsledků parlamentních voleb v roce 1990. Sborník České geografické společnosti 96(1), 1–14.

BUČEK, J. (2001): Responding to Diversity: Solutions at the Local Level in Slovakia. In: Bíró, A. M., Kovács, P. (eds.) Diversity in Action: Management of Multi-ethnic Communities in Central and Eastern Europe. Budapest: LGI/OSI, pp. 273–306.

BUČEK, J. (2002): Regionalization in the Slovak Republic – from administrative to political Regions. In: Gerard, M. (ed.) Regionalization for development and accession to the European Union: a comparative perspective. Budapest: Local Government and Public Reform Initiative, pp. 141–177.

BUDGE, I., FARLIE, D. J. (1983): Explaining and Predicting Elections: Issue Effects and Party Strategies in Twenty-Three Democracies. London, Allen and Unwin.

CARMINES, E. G., HUCKFELDT, R. (1996): Political Behavior: An Overview. In: Goodin, R., Klingemann, H. D. (eds.) A New Handbook of Political Science. Oxford: Oxford University Press, pp. 223–254.

CLARK, M. (2009): Valence and electoral outcomes in Western Europe 1976–1998. Electoral Studies 28(1), 111–122. https://doi.org/10.1016/j.electstud.2008.07.009

ČMEJREK, J. (2008): Obce a regiony jako politický prostor. Praha, Alfa.

Databases of Statistical Office of the Slovak Republic 2014.

DOSTÁL, O. (2002): Národnostné menšiny. In: Kollár, M., Mesežnikov, G. (eds.) Slovensko 2002: Súhrnná správa o stave spoločnosti. Bratislava: Inštitút pre verejné otázky, pp.195–212.

DOWNS, A. (1957): An Economic Theory of Democracy. New York, Harper and Row.

FABRE, E., MADDENS, B., SWENDEN, W., POGORELIS, R. 2005. Partis politiques nationaux en crise? Organisation des partis et decentralisation. Une comparaison de l'Espagne et du Royaume Uni. Res Publica 47(1), 36–57.

FABRE, E., MARTÍNEZ-HERRERA, E. (2009): State-wide parties and regional party competition. Ananalysis of party manifestos in the UK. In: Maddens, B., Swenden, W. (eds.) Territorial Party Politics in Western Europe. Basingstoke: Palgrave, pp. 229–248. https://doi.org/10.1057/9780230582941_12

FIORINA, M. P. (1981): Retrospective Voting in American National Elections. New Haven, Yale University Press.

HOOGHE, L., MARKS, G., SCHAKEL, A. H. (2010): The rise of regional authority. A comparative study of 42 democracies. London, Routledge.

HOPKIN, J. (2003): Political decentralisation and party organisational adaptation: A framework for analysis. European Urban and Regional Studies 10(3), 227–237. https://doi.org/10.1177/09697764030103004

HOPKIN, J., BRADBURY, J. (2006): British statewide parties and multi-level politics. Publius: The Journal of Federalism 36(1), 135–152. https://doi.org/10.1093/publius/pjj008

IVANIŠEVIČ, S., KOPRIČ, I., OMEJEC J., SIMOVIČ, J. (2001): Local government in Croatia. In: Kandeva, E. (ed.) Local governments in Central and Eastern Europe. Budapest: Local Government and Public Reform Initiative, pp. 179–240.

JEFFERY, Ch., HOUGH, D. (2003): Regional elections in multi-level systems. European Urban and Regional Studies 10(3), 199–212. https://doi.org/10.1177/09697764030103002

JEFFERY, Ch., HOUGH, D. (2006): Devolution and electoral politics: where does the UK fit in? In: Jeffery, Ch., Hough, D. (eds.) Devolution and electoral politics. Manchester: Manchester University Press, pp. 248–256.

JEHLIČKA, P., KOSTELECKÝ, T., SÝKORA, L. (1993): Czechoslovak Parliamentary Elections 1990: Old Patterns, New Trends and Lots of Surprises. In: O'Loughlin, J., van der Wusten, H. (eds.) The New Political Geography of Eastern Europe. London: Belhaven Press, pp. 235–254.

JEHLIČKA, P., SÝKORA, L. (1991): Stabilita regionální podpory tradičních politických stran v českých zemích (1920–1990). Sborník České geografické společnosti 96(1), 81–95.

KLING, J. (2008): Regionálna politika a verejná správa. In: Fazekas, J., Hunčík, P. (ed.) Maďari na Slovensku (1989–2004) / Magyarok Szlovákiában (1989–2004). Šamorín: Fórum inštitút pre výskum menšín, pp. 293–316.

KLINGEMANN, H. D., HOFFERBERT, R. I., BUDGE, I. (1994): Parties, Policies and Democracy. Boulder, Westview Press.

KOSTELECKÝ, T. (1993): Volby očima geografa. In: Sýkora, L. (ed.) Teoretické přístupy a vybrané problémy v současné geografii. Praha: Katedra sociální geografie a regionálního rozvoje PriF UK, pp. 167–186.

KOSTELECKÝ, T. (2000): Volební systémy a politický konflikt v prostoru. In: Jehlička P., Tomeš J., Daněk P. (eds.) Stát, prostor, politika. Vybrané kapitoly z politické geografie. Praha: Katedra sociální geografie a regionálního rozvoje PriF UK, pp. 242–262.

KOSTELECKÝ, T. (2002): Political Parties after Communism: Developments in East-Central Europe. Washington, Woodrow Wilson Center Press.

KOSTELECKÝ, T. (2003): Results of the 1992 and 1996 Parliamentary Elections in the Czech Republic from a Regional Perspective. In: Mansfeldova, Z. (ed.) Czech Republic: The First Elections in the New Republic, 1992–1996. Berlin: Edition Sigma, pp. 84–108.

KOSTELECKÝ, T. (2012): Výsledky voleb do Poslanecké sněmovny v regionalním pohledu. In: Linek, L. (ed.) Voliči a volby 2010. Praha: Sociologické nakladatelství (SLON), pp. 105–131.

KOSTELECKÝ, T., KRIVÝ, V. (2015): Urbánno-rurálne rozdiely voličského správania v Česku a na Slovensku. Sociológia 47(4), 390–413.

KRIVÝ, V. (2002): Regionálne voľby 2001 – analýza výsledkov. In: Mesežnikov, G., Nižňanský, V. (eds.) Reforma verejnej správy na Slovensku 1998–2002: Súvislosti, aktéri, voľby. Bratislava: Inštitút pre verejné otázky, pp. 201–249.

LIPSET, S. M., ROKKAN, S. (1967): Party Systems and Voter Alignments: Cross–national Perspectives. London, Collier-Macmillan.

MADLEŇÁK, T. (2012): Regionálna diferenciácia volebného správania na Slovensku (1998–2010). Bratislava, Veda.

MIKUŠ, R., GURŇÁK, D., MÁRIÁSSYOVÁ, A. (2016): Analýza volebnej podpory Mariána Kotlebu ako reprezentanta krajnej pravice v krajských voľbách 2013. Sociológia 48(1), 48–70.

MESEŽNIKOV, G. (2006): Politické strany v regionálnych voľbách 2005. In: Mesežnikov, G. (ed.) Regionálne voľby 2005. Bratislava: Súvislosti a výsledky. Inštitút pre verejné otázky.

PALLERÉS, F., KEATING, M. (2003): Multi-level electoral competition: regional elections and party systems in Spain. European Urban and Regional Studies 10(3), 239–255. https://doi.org/10.1177/09697764030103005

PETROCIK, J. (1996): Issue ownership in Presidential elections, with a 1980 case study. American Journal of Political Science 40(3), 825–840. https://doi.org/10.2307/2111797

POP, L. (2002): Autonomy of local government administration in Romania. In: Soós, G., Tóka G., Wright, G. (eds.) The state of local democracy in Central Europe. Budapest: Local Government and Public Reform Initiative, pp. 287–369.

REIF, K. (1985): Ten second-order national elections. In: Reif, K. (ed.) Ten European Elections. Gower: Aldershot, pp. 1–36.

REIF, K., SCHMITT, H. (1980): Nine second–order national elections – A conceptual framework for the analysis of European election results. European Journal of Political Research 8(1), 3–44. https://doi.org/10.1111/j.1475-6765.1980.tb00737.x

ROLLER, E., van HOUTEN, P. (2003): A national party in a regional party system: The PSC-PSOE in Catalonia. Regional and Federal Studies 13(3), 1–22. https://doi.org/10.1080/13597560308559432

SCHAKEL, A. (2011): Ideal type second-order elections: Regional elections in six Central and Eastern European countries [online]. Paper presented at the 1st European Conference on Comparative Electoral Research. Sofia, 1–3 December 2011 [quoted on 3 April 2014]. http://true-european-voter.eu/node/101

SCHAKEL, A. (2013): Congruence Between Regional and National Elections. Comparative Political Studies 46(5), 631–662. https://doi.org/10.1177/0010414011424112

SOÓS, G., KÁLMÁN, J. (2002): Report on the state of local democracy in Hungary. In: Soós, G., Tóka, G., Wright, G. (eds.) The state of local democracy in Central Europe. Budapest: Local Government and Public Reform Initiative, pp. 20–105.

STOKES, D. (1963): Spatial models of party competition. The American Political Science Review 57(2), 368–377. https://doi.org/10.2307/1952828

STOKES, D. (1992): Valence politics. In: Kavanagh, D. (ed.), Electoral Politics. Oxford: Clarendon Press, pp. 141–164.

TUCKER, J. A. (2002): The first decade of post-communist elections and voting: what have we studies, and how have we studies it? Annual Review of Political Science 5(1), 271–304. https://doi.org/10.1146/annurev.polisci.5.100201.102917

VAN BIEZEN, I., HOPKIN, J. (2006): Party organization in multi-level contexts. In: Hough, D., Jeffery, C. (eds.) Devolution and Electoral Politics. Manchester: Manchester University Press, pp. 14–36.

VOŽENÍLEK, V., ŠARADÍN, V., NĚMCOVÁ, Z. (2010): Atlas voleb do zastupitelstva Olomouckého kraje 2000, 2004 a 2008. Olomouc, Univerzita Palackého.

WYN JONES, R., SCULLY, R. (2006): Devolution and electoral politics in Wales. Publius: The Journal of Federalism 36(1), 115–134. https://doi.org/10.1093/publius/pji034

ZARYCKI, T. (2000): Politics in the periphery: Political cleavages in Poland interpreted in their historical and international context. Europe-Asia Studies 52(5), 851–873. https://doi.org/10.1080/713663091

ZARYCKI, T. (2015): The electoral geography of Poland: between stable spatial structures and their changing interpretations, Erdkunde 69(2), 107–124. https://doi.org/10.3112/erdkunde.2015.02.02

RESUMÉ

Ideologie, konfliktní linie a volební chování v krajských volbách na Slovensku v letech 2009 a 2013

Vycházeje z výsledků regionálních voleb uskutečněných na Slovensku v roce 2013, hlavním cílem předkládaného příspěvku bylo posoudit regionální kontext působících sociálně-politických konfliktních linií ovlivňujících volební rozhodnutí společnosti v regionálním měřítku. Při respektování politických dohod a hodnotově-ideologického vybavení politických subjektů ucházejících se o zvolení jejich kandidátů do rozhodovacích orgánů samosprávných krajů, uvažovali jsme o působení dvou nejvýznamnějších sociopolitických štěpení společnosti, a sice socioekonomickém (pravicově-levicovém) a etnickém (nacionalistickém) volebně-preferenčním konfliktu. Jako alternativa k nim vystupuje v případě voleb do regionálních samospráv možnost volit nezávislé kandidáty. Volební chování elektorátu je ve volbách do regionální samosprávy v největší míře determinováno levo-pravou konfliktní linií, která ovlivňuje téměř 60 % volebních výsledků (získaných mandátů). Etnické štěpení volebních rozhodnutí společnosti je přítomno u jedné čtvrtiny křesel, téměř pětina mandátů se vztahuje k alternativě nezávislých kandidátů. V mezivolebním srovnání rostl na celoslovenské úrovni význam etnické konfliktní linie, stejně tak možnost volby nezávislých kandidátů, přičemž sociálně-ekonomický rozměr hlasování voličů mírně poklesl (vlivem konkrétních politických dohod). Regionální kontext však dokáže sledované vztahy výrazným způsobem modifikovat a vytvářet si tak vlastní závěry o volebním chování obyvatelstva. Levicově-pravicové štěpení elektorátu je příznačné pro regiony největších měst Slovenska (v závislosti na konkrétním kraji 75–90 % křesel), přičemž nacionalistický konflikt se projevuje téměř výhradně v jižních částech Slovenska na smíšeném území obývaném Slováky a Maďary (40–85 % mandátů). Alternativu nezávislých kandidátů dokázali ve zvýšené míře prosadit obyvatelé severozápadního Slovenska a jeho centrální části (25–30 % křesel). Výpovědní hodnota těchto zjištění je však v případě voleb do regionálních samospráv (stejně tak voleb do Evropského parlamentu) oslabená nízkou mírou volební angažovanosti elektorátu.

Martin Plešivčák
Department of Human Geography and Demography
Faculty of Natural Sciences
Comenius University in Bratislava
Slovakia
E-mail: plesivcak@fns.uniba.sk

THE ENERGY–POVERTY NEXUS: VULNERABILITY OF THE URBAN AND PERI-URBAN HOUSEHOLDS TO ENERGY POVERTY IN ARBA-MINCH TOWN, SOUTHERN ETHIOPIA

AHMED MUSTEFA ALI[1], TEBAREK LIKA MEGENTO[2]

[1] Department of Geography and Environmental Studies, Mizan-Tepi University, Ethiopia
[2] Department of Geography and Environmental Studies, Addis Ababa University, Ethiopia

ABSTRACT

The study was conducted in Southern Ethiopia with the objective of investigating the linkages between domestic energy consumption and income poverty among households residing both in and surrounding parts of Arba-Minch town. The research design is mainly based on the quantitative methods and complemented with the qualitative ones. For the purpose of the study, 658 sample households have been selected from in and around the town based on random sampling design and the field data were collected using questionnaires, focus group discussions and interviews with relevant individuals. Data on the consumption of energy sources for this study were gathered in terms of expenditures (ETB) which were later converted to energy heat values measured in terms of MJ. The study examines the relevance of energy switching and fuel stacking models and the findings of this research provide insights for slow energy transition prospect in household energy use. The finding of the study indicated households do not simply substitute one fuel for another as household income increases. Regardless of their economic status, the majority of households depended on wood fuels as their primary source of cooking energy. The study reveals that commercial cooking fuels become increasingly expensive. It is becoming difficult to obtain affordable energy technologies that convert energy to useful services. A significant portion of urban and peri-urban households continue to suffer as their incomes have not kept pace with the rising prices. Therefore, for the majority of households, meeting the energy requirement in a sustainable manner continues to be a major challenge. Increasing end-use efficiency should be given greater emphasis as an important prerequisite by employing proper end-use technologies to change households' cooking practices so that household energy-related problems tackled and energy can lead to more equitable sustainable livelihoods.

Keywords: energy poverty, income poverty, energy switching, fuel stacking, Arba-Minch

Received 26 September 2016; Accepted 26 April 2017; Published online 12 June 2017

1. Introduction

Energy is one of the most essential inputs for sustaining people's livelihoods and without energy modern life would generally cease to exist (Clancy et al. 2003). According to the United Nations Development Program (UNDP) (2005) and Khandker et al. (2010) access to modern, sustainable, affordable, and reliable energy services is considered central not only to achieve the Millennium Development Goals (MDGs) but also to improve the quality of life and sustain the socio-economic conditions of the people.

Recently, the issue of energy access has been receiving more attention than ever before and it is recognized by policy makers as a significant factor in achieving sustainable livelihoods. In another major study, International Energy Agency (IEA) (2007) and World Bank (2011) stated that clean, efficient, affordable and reliable energy services are necessary to reduce poverty, promote gender equality, improve food security, health and education of the citizens, and enhance sustainable management of natural resources. The World Health Organization (WHO) (2011) report indicates that lack of access to convenient and efficient energy services is a major barrier to achieving meaningful and long-lasting solutions to poverty.

Cecelski (2004) asserted that despite many efforts, energy poverty is widespread, and gender inequality exits at every level of the energy sector. Similarly, Barnes et al. (2004) and UNDP (2009) stated that more people across the world are now subject to energy poverty or energy deficiency. Energy-poverty nexus exists at the household levels, where they use disproportionately more traditional biomass fuels. Garima Jain (2010) further indicated that the income poor face high burden of energy poverty as they tend to spend a larger share of their income on purchasing inefficient and harmful energy fuels.

Despite the fact that electricity consumption is likely to reach nearly all the households, the findings of this research provide insights for slow energy transition prospect in household energy use. There seems to be some evidence to indicate that number of urban households are unable to change their energy consumption from using woody biomass to modern energy fuels by installing improved cooking stoves thus, they consume less end-use cooking energy services. Still most urban households in the study area are the principal consumers of traditional fuel and are paying substantial portions of their incomes for energy. In spite of the significant household electrification program in the last few years, most urban and peri-urban households still appear not to be benefiting

https://doi.org/10.14712/23361980.2017.9
Ali, A. M. – Megento, T. L. (2017): The energy–poverty nexus: Vulnerability of the urban and peri-urban households to energy poverty in Arba-Minch town, Southern Ethiopia
AUC Geographica, 52, No. 1, pp. 116–128

significantly from the availability of electricity. There are sudden and frequent blackouts and voltage drops which can make electricity a very unreliable source of energy for use domestically and the users find it hard to predict its availability. It is therefore likely that such limited use of conventional fuels and significant reliance on biomass fuels deter opportunities of most residents for economic and social advancement.

The main objective of this study was to explore the relationship between domestic energy consumption and income poverty among households in and around the town of Arba-Minch, Southern Ethiopia. This study therefore, contributes knowledge to the field of energy and it could be beneficial in order to signify how poorly a household is doing in meeting the basic energy needs. It analyses measures taken to alleviate energy poverty and recommends regulatory and policy measures as way forward.

2. Theoretical Considerations

IEA (2009) reveals that the various types of energy resources used for different purposes can be classified as traditional and modern ones. The term traditional energy source is used by Karekezi and Kithyoma (2005) to refer to readily available, low cost and unprocessed fuel. Clancy et al. (2003) used the term biomass fuel interchangeably with traditional fuel as biomass fuel is synonymous to 'traditional' fuel. Barnes et al. (2004) and Kahndker et al. (2010) used clean energy and modern energy interchangeably. According to IEA (2009) the modern energy sources (such as kerosene, electricity and LPG – Liquefied Petroleum Gas) are considered to be those that have a high energy density, high combustion efficiency and high heat-transfer efficiency so that they are less hazardous for health and save time and costs for their users.

There are two quite commonly-used measures of energy use: gross and end-use energy. The term 'gross energy' to refer to the amount of total input of energy that is burned for cooking regardless of the efficiency of the appliances that people use (Clancy et al. 2003),whereas the term end-use energy refers to the amount of energy effectively used to perform the task required by the end user (Barnes et al. 2004). A further definition is given by Kahndker et al. (2010) who describe useful or "delivered" energy as the energy that is adjusted for the efficiency of the appliance, technology and mode of use by the household.

The other frequently used term among energy and development specialists is energy poverty. Although the term is widely used in literature, one hardly comes across a clear definition. This concept has been increasingly debated and loosely defined (Heltberg 2005; IEA 2009; Barnes et al. 2010; and Getamesay et al. 2015). So far, many approach being used to define and measure energy poverty. For instance, Goldemberg (1990) measured energy poverty in terms of physical energy amount without considering economic aspects and identified 32.1 kilograms of oil equivalent (kgoe) per household per month as the minimum amount. While other studies (such as Pachauri and Spreng 2004; and WHO 2011) estimated energy poverty on the basis of economic or expenditure aspect. Energy poverty is at a level when households' energy expenditure is more than 10 percent of the disposable income, excluding other factors.

In exploring the changing patterns of energy use in the household, researchers such as Barnes et al. (2004), Reddy (2004), Farsi et al. (2005) and Nkomo (2007) have developed the notion of an energy switching hypothesis as a model to explain the shift between traditional solid fuels and modern non-solid fuels in order to meet household's energy needs as the household pass certain income thresholds. As noted by Treiber et al. (2015) the linear model predicts a positive relationship between socio-economic development and transition to more efficient, cleaner, and costly energy sources. The central idea of "energy ladder" hypothesis is to describe the patterns of energy usage associated with certain income levels. It prescribes income of the households to be the sole factor and it is a key determinant in the selection of a fuel and the movement towards other alternatives. It does not appropriately account for other factors that are likely to affect household energy services.

However, other studies by Masera et al. (2000), Heltberg (2005), Ntobeg (2007), Gundimeda and Köhlin (2008), Alemu and Köhlin (2008), and Kammen and Kirubi (2009) challenged the energy switching hypothesis and more concerned with fuel stacking hypothesis which shows the use of multiple fuels rather than completely switching from one fuel to another. Surveys (such as Masera et al. 2000; Farsi et al. 2005; Alemu and Kohlin 2008; and Treiber et al. 2015) provide important insights into the simultaneous use of different fuel regardless of income levels. The multiple fuel model gives a set of factors that together explain why energy diversification may be a rational option for households (Masera et al. 2000). The model proposed here gives guidance and a better understanding of the various influencing factors that need to be considered when implementing a development program associated with energy and technology (Treiber et al. 2015). The longitudinal survey conducted by Masera et al. (2000) in the region of Central Michoacan, Mexico, demonstrates the multiple fuel models rather than the energy switching scenario. They discovered that, rather than making concise transitions from fuel to fuel, or stove type to stove type, along the energy ladder, families in Michoacan often show the pattern of fuel stacking. According to them, fuel wood is very seldom replaced entirely when families adopt LPG, none of the family ceased using fuel wood even in the households that have been using LPG for many years. They concluded that multiple cooking fuel use patterns have been reported frequently in the households by taking the technical, socioeconomic and cultural aspects into consideration.

Heltberg (2004) analyzed the determinants of fuel switching using comparable household survey data from Brazil, Ghana, Guatemala, India, Nepal, Nicaragua, South Africa, and Vietnam. He argued that larger households are more likely to consume multiple fuels, both solid and non-solid. The study by Meikle and Bannister (2005) found that households in Tanzania, whether poor or non-poor, do not make exclusive use of one fuel, nor is only one fuel type used for only one activity. Instead for a mixture of practical and cultural reasons they use a mix of modern and traditional fuels. Similarly, Treiber et al. (2015) found that complete switching, where one fuel totally substitutes for another, is rare in Kenya. These writers evaluate and criticize energy switching hypothesis as it fails appropriately to account for other factors that are likely to affect household switches to modern energy services. Multifaceted demands of the households are an important driver of the diversification. Individual characteristics and social and cultural tradition influence the final choice. Households use various energy carriers, modern and traditional, and devices to secure a continuous energy supply and counteract potential access and availability issues.

This paper examines household energy consumption patterns in the light of energy switching hypothesis (Barnes et al. 2004; Reddy 2004; and Farsi et al. 2005) which explain the shift between traditional solid fuels and modern non-solid fuels in order to meet household's energy needs as the household pass certain income thresholds. Energy switching hypothesis shows a sequential change of fuels as income rises and it is used to describe the way in which households climb the ladder with increase in economic status (Khandker et al. 2010). It is wrong to assume that electricity substitutes biomass use in urban areas, in spite of the fact that there are substantial number of urban households with access to electricity. The most important issue is not electrification alone since the majority makes no use of electricity for cooking. Instead of moving up the ladder step by step as income rises, most households tend to consume a combination of fuels for cooking purpose depending on many more factors. Even the majority of higher incomes households do not currently substitute wood fuels for other conventional fuels for the purpose of baking and cooking.

Pachauri and Spreng (2004) noted that poor households spend less cash on energy than the more wealthy households, but the percentage of income the poor spend on energy is typically much greater. According to Barnes et al. (2004) and Garima (2010) urban poor spend a larger share of their income on purchasing inefficient and harmful fuels and face high burden of energy poverty. The World Bank (2011) has carried out a global survey of 45 cities and 20,000 households. It is found that poor urban households spend a significant portion (15 to 22 percent) of their cash incomes on energy because cooking with fuel wood is inefficient compared with cooking with modern fuels.Poor households in South Africa spend about 15–28 percent of their income on energy, and the poor in Arusha, Tanzania, spend as high as 40 percent of their incomes (Meikele and Banister 2005). The survey in Addis Ababa alone shows over 15 percent of the cash income of the lowest income group is spent on cooking fuel (Alemu and Köhlin 2008). Overall, there seems to be some evidence to indicate that the higher financial burden faced by the poorer households in meeting their energy needs.

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (2008) suggests that the reliable and efficient provision of modern energy services is a central part of the global fight against poverty. Lack of energy services is directly correlated with the major elements of poverty, and aggravates many social concerns, including inadequate healthcare, lack of education, unemployment and inequity as well as threatens the achievement of the Millennium Development Goals (MDGs). Urban centres have long been dependent on rural hinterlands for their fuel. The increasing dependence of the urban centres on rural hinterlands has a much more serious environmental consequence which has resulted in growing fuel scarcity and higher firewood prices in urban centres, thereby undermining the livelihoods of the urban poor (Barnes et al. 2004). As most towns in developing countries are growing rapidly, urban growth is paralleled by increasing demand for energy to meet consumption needs (World Bank 2011). Wickramasinghe (2007) and Garima (2010) stated energy poverty is a growing problem among low income groups residing in urban areas as they always have limited access to clean fuels.

According to Economic and Social Commission for Asia and the Pacific (ESCAP) (2008) billions of people worldwide are energy poor and require access at affordable prices to maintain a minimum standard of living. As Clancy et al. (2006) and Kammen and Kirubi (2009) noted the problem of energy poverty is found to be acute in sub-Saharan countries where modern fuels are difficult to procure. Sub-Saharan Africa has 9 percent of the world's population and consumes only 2.7 percent of world commercial primary energy. More than 80 percent of its population depends on traditional biomass as their primary energy source (WHO 2009). According to Organization for Economic Cooperation and Development (OECD) (2010) the number of new electricity connections in sub-Saharan Africa is outpaced by population growth. Electricity consumption per person in the region is only 0.9 percent (Barnes et al. 2010). Moreover, World Health Organization (WHO) (2009) estimated that over 70 percent of the population of sub-Saharan Africa is without electricity. Half of the population in sub-Saharan Africa is expected to remain without access to electricity even in 2030.

Like many other sub-Saharan Africa countries, Ethiopia depends heavily on traditional energy consumption with minimal use of modern energy sources (Zenebe 2007), hence the country is having difficulty in meeting the rapidly rising demand for modern energy (Nebiyu 2009). More than 67 million people are dependent on biomass energy to meet their cooking, heating, lighting and hygiene needs (UNDP 2009; IEA 2010). As Araya and Yisak (2012) noted for more than 75 percent of rural households and more than 57 percent of urban household, fuel wood is the major source of fuel for cooking. In spite of the improvement of level of access to clean fuels in the last few years, most urban and peri-urban households in the study area still appear not to be benefiting significantly from improved modern fuel supply availability. A substantial portion of the urban households continue to suffer as their incomes have not kept pace with the rising prices and face higher financial burden to meet their cooking demands. The energy-poverty nexus in urban areas of Ethiopia has been less studied than in rural areas although the body of knowledge is beginning to grow. Those urban studies are confined to the major cities of the country focusing on the consumption pattern mainly at a national level (Bereket 2002; Kebede et al. 2002; Samuel 2002; Zenebe 2007; and Yonas et al. 2013). Therefore, providing basic energy services to the urban and peri-urban poor is an important issue that requires far more attention from policy makers in order to alleviate poverty.

3. Material and Methods

The study area, Arba-Minch, is located at 505 km south of the capital, Addis Ababa and 275 km from the regional capital, Hawasa and lies astronomically between 06°05´N latitude and 37°38´E longitude.According to Arba-Minch Town Administration Office (2014), the town together with its peri-urban area, has an area of 5,557 hectares and an estimated total population of 104,107 with the population density of 13 people per hectare and average family size of 4.5 persons. Out of the total population, 51.81 percent are females and 48.19 percent are males. The area is one of the fastest growing urban areas in the country with annual population growth rate of 4.8 percent and a doubling time of 15 years. Currently the rapid population growth of the town is related to immigration of people from the surrounding highlands resulting in the development of squatter settlements in many parts of the town.

For primary data acquisition, this research used household survey method as the main methodological approach to collect information from selected households. Quantitative data were collected by using a cross-sectional survey of urban and peri-urban households that was carried out over three months from August to October, 2014. Structured, pre-tested and interviewer-administered

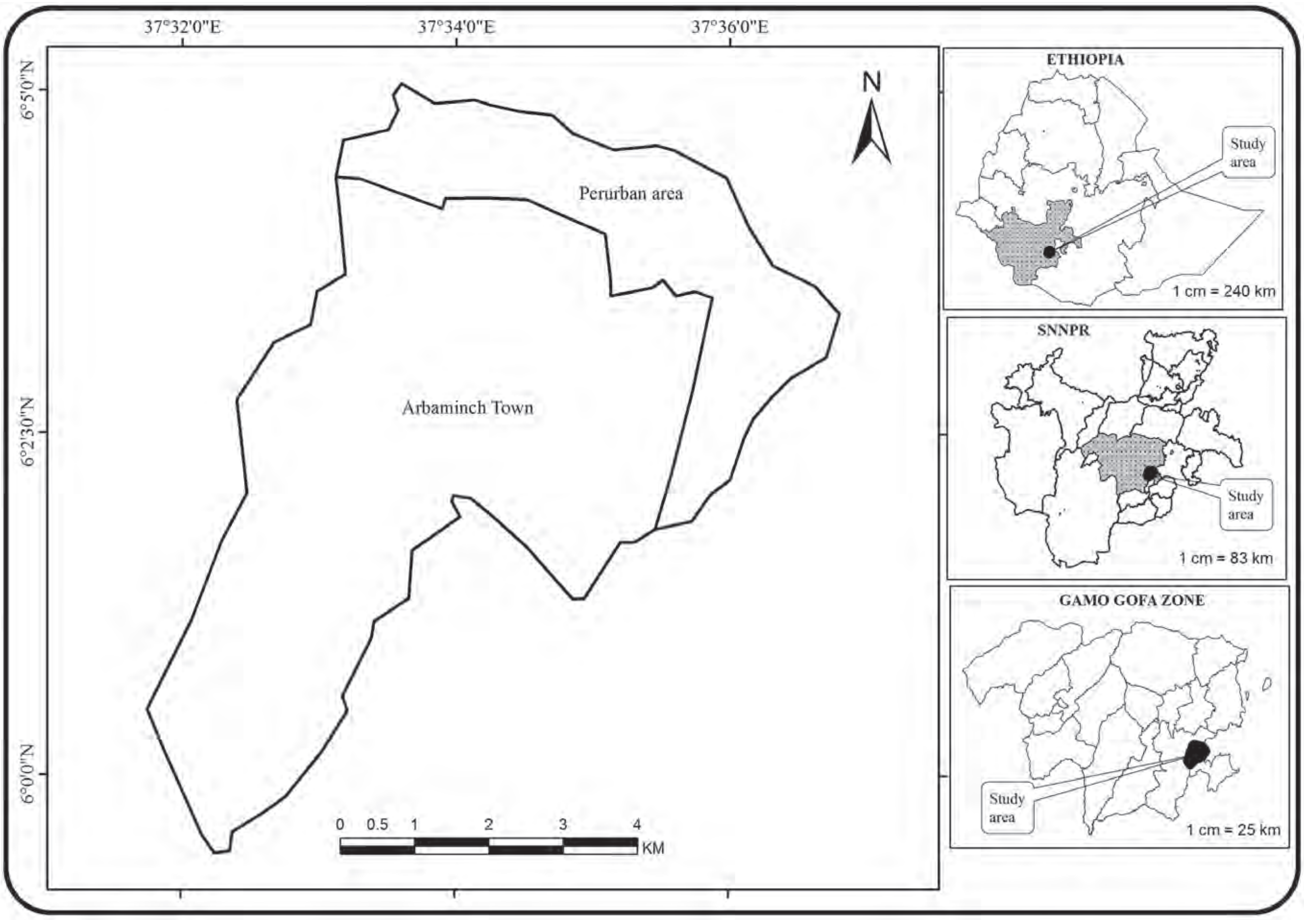

Fig. 1 Location map of the study area.
Source: Ethio-GIS, 2014.

questionnaires were used to collect such quantitative data. Qualitative data were collected using Focus Group Discussions (FGDs) and in-depth interviews.

The target population for the study was the entire urban households residing within the town and Kola-shara (peri-urban *kebele* – the smallest administrative unit under city or town administration), which was taken to be one of the sample *kebeles* with the intention to represent peri-urban area. Two-stage sampling technique was applied to select the sample households. In the first stage, sample *kebeles* (the primary sampling units) were selected purposely from the study area and then sample households (the secondary sampling units) were selected from each *kebele* randomly. For sampling purposes, the *kebele*s were categorized into two strata based on based on the dominance of the type of residential housing units. After classifying the *kebeles* into two strata, three *kebeles* from each stratum were selected. Stratum one (*kebeles* with more shanty houses) has three *kebeles*, namely, Birie, Kulfo and Kola-shara. Stratum two (*kebeles* with more of better off housing units) has also three *kebeles*, namely, Chamo, Dil-fana and Mehal-Ketema.A total of 658 sample households were selected randomly based on the list available in all *kebeles*. The number of sample households for each *kebele* is proportional to the total number of households in each sample *kebele* administration (Table 1).

4. Results and Discussion

4.1 Demographic and socio-economic characteristics of respondents

One of the most important characteristics of households that need to be considered is the size of the household and its composition. The gender composition of households reveals that MHHs (Male-headed households) are more in number (383) than their female counterparts (275). The total number of family members in the sampled households was 3,180, of which female constitutes 51.95 percent and male 48.02 percent. The majority of the sample respondents (65.96%) have reported to have between 4 and 6 family members while a few of them (21.28%) have between 1 and 3 members. On average, there are 4.83 family members in a household while the range is between 1 and 10.

Out of the total sample households, the maximum age observed from sample respondents was 68 while the minimum is 23. The majority of the respondents (41.64%) are found between 41 and 50 age range. Almost three fourth of the sample households (74.4 %) have attended formal education and are literate. Only a quarter of the total sample population (25.6%) has never attended formal education but can read and write. Regarding housing conditions, the majority of the residential units are poorly constructed and of low standard. Most of the housing units (89%) is made of mud, wood and corrugated sheets while only a small share of the residential units (11%) built using hollow blocks or concretes. With respect to dwelling ownership of the sample households, currently more than three fourth of the sample households (75.4%) live in their own houses, and 17.5 percent and 7.1 percent in rented *kebele* and private houses, respectively. Those who lacking own houses are also living in an overcrowded rooms and poor housing conditions with a serious lack of basic facilities.

4.2 Household Income and Fuel Expenditure

More than one third of the sample household heads (35.5%) are full time private and government employees and they receive much of their income from monthly salaries, whereas almost two-thirds of the participants (64.5 %) do not earn a regular income or salary. Of the total non-employed household heads, nearly a quarter of sample households (23.6%) rely on petty trade (Ethiopian Birr – One USD was equivalent to 18.75 ETB at the time of the survey) for their main source of income. Medium and higher traders occupy the next position (18.1%) followed by daily laborers (9.3%), (9.1%), farmers (7.1%), and the rest (2.5%) was pensioners. For those who engaged in farming, livestock income was quantified from sales of livestock and livestock products and crop income was quantified from the sale of all crops, including cereals, pulses, horticultural crops and other cash crops during the year. The better off households in peri-urban area continue to engage in irrigated fruit farming and normally earned their main income through the sale of fruits, particularly banana and mango. Besides fruits, some households sell a small part of their own harvest, like maize. Though a quarter of all households do not own any livestock, not even chickens, few households earned their income from the sale of livestock and livestock products, including cattle, goats and chicken.

Nearly a quarter of the households (23.25%) are earning annual per capita income of more than 8,001 ETB – Ethiopian Birr (one USD was equivalent to 18.75 ETB at

Tab.1 Household size and sample *kebeles* in the study area.

Sample *kebele*	**Kolla-Shara**	**Kulfo**	**Bire**	**Mehal-ketema**	**Dilfana**	**Chamo**	**Total**
Total Household size	1463	1796	1712	1346	1471	1717	9505
Sample Household size	86	132	118	98	96	128	658

Source: Arba-Minch Town Administration Office, 2014 and Field survey, 2014.

the time of the survey) a year whereas 76.74 percent of the residents earn annual per capita income of less than 8,000 ETB to support basic needs of their family members. the study revealed that almost two-thirds of the sample households (63.68%) earn mean monthly income of less than 2,000 ETB. Out of the survey households only 11.10 percent of the households were having an income greater than 3,000 ETB per month. Mean monthly income for the sample households was 2,315 ETB. The lowest monthly income for the sample households was 800 ETB, while the highest was 6,500 ETB per month. There is wide disparity in income among these groups, which can be explained by coefficient of variation of 46.48 percent.

Nearly half of the sample households (47.42%) have annual per capita income of below 5,000 ETB and belong to the low income category. About 39.36 percent were earning in between 5,001 and 10,000 ETB and belong to the middle income households, and nearly a quarter (13.22%) were having an income greater than 10,001 ETB per year and belong to high income category. Such income categorization cannot be generalized and hence is not a representation of the situation in the entire country. It may differ from region to region and from locality to locality.

As indicated in Table 2, the average monthly income for low income households was 1,517 ETB. The highest figure may go as high as 3,166 ETB and the lowest as low as 800 ETB. The average monthly income for the middle income households was 2824 ETB with the minimum income of 900 ETB and the maximum income of 5000 ETB. In the high income group, the monthly income varies from minimum income of 1,000 ETB to the maximum income of 6,500 ETB with an average monthly income of 3,570 ETB.

There are also large variations in the pattern of energy requirements across households belonging to different income classes. At the same time, as can be seen from Table 2, the average monthly expenditures of households on various types of energy differ according to income levels. The average monthly expenditure on domestic energy per household was 266 ETB for the low, 314 ETB for the middle and 302 ETB for the high income groups.

Unlike the average household monthly expenditure, per capita energy expenditures made on domestic energy significantly increases with a rise in a family income. Monthly per capita energy expenditures for all sample households was 66 ETB and it varies from 55 ETB for the low income households to as high as 105 ETB for the high income households and per capita average monthly expenditure on domestic energy was 71 ETB for medium income group. The average monthly fuel expenditure for the sample households was 290 ETB, which makes up 13 percent of the family mean monthly income. The lowest monthly expenditure for the sample households was 29 ETB, while the highest was as high as 456 ETB per month. The disparity in expenditure among sample households, which can be explained by coefficient of variation of 24.75 percent, is smaller.

For the low income households, the mean monthly expenditure on fuels was 266 ETB which constitutes 17.51 percent of the average households' monthly income. This creates a higher financial strain on the budget of households of this income group. The standard deviation of 66.89 and coefficient variation of 25.18 percent shows that disparity in the expenditure on energy for the group. For the middle income households, the average monthly expenditure on various energy resources was 314 ETB which constitute 11.13 percent of the average income of the group. The 22.12 percent coefficient of variation shows that there was low variation in expenditure made on energy among households of this income group. In the high income group, the average monthly expenditure on fuels for this group was 302 ETB which constitute 8.45 percent of the average income of the group. The coefficient variation of 22.52 percent reflects that there was low disparity in expenditure made by households of this group with less significant strain on household budget. This implies that although the lower income groups do have fewer energy expenditures they spend a great share of their incomes on biomass fuel. They pay more per unit of energy than the better off households as they have less purchasing power and failing to make shift to other alternative sources of energy (Table 3).

The average household monthly biomass fuels use was 183 ETB for low income households. The figure falls to 177 ETB for the middle income households and 136 ETB for the high income households. On the other hand, the share of both the average household expenditures on conventional fuels in households' energy budget increases as we move from low to high-income groups. The average

Tab. 2 Mean monthly incomes and expenditures by income group (in ETB).

Income Group	Annual per Capita Income Range	Household Income			Fuel Expense			
		Mean	SD	Cv	Mean	SD	Cv	As % of The Income
Low	Below 5,001	1,517.65	418.75	27.59	265.70	66.89	25.18	17.51
Middle	5,001–10,000	2,824.53	909.84	32.21	314.32	69.53	22.12	11.13
High	Over 10, 001	3,570.00	1,029.77	28.85	301.69	67.94	22.52	8.45
Average		2,315.09	1,076.08	46.48	290.15	71.82	24.75	12.53

Sd: standard deviation, CV: coefficient of variation

Tab. 3 Mean monthly expenditures on fuels by income group (in ETB).

Fuel Type	Low Income Households		Middle Income Households		High Income Households	
	Per household	Per capita	Per household	Per capita	Per household	Per capita
Biomass fuels	182.54	37.80	176.81	41.06	136.30	47.90
Conventional fuels	82.99	17.39	137.46	30.31	165.39	56.64
Total	265.53	55.19	314.27	71.37	301.69	104.54

Source: Field survey, 2014.

monthly household conventional fuels expenditure was 83 ETB for the low, 137 ETB for the medium and 165 ETB for the high income group. There is a considerable variation in expenditure patterns on household energy resources by the sample households depending up on a household's economic status. The amount of expenditure made on fuels for domestic purpose is creating more pressure on family budget as the result of increasing scarcity of fuels. The evidence presented in this section suggests that the higher financial burden faced by the poorer households in meeting their energy needs. Fuel price increase was a challenge for urban and peri-urban households and there is high strain on household's budget particularly among households of the low economic strata who often end up spending a substantial proportion of their household income on energy when compared to the share spent by high income households. It is found that poor urban households spend a significant portion of their cash incomes on energy because cooking with fuel wood is inefficient compared with cooking with modern fuels.

4.3 Data Conversion

The amount of heat energy consumed from each specific energy source can be estimated by converting its expenditure into heat value. Therefore, for conversion mechanism, total expenditure of each household on fuels is multiplied by the constant to get the heat value consumed by a household. In the field work conducted, the price of fuel wood ranged from 50 ETB per 25 kg (2 ETB per kg) in peri-urban area to 80 ETB per 25 kg (3.20 ETB per kg) in the town. Fuel wood vendors serve almost all sample households at an average price of 2.60 ETB for one kg of fuel wood. That means a household buys 0.38 kg for one ETB. One kg of fuel wood provides heat value of 15.07 MJ. Therefore, a household gets 5.73 MJ (15.07 × 0.38) gross heat value of fuel wood for one ETB (Annex 1). This constant is important to convert household expenditure on fuel wood into gross heat value (MJ). For the rest of energy sources, the constants were manipulated in the same way.

Charcoal is sold at about 70 ETB per 30 kg sack of charcoal in peri-urban area (2.33 ETB/kg) while the price of 30 kg sack of charcoal is 120 ETB in the town (4 ETB/kg). The average price of a kilogram of charcoal was 3.17 ETB. One kilogram of charcoal provides heat value of 29.73 MJ. So for one ETB a household could get 9.51 MJ (29.73 × 0.32) heat value of charcoal (Annex 1). In the case of sawdust, 5.02 percent of the sample households use this resource. Of the total users, only 1.22 percent got sawdust for free and the rest users normally buy the fuel from sawmill. The average price of sawdust was 5 ETB per kg. Thus, a household bought 0.2 kg of sawdust for one ETB. One kilogram of this fuel delivers 16.75 MJ heat value of sawdust. So a household could get 3.35 MJ (0.2 × 16.75) heat value of sawdust for the expenditure of one ETB on sawdust (Annex 1).

According to Ethiopian Electricity Utility (EEU), Arba-Minch Branch, the price of electricity was based on fixed rate of payment for electricity consumed (Annex 2). The payment rates of electricity vary in slabs of the total amount of electricity consumed. The monthly rate of payment per kWh varies from 0.27 ETB if the electric consumption was 50 kWh and less to 0.69 ETB for 501 kWh and above. That is, for example, if the total electric energy consumed is 100 kWh, the first 50 kWh is rated at about 27 cents per kWh and the second 50 kWh is rated at about 36 cents per kWh.

As Table 6 shows the average price of electricity paid by surveyed households was 0.39 ETB per kWh. Since 0.39 ETB was equivalent to one kWh, one ETB was equivalent to 2.56 kWh. Thus, a household bought 2.56 kWh of electricity for one ETB. One kWh of electricity is equivalent to 3.6 MJ of energy. Therefore, for one ETB, a household buys heat value of 9.22 MJ (2.56 × 3.6) (Annex 1). Almost all kerosene users buy a liter of kerosene by 15 ETB from petrol station. Thus, 0.07 liter of kerosene was obtained for one ETB. One liter of kerosene delivers 33.62 MJ of heat value. Therefore, 0.07 liter of kerosene delivered 2.35 MJ (0.07 × 33.62) of heat value (Annex 1). Considering the price of each energy type, expenditure made on source of fuel was converted to gross energy in terms of heat value (MJ). Accordingly, on average, fuel wood, charcoal, saw dust, electricity, and kerosene, have got a gross heat value of 5.73, 9.51, 3.35, 9.22 and 2.35, respectively. As far as dung cake and biogas are concerned, households usually procure for free from own cattle near the house throughout the year. Unlike other fuels, the study here used the amount of heat energy per their respective units of energy rather than their prices as reference to find out their gross heat values (MJ). It has been reported by UNDP (2009) cited in Ethiopian Ministry of Water & Energy (MoWE) (2011) that one kilogram of dung cake and one cubic meter of biogas can provide heat values of 14.50 MJ and 22.80 MJ, respectively. Therefore, these constants by themselves are also important to convert household consumption into gross energy heat value.

4.4 Households' Gross and End-use Energy Consumption

As shown in table 4, the mean monthly household gross energy consumption in terms of heat values delivered varies from 2,002.79 MJ for the low income group to 2,477.04 MJ for medium income group with the average monthly household gross energy consumption of 2,251.96 MJ for the sample households. On the other hand, with the rise of the household income, there is a significant proportion of increase in the mean monthly per capita consumption of energy in terms of heat value. The mean monthly per capita consumption of gross energy for the study area was 528.34 MJ. It ranges from 415.37 MJ for the low income households to 838.03 MJ for the high income households.

The average monthly domestic biomass fuels consumed varies from the lowest (1,151.29 MJ) for high income households to the highest (1,408.36 MJ) for medium income households. On the other hand, there is a proportional increase of per capita consumption of biomass fuels with income of the households. The average monthly per capita biomass fuels consumption varies from 286.33 MJ for low income households to 400.32 MJ for the high income households. Both the average household and per capita gross conventional fuels consumption proportionately increases with income of the households. The respective household and per capita gross conventional fuels consumption varies from 618.22 MJ and 129.04 MJ for low income households to 1285.04 MJ and 437.71.16 MJ for high income households.

From the previous discussion, it can be seen that the consumption of fuels was estimated in the total input household energy consumption regardless of the efficiency of fuels and appliances used. The difference is waste heat that escapes around the sides of the pan. Consumption of energy in terms of end-use energy utilized varies considerably from household to household. There is a corresponding increase for useful energy consumption with a rise in a household income. The average monthly end-use energy received by a household ranges from 674.47 MJ in the low income households to 1,160.55 MJ in the high income households.

Wood fuels (wood and charcoal) are by far the most used cooking fuels for a large majority of households in spite of the growing scarcity and price of these resources. The main reason for preferring this energy source is affordability of the fuel and the related stoves. Despite paying higher prices for useable energy, most urban and peri-urban households use less useful energy per household due to the inefficiency of traditional fuel-using cooking stoves. Households often continue to cook with biomass fuels and cannot easily make a transition to electricity in order to satisfy their cooking needs since the high costs of modern cooking fuels and stoves are major constraints for them. It is becoming increasingly difficult for most people to obtain affordable energy technologies that convert energy to useful services. The findings revealed that the provision and adoption of modern energy technologies such as LPG has not been a great success due to lack of general availability and much higher cost for household use. Although there is significant interest in the area, the cylinder is not available at affordable price. Cost of electrical cooking and LPG gas using appliances are beyond the financial reach of most households. Moreover, frequent erratic supply of electricity makes it difficult for households to access energy for the purpose of cooking.

Tab. 4 Mean monthly gross energy consumption (in MJ) by income class and fuel type.

Fuel Type	Low Income Households		Middle Income Households		High Income Households	
	Per household	Per capita	Per household	Per capita	Per household	Per capita
Biomass fuels	1,384.57	286.33	1,408.36	324.51	1,151.29	400.32
Conventional fuels	618.22	129.04	1,068.68	234.16	1,285.04	437.71
Total	2,002.79	415.37	2,477.04	558.67	2,436.33	838.03

Source: Field survey, 2014.

Tab. 5 Mean monthly end-use energy consumption (in MJ) by income class and fuel type.

Fuel Type	Low Income Households		Middle Income Households		High Income Households	
	Per household	Per capita	Per household	Per capita	Per household	Per capita
Biomass fuels	216.79	44.86	237.07	54.20	207.58	71.53
Conventional fuels	457.68	95.55	790.32	173.24	952.97	324.51
Total	674.47	140.41	1,027.39	227.44	1,160.55	396.04

Source: Field survey, 2014.

Regarding the average monthly end-use energy received, electricity has the largest share followed by charcoal and kerosene. The share of other fuels in the heat value of useful energy is not important. For the low income group, the average monthly domestic consumption of electricity was 443.21 MJ; this figure rises to 765.36 MJ for the medium and 927.71 MJ for the high income groups. Consumption of kerosene varies from 9.71 MJ for the low income group to 17.95 MJ for the medium income group and 20.01 MJ for the high income group. Low income households receive 154.24 MJ of charcoal, while the middle and high income groups receive 191.35 MJ and 184.77 MJ, respectively. Monthly per capita biogas consumption ranges from nil for high income group to 1.87 MJ for middle income households. Despite the fact that the majority of middle and higher income households combine the use of biomass fuels with other clean source of energy particularly kerosene to satisfy their cooking needs, wood fuels remain the dominant fuel among the lower income households.

Tab. 6 Share of household and per capita end-use energy out of the total input energy (MJ).

Income Group	Gross Energy (MJ)		End-use Energy (MJ)	
	Per household	Per capita	Per household	Per capita
Low	2,002.79	415.37	674.47	140.41
Middle	2,477.04	558.67	1,027.39	227.44
High	2,436.33	838.03	1,160.55	396.04

Source: Field survey, 2014.

The amount of end-use energy received by a household rises with an increase in household income. The households of the lower economic levels receive less amount of useful energy as compared to households in the high economic levels. A household in the low income group receives 33.68 percent of its gross energy input, while that of mid and high income groups receive 41.48 percent and 47.64 percent, respectively (Table 6). This indicates that with a rise in a household income, there is a tendency for households to use multiple fuels and stoves for baking and cooking. An increase in household income does not necessarily mean an overall switching, where biomass cooking fuels totally substitutes for clean cooking energy sources. It is becoming increasingly difficult for most people to obtain affordable energy technologies that convert energy to useful services. The ability to use any modern fuel is dependent on the energy-users' ability to afford not only the fuel on a regular basis but also their ability to pay for the energy-using appliances.

According to Masera et al. (2000) and Treiber et al. (2015) in many households, traditional stoves are used at the same time as improved cook-stoves, or the different stoves may be used for different foods. The study has shown that switching from biomass to conventional fuels for baking and cooking was difficult for more than half of the sample households (52.3%). Fuel switching is partial for 44.8 percent of the households while only a minority (2.9%) switches completely. The study results indicate that there is a tendency to use more wood fuels with limited conventional fuels for the purpose of baking and cooking. This means the consumption of wood fuels for baking and cooking is not declining at all income levels. Wood fuels are still the choice of most households for baking and cooking purposes regardless of household's economic status.

The use of modern fuels is always accompanied by traditional fuels and any conventional fuel does not completely substitute biomass. In an investigation into household energy consumption, Maseraet al. (2000) concluded that the specific fuel-mix choice and the relative consumption of each fuel is governed by the characteristics of the fuels and end use devices; specific aspects related to fuel availability; and the local cultural and social context that determines household preferences regarding cooking fuels and lifestyles.

4.5 Energy poverty and low income residents

As the focus of this study is on household energy spending and the differences between income groups, some of our analysis is relevant for the important issue of energy poverty. In validating Boardman's (2014) argument that raising income can lift a household out of poverty, but rarely out of energy poverty, the situation of energy poverty among urban and peri-urban households is analyzed based on the expenditure approach to identify whether households are energy poor or not. Although many researchers have similar ideas in the definition of energy-poverty, they fail to agree on what exactly is the minimum level of energy-poverty line. It can be classified as either based on measures of physical energy requirements (Goldemberg 1990) or energy expenditures (Pachauri and Spreng 2004; Boardman 2014).

Pachauri and Spreng (2004), WHO (2011) and ESCAP (2012) adopt a cutoff point of 10 percent of total expenditure because it is frequently mentioned in the literature as common level of expenditure for poor households and classified households as energy poor if more than 10 percent of their total monthly household income is devoted to energy expenditure. The energy-poverty estimation outlined in this paper is based on energy expenditures. It describes a household as energy poor or in energy-poverty if the energy-poverty ratio is greater than 0.1. Households with energy expenditure exceeding this threshold are considered to be energy poor and are consequently likely to be confronted with difficult choices between meeting energy requirements on the one hand and sacrificing other important competing spending priorities on the other.

The problems recounted by the respondents in this study show that the energy poor that spend over

10 percent of their income on energy are predominant. The majority of the sample households (72.9%) face burden of energy poverty and often end up spending a substantial proportion of their household income on energy. Out of this figure more of them (59.38%) are from low income households, about 34.79 percent are from medium income households and only a minority (5.83%) is from high income households. Households with monthly income of 2,500 ETB and less were assumed to represent less income residents and further examined in the analysis as they have a high probability of being affected by energy poverty in terms of availability of energy, safe and reliable supply, and affordability.

It was found that the problem of energy poverty is acute among the poor households as people with less income have limited access to clean fuels. This implies that low income families clearly suffer from energy poverty because they do not have the minimum amount of energy for their basic necessities of living. Fuel crisis affects families of the lower economic status adversely as opposed to the high income groups. Income poor faces high burden of energy poverty as they tend to spend a larger share of their income on purchasing inefficient and harmful energy fuels. A family in this lower economic status on an average has an income of ETB 1,640.80 and spends up to 17.5 percent of its income on domestic energy. This becomes a large economic burden on their budget. For this reason, of the total 423 low income residents, the majority (92.2%) are energy poor while only the rest (7.8%) are non-energy poor.

Biomass fuel prices in urban markets often rise rapidly as wood resources are seriously depleted in the study area, thus the poor are still inadequately served by energy supplies and they face higher financial burden to meet their basic energy needs. Among the major problems encountered by inhabitants of the town, escalating price of traditional fuels and growing strains on household's budget particularly among households of the low economic strata emerged as the main threats. Traditional fuels particularly fuel wood and charcoal have become scarce and expensive thereby forcing households to expend significant portion their limited income on energy. The fact that cash income is so low that even modest changes in energy expenditures can be a real hardship for them. They are unable to use modern energy for cooking, as they have limited access to modern end use technologies and large dependence on least efficient traditional fuels. Thus, they consume less end-use cooking energy services.

The end-use energy consumption level of energy poor households lowers as they are unable to use modern energy for cooking and they tend to stick to consumption of wood fuels. The fuel poor tend to live in energy inefficient properties as a result of insufficient capital expenditure and, therefore, they have fewer opportunities to engage in educational and income-generating activities. Meeting the energy requirement in a sustainable manner continues to be a major challenge for the majority of urban households. Therefore, The heavy dependence together with inefficient utilization of biomass resources for energy have resulted in high depletion of the forest resources and serious adverse consequences for health, environment and economic development which hinder households' efforts to improve their living situations. Most households in income poverty were in energy poverty as they find it difficult to acquire high priced cleaner fuels. Such limited use of clean energy and reliance on traditional biomass deter opportunities for economic and social advancement. Therefore, reducing energy poverty helps to reduce income poverty.

As can be seen from Table 7, energy poor households predominantly depend on biomass fuels (242.32 MJ) which is more than the biomass consumption by energy non-poor households (174.08 MJ). While energy non-poor households, on an average, consume 845.42 MJ of conventional energy much more than the conventional consumption by energy poor households (587.32 MJ). The prevalence of solid fuel use in this study was 26.9 percent; it was higher in the energy poor households (35.2%) than in the energy non-poor households (21.7%). This implies that the end-use energy consumption level of energy poor households lowers as they tend to stick to consumption of biomass fuels. This indicates the growing level of energy poverty in the area which needs to be addressed at the earliest. Such limited use of conventional fuels and significant reliance on biomass fuels deter opportunities of most residents for economic and social advancement. This is indeed a problem of the vicious cycle of energy poverty: lack of energy affects the economic activities of households and in turn limits their ability to make use of energy services. Access to energy alone is not enough to combat poverty, says UNDP report (2011), the poor need support to generate income so that

Tab. 7 Mean monthly gross and end-use energy consumption patterns of energy-poor and energy non-poor households (in MJ).

Consumption Type	**Energy Poor Households**		**Energy Non-poor Households**	
	Gross Energy (MJ)	End-use Energy (MJ)	Gross Energy (MJ)	End-use Energy (MJ)
Biomass fuels	1,503.48	242.32	988.35	174.08
Convectional fuels	793.28	587.32	1,142.79	845.42
Total	2,296.76	829.64	2,131.15	1,019.51

Source: Field survey, 2014.

energy becomes affordable, which in turn will improve household living standards.

5. Conclusion

The study reveals that electricity consumption is likely to reach nearly all the households in urban areas while no considerable switching from wood to electricity had occurred in household energy use. Despite the fact that a majority of sample households used electricity at home, wood fuels (wood and charcoal) remain to be dominant sources of energy for baking and cooking purposes regardless of household's economic status. A rise in household incomes does not necessarily mean a departure from the use of biomass. The problem of energy poverty is acute among the income poor households as people with less income have limited access to clean fuels. This implies that low income families clearly suffer from energy poverty because they do not have the minimum amount of energy for their basic necessities of living. It is common the income poor are more likely to be energy poor; however the energy poor are not all income poor. Thus, reducing energy poverty helps to reduce income poverty.

An increase in household energy demand has led to massive deforestation on the outskirts of the town. This has resulted in serious shortage of wood fuels and higher prices. One great concern, however, is the local authority does little to control access to the hinterland forests of the town from where wood fuel is extracted and supplied. The local government should give attention to the amount of depleted natural resources and rate of rapid deforestation to lessen the environmental impact from overexploitation of these resources. A key policy priority should therefore be to plan for the long-term care of endangered forests. There is a need to develop sustainable energy sources and practicing afforestation and forest management programs to overcome the problem of deforestation of natural forest.

A reasonable approach to tackle this issue could be to review the energy development strategies and search for mechanisms that minimize dependence on biomass fuel. This study suggests that increasing end-use efficiency should be given greater emphasis as an important prerequisite and cost effective solution to tackle household level energy problem. It is important to change households cooking practices by employing proper end-use technologies so that the pressure on surrounding forests and soil resources could be alleviated and household energy-related problems tackled. To generate achievable policy strategies and development targets with regards to energy poverty, there is a need for more studies at the local level to allow further assessment of local dimensions of the subject. A further study could assess the long-term and wider range effect of energy poverty at household levels. Such studies could help in the design of better strategies and policy instruments in the energy sector.

Acknowledgements

This research was financially supported by the Ministry of Education of the Ethiopian Democratic Republic, Addis Ababa University. Authors would like to thank the executive editor Eva Štefanová as well as the two anonymous reviewers for their constructive comments and recommendations.

REFERENCES

Alemu, M., Kohlin, G. (2008): Determinants of Household Fuel Choice in Major Cities in Ethiopia. Environment for Development: Discussion paper series, August 2008, EfD DP 08-18. http://www.rff.org/files/sharepoint/WorkImages/Download/EfD-DP-08-18.pdf

Araya, A., Yisehak, D. (2012): Sustainable Household Energy for Addis Ababa, Ethiopia, Journal of Sustainable Development 8, 1–11. http://dx.doi.org/10.7916/D86W99RV

Arba-Minch Town Administration Office (2014): Annual Magazine for the year 2013. Arba-Minch Manucipality, No. 12, p. 15.

Barnes, D., Krutilla, K., Hyde, W. (2004): The Urban Household Energy Transition: Energy, Poverty, and the Environment in the Developing World. World Bank Policy Research Working Paper No. 6903. https://www.esmap.org/sites/esmap.org/files/Rpt_UrbanEnergyTransition.pdf

Boardman, B. (2014): Fixing fuel poverty: Challenges and Solutions. Taylor and Francis. https://doi.org/10.4324/9781849774482

Cecelski, E. (2004): Re-thinking Gender and Energy: Old and New directions. Energy, Environment and Development (EED), ENERGIA/EASE Discussion Paper. http://www.hedon.info/docs/RethinkingGenderAndEnergyOldAndNewDirections.pdf

Clancy, J. (2006): Enabling urban poor livelihoods policy making: understanding the role of energy services, Department for Technology and Sustainable Development, Centre for Clean Technology and Environmental Policy, University of TwenteEnschede, The Netherlands. DFID KaR project R8348. http://doc.utwente.nl/59064/1/Clancy04enabling.pdf

Clancy, J., Skutsch, M., Batchelor, S. (2003): The Gender-Energy-Poverty Nexus: Finding the energy to address gender concerns in development. Paper prepared under the United Kingdom's Department for International Development (DFID) Project CNTR998521. https://core.ac.uk/download/pdf/11462752.pdf

Economic and Social Commission for Asia and the Pacific (ESCAP) (2008): Energy Security and Sustainable Development in Asia and the Pacific, Working paper series. http://www.unescap.org/sites/default/files/energy-security-ap.pdf

Ethiopian Electrical Utility (EEU) (2012): Ethiopian Power System Expansion Master Plan Update (EPSEMPU).

Farsi, M., Filippini, M., Pachauri, S. (2005): Fuel choices in urban Indian households, Environment and Development Economics 12(6), 757–774. https://doi.org/10.1017/S1355770X07003932

Getamesay, B., Workneh, N., Getachew, E. (2015): Energy Poverty in Addis Ababa City, Ethiopia. Journal of Economics and Sustainable Development 6(3), 26–34. http://iiste.org/Journals/index.php/JEDS/article/view/19913

GIZ (2008): Baseline Study Access to Modern Energy Services in Ethiopia (AMES-E). Deutsche Gesellschaftfür Internationale Zusammenarbeit: Eschborn, Germany.

Goldemberg, J. (1990): One kilowatt per capita. Bulletin of the Atomic Scientists 46(1), 12–26. http://dx.doi.org/10.1080/00963402.1990.11459775
GTZ-Sun (2010): Household Energy Baseline Survey in Addis Ababa, Addis Ababa, Ethiopia.
Gujarati, D. (2004): Basic Econometrics, Fourth edition, The McGraw-Hill Companies, India. https://www.hse.ru/data/2011/04/26/1210823708/Gujarati%20D.N.%20Basic%20Econometrics,%203e,%201995.pdf
IEA (2006): World Energy Outlooks, Paris, France.
Gundimeda, H., Köhlin, G. (2008): Fuel demand elasticity for energy and environmental policies:Indian sample survey evidence. Energy Economics 30(2), 517–46. https://doi.org/10.1016/j.eneco.2006.10.014
Heltberg, R. (2004): Fuel switching: evidence from eight developing countries. Energy Economics 26(5), 869–887. https://doi.org/10.1016/j.eneco.2004.04.018
Heltberg, R. (2005): Factors determining household fuel choice in Guatemala. Environment and Development Economics 10(3), 337–361. https://doi.org/10.1017/S1355770X04001858
International Energy Agency (IEA) (2007): Energy Balances of non-OECD Contries, Paris. https://www.iea.org/publications/freepublications/publication/WorldTrends_NonOECD_countries2015.pdf.
International Energy Agency (IEA) (2009): World Energy Outlook, International Energy Agency, Paris. http://www.worldenergyoutlook.org/media/weowebsite/2009/WEO2009TOC.pdf
International Energy Agency (IEA) (2010): Energy Poverty: How to make modern energy access universal? Special Edition for Experts of World Energy Outlooks 2010 on the UN General Assembly on the Millennium Development Goals. Paris, France. http://www.worldenergyoutlook.org/media/weowebsite/2010/weo2010_poverty.pdf
Jain, G. (2010): Alleviating Energy Poverty: Indian Experience, Regulatory Studies and Governance Division, The Energy and Resources Institute. http://www.indiaenergycongress.in/montreal/library/pdf/319.pdf
Kammen, D. M., Kirubi, C. (2008): Poverty, Energy and Resource Use in Developing Countries. Annals of the New York Academy of Sciences, 1136, 348–357. https://doi.org/10.1196/annals.1425.030
Karekezi, S., Kithyoma, J. (2005): Sustainable Energy in Africa: Cogeneration and Geothermal in the East and Horn of Africa – Status and Prospects, Nairobi, AFREPREN/FWD.
Kebede, B., Bekele, A., Kedir, E. (2002): Can the Urban Poor Afford Modern Energy? The Case of Ethiopia. Energy Policy 30(11–12), 1029–1045. https://doi.org/10.1016/S0301-4215(02)00056-3
Khandker, S., Barnes, D., Samad, H. (2010): Energy Poverty in Rural and Urban India: Are the Energy Poor Also Income Poor? World Bank Development Research Group Agriculture and Rural Development Team. Policy Research Working Paper, 5463. https://doi.org/10.1596/1813-9450-5463
Krugman, H., Goldemberg, J. (1983): The energy cost of satisfying basic human needs. Technological forecasting and social change 24, 45–60.
Masera, O., Saatkamp, B., Kammen, D. (2000): From Linear Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to the Energy Ladder Model. World Development 28(12), 2083–2103. https://doi.org/10.1016/S0305-750X(00)00076-0
Meikle, S., Bannister, A. (2005): Focus on the significance of energy for poor urban livelihoods:Its contribution to poverty reduction. Working Paper No. 126, ISSN 1474-3280.
Ministry of Water and Energy of Ethiopia (MoWE) (2011): Energy Balance of Ethiopia and Statstics for the Years 2005/6–2009/10. Addis Ababa: Ministry of Water and Energy of the Democratic Republic of Ethiopia.
Nebiyu, A. (2009): Domestic energy consumption and deforestation in Harari region assessment of students' awareness and views. School of Graduate Studies. Department of Geography and Environment Education. Addis Ababa, Ethiopia. http://everythingharar.com/images/pdf/publication/Nebiyu_M.A_Thesis2.pdf
Nkomo, J. C. (2007): Energy use, poverty and development in the SADC. Journal of Energy in Southern Africa 18(3), 10–17. http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/jesa/18-3jesa-nkomo.pdf
Ntobeg, N. (2007): Rural Energy Systems and the Rural Development Process: A case study from Limpopo Province. Submitted in fulfilment of the requirements forthe degree of Master of ARTS in the subject geography at the University of South Africa, Pretoria.
Pachauri, S., Spreng, D. (2004): Energy use and energy access in relation to poverty. Ecomomic and Political Weekly 39(3).
Reddy, S. (2004): Economic and Social Dimensions of Household Energy Use: Case Study of India, Proceedings of IV Biennial International Workshop "Advances in Energy Studies". Unicamp, Campinas, SP, Brazil, June 16–19, 2004, 469–477.
Samad, A., Barnes, D., Khandker, S. (2010): Energy Access, Efficiency, and Poverty: How Many Households Are Energy Poor in Bangladesh? World Bank Policy Research Working Paper No. 5332. http://dx.doi.org/10.1596/1813-9450-5332
Samuel, F. (2002): Households' Consumption Pattern and Demand for Energy in Urban Ethiopia. MSc thesis, Addis Ababa University, Ethiopia. Ethiopia. PhD thesis. Department of Social Sciences, Wageningen University.
Treiber, M. U., Grimsby, L. K., Aune, J. B. (2015): Reducing energy poverty through increasing choice of fuels and stoves in Kenya: Complementing the multiple fuel model. Energy for Sustainable Development 27, 54–62. http://condesan.org/mtnforum/sites/default/files/publication/files/1-s2.0-s0973082615000320-main.pdf
United Nations Development Program (UNDP) (2005): Energy Services for the Millennium Development Goals: Achieving the Millennium Development Goals. http://www.unmillenniumproject.org/documents/MP_Energy_Low_Res.pdf
United Nations Development Program (UNDP) (2009): The Energy Access Situation in Developing Countries: A Review Focussing on Least Developed Countries and Sub-Saharan Africa. http://www.undp.org/content/dam/undp/library/Environment%20and%20Energy/Sustainable%20Energy/energy-access-situation-in-developing-countries.pdf
Wickramasinghe, A. (2007): Issues of Affordability and Modern Energy Technology: Barriers to the Adoption of Cleaner Fuels for Cooking.
World Bank (2011a): Household Cook stoves, Environment, Health, and Climate Change: a new look at and old problem. The Environment Department, World Bank, Washington DC. http://cleancookstoves.org/resources_files/household-cook-stoves.pdf
World Bank (2011b).Unleashing the Potential of Renewable Energy in India. http://siteresources.worldbank.org/EXTENERGY2/Resources/Unleashing_potential_of_renewables_in_India.pdf
World Health Organization (WHO) (2009): Indoor Health Pollution Takes a Heavy Toll on Health. http://www.who.int/mediacentre/news/notes/2007/np20/en/index.html
World Health Organization (WHO) (2011): Broader Impacts of Household Energy. http://www.who.int/indoorair/impacts/en

Yonas, A., Abebe, D., Köholin, G., Alemu, M. (2013): Household Fuel Choice in Urban Ethiopia: A Random Effects Multinomial Logit Analysis. Resources for the Future, Discussion Paper, EfD DP 13-12. http://www.efdinitiative.org/sites/default/files/publications/efd-dp-13-12.pdf

Zenebe, G. (2007): Household Fuel Consumption and Resource Use in Rural-Urban Ethiopia. PhD Thesis, Wageningen University, The Netherlands. http://library.wur.nl/WebQuery/wurpubs/fulltext/31629

ANNEXES

Annex 1. Costs and calorific values (energy contents) of various fuels

Fuel type	Unit	Energy content (MJ/unit)	Average price in ETB	Constants to convert expenditure into gross energy content (MJ)	Fuel efficiency ratio	Constants to convert expenditure into useful energy content (MJ)
Fuel wood	kg	15.07	2.60	5.73	0.10	0.573
Charcoal	kg	29.73	3.17	9.51	0.20	1.902
Dung cake	kg	14.50	none	14.50	0.12	1.740
Sawdust	kg	16.75	5.00	3.35	0.16	0.536
Kerosene	Lt	33.62	15.00	2.35	0.50	1.175
Biogas	Cu m	22.80	none	22.80	0.55	11.400
Electricity	kWh	3.60	0.39	9.22	0.75	6.915

Source: UNDP, 2017; MoWE, 2011.

Annex 2. Varying rates of payment for electricity consumed

Slabs of electricity consumed (kwh)	0–50	51–100	101–200	201–300	301–400	401–500	501–above
Range of payment (in Birr)	0–13.50	13.51–36.00	36.01–100	100.01–165	165.01–280.00	280.01–295.00	295.01–above
Rate of payment (Birr/kwh)	0.2730	0.3564	0.4993	0.5500	0.5666	0.5880	0.6943

Source: Ethiopan Electric Utility, Arba-Minch Branch, 2014.

RÉSUMÉ

The energy–poverty nexus: Vulnerability of the urban and peri-urban households to energy poverty in Arba-Minch town, Southern Ethiopia

The study was conducted in Southern Ethiopia with the objective of investigating the linkages between domestic energy consumption and income poverty among households residing both in and surrounding parts of Arba-Minch town. The finding of the study indicated households do not simply substitute one fuel for another as household income increases. Regardless of their economic status, the majority of households depended on wood fuels as their primary source of cooking energy. The study reveals that commercial cooking fuels become increasingly expensive. It is becoming difficult to obtain affordable energy technologies that convert energy to useful services. A significant portion of urban and peri-urban households continue to suffer as their incomes have not kept pace with the rising prices. Therefore, for the majority of households, meeting the energy requirement in a sustainable manner continues to be a major challenge. Increasing end-use efficiency should be given greater emphasis as an important prerequisite by employing proper end-use technologies to change households' cooking practices so that household energy-related problems tackled and energy can lead to more equitable sustainable livelihoods.

Ahmed Mustefa Ali
Department of Geography and Environmental Studies
Mizan-Tepi University
Ethiopia
E-mail: kahhaa@yahoo.com
Tel.: +251911964374

Tebarek Lika Megento
Department of Geography and Environmental Studies
Addis Ababa University
Ethiopia
E-mail: tebarek.lika@aau.edu.et
Tel.: +251911166385

ANALYSIS OF SIGNIFICANCE OF ENVIRONMENTAL FACTORS IN LANDSLIDE SUSCEPTIBILITY MODELING: CASE STUDY JEMMA DRAINAGE NETWORK, ETHIOPIA

VÍT MACA, JANA SMOLÍKOVÁ

Charles University, Faculty of Science, Department of Physical Geography and Geoecology, Czechia

ABSTRACT

Aim of the paper is to describe methodology for calculating significance of environmental factors in landslide susceptibility modeling and present result of selected one. As a study area part of a Jemma basin in Ethiopian Highland is used. This locality is highly affected by mass movement processes. In the first part all major factors and their influence are described briefly. Majority of the work focuses on research of other methodologies used in susceptibility models and design of own methodology. This method is unlike most of the methods used completely objective, therefore it is not possible to intervene in the results. In article all inputs and outputs of the method are described as well as all stages of calculations. Results are illustrated on specific examples. In study area most important factor for landslide susceptibility is slope, on the other hand least important is land cover. At the end of article landslide susceptibility map is created. Part of the article is discussion of results and possible improvements of the methodology.

Keywords: slope movements, natural hazards, susceptibility analysis, Ethiopian Highland

Received 26 September 2016; Accepted 26 April 2017; Published online 1 June 2017

1. Introduction

Ethiopia like other developing countries depends on domestic agricultural production, struggling with infrastructure and healthcare is also at a low level. Among these factors there is also added impact of catastrophic natural processes. Landslides in this area have caused enormous material damage and also human deaths. Effects of those losses are huge and locals are dealing with them difficulty. Therefore, prevention should be a priority concern.

This paper focuses on analysis of significance of environmental factors in landslide susceptibility modeling. Aim of the paper is to describe methodology for calculating significance of environmental factors in landslide susceptibility modeling and present result of selected one. The main environmental factors in this area are: slope, altitude, lithology, land cover, distance from geological boundary and distance to river. The methodology for landslide susceptibility modelling that was used is also described. Based on this methodology results, the importance of the factors is concluded. Main idea is comparison of the real distribution of slope movements against the expected occurrence across the classes of input layers. Used methodology is universally applicable and the results it generates match reality well. Map of landslides susceptibility based on used methodology is presented.

The knowledge of the landslides spatial distribution and significance of their environmental factors can be a key driver in landslide protection which is the reason for creating susceptibility models. Models are created with aim to identify the places where these phenomena occur most frequently and where the probability of occurrence of this phenomenon is the highest. These models are often created as a result of intersection of environmental factors and triggering factors. These factors have been described in the previous chapter. The process and inputs of these models are divided into several groups. Their results are however always maps of susceptibility. Susceptibility and vulnerability maps usually divide study area into several zones according to the probability of occurrence of the phenomenon.

Soeters, van Westen 1996, van Westen et al. 1997a, van Westen et al. 1997b developed a classification model for evaluating the landslide hazard. Divides them into: inventory, heuristic, statistical and deterministic. Overview of these methods was also done by J. Klimeš (Klimeš 2003; Klimeš 2007).

Beside quantitative methods most dominant are subjective approaches or semi-subjective approaches, where authors set importance of input parameters. Regarding the works in Ethiopian highlands area various approaches and methods were used. At semi-subjective study from Dejen-Gohatsion location performed by Ayele et al. 2014 Weighted Linear Combination (WLC) method were applied. This statistical approach takes reclassified raster (0–255) layers for each parameter and then combine them together to get landslide susceptibility map. They consider seven influencing factors: Groundwater, Geology, Slope, Aspect, Structure, Land Use/Land Cover and Drainage conditions. Weakness of this study is in reclassification step where Ayele is working with assumptions about landslide occurrence, such as: with increasing

https://doi.org/10.14712/23361980.2017.10
Maca, V. – Smolíková, J. (2017): Analysis of significance of environmental factors in landslide susceptibility modeling: Case study Jemma drainage network, Ethiopia
AUC Geographica, 52, No. 1, pp. 129–136

Tab. 1 Pair wise comparison matrix.

Parameters	Geology	Groundwater	Drainage	Slope	Structure	LULC	Aspect
Geology	1						
Groundwater	1	1					
Drainage	5/7	5/7	1				
Slope	5/7	5/7	1	1			
Structure	3/7	3/7	3/5	3/5	1		
LULC	1/7	1/7	1/5	1/3	1/3	1	
Aspect	1/7	1/7	1/5	1/3	1/3	1	1

Source: Ayele et al. 2014, p. 26.

slope number of landslides is increasing, or with increasing distance from river channel number of landslides is decreasing. These assumptions he then apply as reclassification rule. As results they got seven raster layers on scale 0–255, the higher the number the higher the landslide occurrence and vice versa. After the standardization to common scale of each controlling factor, weight is given for each layer based on pair-wise comparison of two data layers at the same time, using pair-wise comparison.

Another weakness is that ratings assigned during the pair-wise comparison are subjective based on the knowledge from the fieldwork. These pairwise comparisons are then analyzed (analytical hierarchy process) to produce a set of weights that sum to one. The larger the weight means the more influencing is the factor. Highest importance was setted to geology and groundwater conditions (both 24%), then slope and drainage (17%). Aspect and Land cover have lowest importance on landslide occurrence (3%). Pair wise analysis for landslide assessment was also performed by Nechyba et al. 2016. In this work, there go beyond standard building of factors matrix (11 input layers) and they add uncertainty parameter.

Dejen-Gohatsion location was also study area in Asfaw (2010). Author is comparing two different approaches to landslide susceptibility. One is van Westen et al. (1997b) methodology, which is described later in results chapter. Briefly it compares expected occurrence of landslide with real occurrence. The higher is the ratio of real to expected occurrence the more favorable conditions for landslide occurrence. Second is pair pair-wise analysis in combination with certainty factor.

Asfaw also pointed out that landslide impact on other factors is often forgotten. For example large landslide significantly changes land cover of the area or hill slope is lowered by landslides. For this reason he didn't use standard layers, but reconstructed layers. In total he used seven input layers for his model, including: altitude, slope, aspect, lithology, landcover, proximity to drainage lines and proximity to road.

The factor proximity to drainage lines shows little impact on landsliding just like in first method. On the other hand proximity to road factor shows a clear indication of the influence of the road in landslide occurrence. Regarding slope class 15°–30° has a CF value of 0.42 (on scale −1;1) whereas slope class 30°–45° has a CF value of 0.78. The higher the value, the more favorable for landsliding. The correlation coefficient between those two methods shows a strong correlation (0.89).

Completely other approaches were used by Maerker et al. 2016 to predict the potential spatial distribution of landslides they used two methods: classification regression tree approach and mechanical statistics method. The first method is based on stochastic gradient boosting (so called boosted regression trees). This method constructs additive regression model which is optimized by least square method in each iteration. The second Maximum Entropy Method (MEM) is based on estimating of distribution function where entropy is maximized. Both methods are fully processed automatically. Model performance parameters show better results for BRT, that outperforms MEM. However MEM still shows good results. Regarding the results both models calculate slope as a most important variable with contribution around 30%.

2. Study area

The study area is located in the central Ethiopian highlands, about 200 kilometers north of the Addis Ababa,

Fig. 1 Location map of the study area.

east of Fiche village (9°43´N 38°54´E). The area is artificially created around the watercourse, left tributary of the Jemma river. It starts at the east where the channel is deeply incised into the valley, the west boundary is a flat area before river confluence with the River Jemma. South border of the area is determined by the watercourse itself. North boundary is defined by highest degree of the structural terrace (slightly extended).

This area has a uniform morphology, which changes beyond borders significantly. Whole area has an elongated shape with an area of about 50 km^2.

Maximum altitude is 2676 m a.s.l., and lowest 1381 m a.s.l. Main soil types in the region are leptosols and vertisols. Vertisols are heavy soils characterized by high content of clay with typical vertisol effect, ability to absorb very high amount of water, but when the soil cracks. As a result of that big cracks and fissures appear where soil erosion fasten up. Leptosols are shallow young soils on solid rocks with high stoniness. In this region mainly litosols can be observed.

Regarding the weather conditions, major influence has altitude (beside geographical location). Temperatures are quite steady during the year without fluctuations. Average temperature is about 20 °C. During winter months northeast wind brings dry continental air, during summer months there flows humid south monsoon. Topography has major influence on precipitation distribution in the region. Lowest precipitations are in the northern part (500–1000 mm/year) and are increasing to the southwest (1800 mm/year). Also distribution over the year is highly irregular, over 80% of the year precipitation amount is concentrated between July and October. Common landcover is low vegetation, grasses, shrubbery in combination with fertile ground. This distribution of landcover is a result of strongly seasonal precipitation and intensive soil erosion.

In study area six geological units can be identified. They are arranged in strips parallel with river at the bottom of the valley. Those strips also match with topography along the region. With increasing distance from the river the altitude is rising. The river bed is composed of alluvial sediments, mesozoic claystone, siltstone and sandstone. With the further away from the river there are layers of sandstone, which at the level of structural terrace ends and merges into belt of lower tertiary basalts. This very narrow strip is covered with tuf sediments intermixed with basalts. This unit occupies a dominant part of the territory. Further from the river higher tertiary basalts cover this unit. This layer forms the edge of another structural terraces.

3. Environmental factors influence for landslide occurrence

For landslide susceptibility studies, the knowledge of environmental factors in study area is crucial. Environmental factors are mostly described as set of selected physiogeographical characteristics of the area. Combination of those factors can cause slope movement even without any additional trigger (rain, earthquake …). Commonly those are the main environmental factors causing slope movements: slope, altitude, lithology, land cover, soil characteristics, vegetation coverage and others. Also people play important role because his acting changes natural characteristics (deforestation, channel changes, terraces building). To evaluate these, remote sensing techniques can be really helpful. But even so, these methods were not widely used in slope movement researches until end of 90s (Mantovani et al. 1996).

Altitude is one of the factors affecting slope stability. Main assumption is that intensity of exogenous processes increases with rising altitude. Exogenous processes disrupt the slope surface which leads to lower stability. As mass movement processes are defined as movement of the material down the slope by gravity (Summerfield 1991, p. 167) then with an increase in the slope the gravitational force acting on the slope material will increase as well as the possibility of slope movement. Clerici et al. (2002) says that slope is commonly regarded as the most important factor in slope stability, this is supported by researches of Woldearegay (2013) or Broothaerts et al. (2012). Land cover is another factor affecting slope stability. In general vegetation coverage via root system

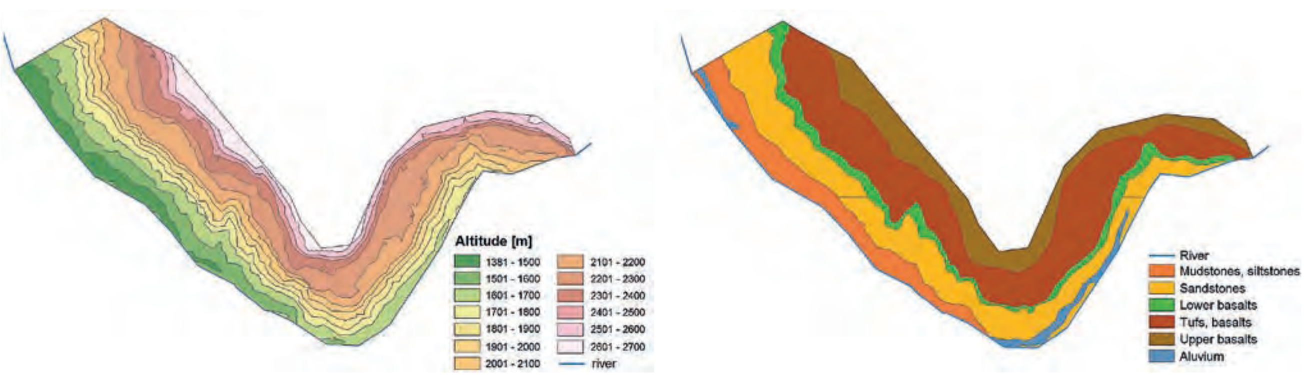

Fig. 2 Geological and topographical map of study area.

has significant stabilization effect on surface. The deeper the root system is the more stable the surface is. Root systems can protect slope from shallow landslides but can not protect from deeply based landslides (Woldearegay 2013). Lithology in meaning of description of the geological substrate plays an important role in slope stability. Rocks differ in properties like hardness, jointing, color,.. Those properties are quantified and called geomorphological resistance. Beside that geology substrate other geology related factors like layers sequence, cracks and faults occurrence or deposition of layers can affect landslide susceptibility. Geological boundary is commonly perceived as zone with lower resistance to exogenous processes, often with occurrence of joints or fractures. Also slope aspect can be considered in some areas. Beside those predisposition factors also triggering factors like precipitation or seismicity are very important for landslide predictability.

4. Data and methods

Input data can be divided into two parts: remote sensing data (DTM) and field research data (landslide layer). Mapping of the landslides was done via Google Earth (ASTER) and supported by fieldwork verification. Main source of the remote sensing data were prepared in Water resource management and environmental protection studies of the Jemma basin for improved food security project (Šíma et al. 2009). Totally was mapped over 200 landslides that were used for setting factors significance. Those landslides are divided into three categories: landslides, topplings and falls and flow movements.

Tab. 2 Class and landslide representation and calculated importance of slope parameter.

Class	Relative class representation	Relative landslide representation	Importance V_{CP}	Rank (Descending)
1	10.27%	0.41%	0.04	3
2	13.53%	0.41%	0.03	2
3	15.49%	1.65%	0.11	4
4	13.10%	6.61%	0.50	5
5	11.54%	9.92%	0.86	6
6	10.79%	13.64%	1.26	7
7	9.15%	16.12%	1.76	8
8	6.75%	17.36%	2.57	9
9	4.01%	12.40%	3.09	10
10	2.60%	8.68%	3.33	11
11	1.63%	6.20%	3.79	12
12	0.73%	3.31%	4.53	13
13	0.27%	2.07%	7.72	14
14	0.13%	1.24%	9.73	14
15	0.02%	0.00%	0.00	1

For getting results from collected data own methodology had to be used. It's not completely new approach, it's based on van Westen's statistical index method (van Westen et al. 1997b). Instead of using polygon data and pixel information, it's transformed to point data layer. Basically main idea is evaluating of significance as ratio of density of slope deformations in the parameter class and density of slope deformations within entire area. If there are more landslides in the parameter class than the class represents within entire area, then this parameter class is favorable for landslide occurrence. For example if there are 50% of the deformations in a class which represents only 30% of the area then it's favorable, if there are 50% of the deformations in a class which represents 70% of the area then it's infavorable.

Using of natural logarithm is optional and causes stretching of the values. With logarithm, results scale is $(-\infty;+\infty)$ with threshold value of 0. Without logarithm it's $<0;+\infty)$ with threshold value of 1.

Formula for class importance, van Westen et al. 1997b:

$$\ln \mathrm{W_i} = \ln\left(\frac{\mathrm{Densclas}}{\mathrm{Densmap}}\right) = \ln\left(\frac{\frac{\mathrm{Npix(Si)}}{\mathrm{Npix(Ni)}}}{\frac{\sum \mathrm{Npix(Si)}}{\sum \mathrm{Npix(Ni)}}}\right)$$

Wi is the weight given to a certain parameter class (e.g. a rock type, or a slope class).

Densclass is the landslide density within the parameter class.

Densmap is the landslide density within entire map.

Npix(Si) is number of pixels, which contain landslides, in a certain parameter class.

Npix(Ni) is total number of pixels in a certain parameter class.

Based on the other landslide susceptibility works from Ethiopian highlands (Ayele et al. 2014; Asfaw 2010; Ayalew, Yamagishi 2004; Ayenew, Bariberi 2005; Zvelebil et al. 2010) main environmental influencing factors were identified: slope, altitude, lithology, land cover, distance from geological boundary and distance to river.

At the beginning all mapped landslides were transformed into point layers and spatial information from underlying datasets were extracted and assigned to them. As a result we had a landslide layer with geology, slope, altitude etc. for each landslide. After this preparation importance of each layer class could be calculated. For determining classes importance was used own method based on Van Westen et al. (1997b) approach.

$$V_{CP} = \left(\frac{R_{CP}}{RA_{CP}}\right)$$

V_{CP} is importance of class C of the parameter P.

R_{CP} is relative distribution of landslides in class C of the parameter P.

RA_{CP} is relative are of the class C of the parameter.

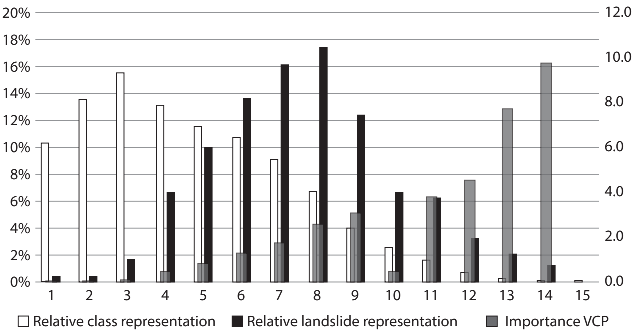

Fig. 3 Class and landslide representation and calculated importance of slope parameter (secondary axis).

Tab. 3 Environmental factors significance.

Parameter	Average importance	Parameters order	Relative factor significance V_{RP}
Lithology	1.04	4	14%
Altitude	1.23	5	16%
Slope	2.81	6	38%
Distance to water course	0.92	3	12%
Land Cover	0.67	1	9%
Distance to geological border	0.79	2	11%

Final class importance is in <0;∞) interval. The lower the values the lower impotance of the class. The higher the values, the higher is the class importance. This formula represents rate of expected occurence of landslides in each class of certain parameter. If the relative occurence of the landslides in a class is higher than relative area of this class (values higher than 1), then this class is favorable for landslide occurence and vice versa. Main advantage of this method is its universality, it can be used in any location with various input data. It's also using an objective approach to evaluate the gathered data without human factor that can affect results accurancy. Also this approach can be completely automatized by writing short script or model that just need landslides dataset and various physiogeographical input data and it will do all the calculations by itself and present the results at the end. Described methodology has some applicable limits, those are described in discussion part.

All those results were unified to a same range of values: 0–255 (using reclassify tool in ArcGis). Importance of each environmental factor was calculated as arithmetic average of all class' significances.

$$V_P = \frac{1}{n}\sum_{P=1}^{n} V_{CP}$$

The predominant influence for landslide occurrence has a slope followed by the altitude and lithology, the smallest is landcover.

5. Results

Main impact on landslide occurrence has a slope. This might be caused by terrain setting in the study area. Area consists of three level of terraces which are separated by terraces levels with very steep slopes (Figure 2). Those parts of the area have highest representation of landslides. Maerker et al. (2016) conducted similar study where same input data were used. In their study two different methods for predicting the potential spatial distribution of landslides were used: classification regression tree approach and mechanical statistics method. Both methods resulted in same results as our study, proposing slope as a major factor for landslide susceptibility.

From calculated results above it's easy to create susceptibility map of landslides for study area. For example LSI – Landslide Susceptibility Index methodology can be used. This approach main idea is to calculate susceptibility for each pixel in the area, to do so we used Weighted Overlay tool. As input significance of parameters (weight) and reclassified data layers based on importance of each class were used. Generated raster had to be reclassified again, so we get map with susceptibility classes. There are many methods for dividing raster into classes, such as the equal interval method, the natural break method etc. In this study, the manual classification method by Galang (2004) was used. This method is based on the assumption that the expected number of landslides in the higher landslide susceptibility class equals two times of the expected number in the next lower susceptibility class. Based on this rule, the raster was reclassified

Tab. 4 Landslide distribution in reclassified susceptibility raster.

Susceptibility class	Area representation	Landslide distribution
1 – Low	40%	6.6%
2 – Middle	27%	13.6%
3 – High	16%	27.3%
4 – Very high	17%	52.5%

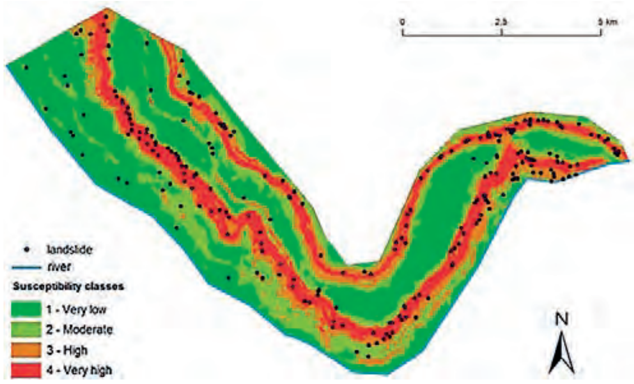

Fig. 4 Landslide susceptibility map with mapped landslides.

to the four classes. As you can see in the map lowest susceptibility class represent almost half of the study area and less than 7% of the landslides are distributed in this class. On the other hand Very high susceptibility class represent only 17% of the area with more than 50% of the landslides are in this class.

6. Discussion

Results of the methodology can be compared to other work from this region (Aeyele et al. 2014). The influence of the distance to the river corresponds with his results. Also results of influence of distance to geological boundary are almost identical 10.3% vs. 11%. Distance to the river has effect of 17%, in my then 12%. This difference can be caused by linear character of input layer. Lineary mapped river represents the streamline and not channel itself which is much wider (sometimes up to 400 m). Regarding differences in other parameters significance, Ayele et al. (2014) calculated considerably lower influence of slope (17%) and higher impact of lithology (24%). Differences can be caused by human factor which is involved in Ayele's methodology where he calculated influences of the classes of each parameter based on his presumptions. For example "with increasing distance from river the number of landslides will decrease". Used methodology is purely statistical, so it avoids these presumptions, which do not have to be true. In case of mentioned distance to river channel Ayele doesn't operate with liner layer problem described above.

Weakspot of used methodology is that landslides were mapped as points which were placed on separation edge. Here we worked with presumption, that most landslides are triggered in upper part. We are aware that this doesn't have to be true, but results characterize distribution well. This has to be considered especially when work is focused in other regions with different physiogeographical characteristics.

As already mentioned, the created model represents the distribution of slope movements well. Since the generated methodology is universal and all calculations are determined by uniform mathematical steps, this methodology is applicable in other areas of the world. As it is a simplification of reality, it is necessary to access the results in such a way. Furthermore, we want to highlight other facts concerning the data that was reflected in my results.

Input data we worked with have different resolution and accuracy, which significantly affects the results accuracy. For example, used digital elevation model with a resolution of 30 meters, from which altitude layer was created, generates the highest slope of 75°. During fieldwork were clearly found places with higher inclinations. This can be due to the method of calculation of slope and the resolution of the incoming digital model which leads to smoothing extreme values.

You can not use data layers with significantly smaller scale than the scale of mapping work. This is case of land cover layer, which has bad resolution. With the low variability of land cover and the similarity of classes it was possible to use this map even with lower resolution. Layers with lower scale would be useless because they do not provide sufficiently accurate information about the distribution.

Probably the most important part was mapping work, during which the landslides were localized. To ensure the quality of this input several times cuts that Google Earth offers has been used. Ability to compare multiple time slices in one view appears to be an advantage, but on the other hand, it is also a disadvantage. Mapping should always be done in the latest data and use the older images as a helper. If it was mapped in older images, the verification of older deformations in the field would be very difficult. Identification of slope movements from satellite images is of course possible and is lately widely used, but the uncertainty is rising if image quality is low. Therefore, this methodology is generally recommended for smaller areas with good image quality. Mapping from satellite images is time consuming and the larger the area and the number of deformations, the more demanding is field verification.

Created methodology is applicable to point marks, but also to the areal elements, where instead of the number of occurrences the relative area will enter into the model. This is one of the possible improvements of this model if they are available background layers in the adequate resolution. Another option for improvement is to run the model on different data sets of landslides (separately for landslides, rock falls and topplings and flow movements). For such extensions greater quantity of the mapped elements would be necessary. For general information, which areas are unsafe for residents, it is sufficient to use a common data file.

The strength of this methodology is the possibility of its complete automation (beside the mapping part). All subsequent procedures can be automated, for example by creating a model in the Model Builder in ArcGIS.

7. Conclusion

The area of this work is located in one of the world's poorest countries, Ethiopia. Residents of Ethiopia are dependent on their own agricultural activities, infrastructure is not developed enough which result is that the trade takes place more on a local scale. To these factors and added impact of catastrophic natural processes are residents exposed on daily basis. One of them are landslides, which in this area have resulted in enormous material damage, but also human death. Impacts of these losses for locals are huge and sometimes even existential. Without knowledge of the susceptibility to these movements, it is impossible to prevent them effectively.

In this study we conducted a statistical analysis using van Westen modified approach to analyse the main driving factors to assess landslides in the Jemma basin in Central Ethiopia. Therefore, we mapped the landslides in a small tributary of the Jemma catchment showing typical characteristics of the entire basin. The mapping of forms and features was performed using GE high resolution images followed by terrain work.

Results in general well corresponds with other works within the region. Totally six input factors were analyzed: altitude, slope, lithology, land cover, distance to river and distance to geological boundary. As parameter with highest influence on landslide occurrence was calculated slope with 38% share followed by altitude and lithology (around 15%). On the other hand land cover had lowest impact (9%). Applied methodology is universal and can be used at other locations across the world. Strengths and weaknesses of the methodology, including the possibility of further improvement are discussed in detail in the discussion.

REFERENCES

ASFAW, Y. E. (2010): Landslide Assessment in Blue Nile Gorge, Central Ethiopia. Masther Thesis, University Gent, 82 p.

AYALEW, L., YAMAGISHI, H. (2004): Slope failures in the Blue Nile basin, as seen from landscape evolution perspective. Geomorphology 136, 1–22. https://doi.org/10.1016/s0169-555x(03)00085-0

AYELE, S., RAGHUVANSHI, T. K., KALA, P. M. (2014): Application of Remote Sensing and GIS for Landslide Disaster Management: A Case from Abay Gorge, Gohatsion–Dejen Section, Ethiopia. In: SINGH, M., SINGH, R., HASSAN, M. (eds.). Landscape Ecology and Water Management. Advances in Geographical and Environmental Sciences. Tokyo, Springer, 15–32. https://doi.org/10.1007/978-4-431-54871-3_2

AYENEW, T., BARBIERI, G. (2005): Inventory of landslides and susceptibility mapping in the Dessie area Northern Ethiopia. Engineering Geology 77, 1–15. https://doi.org/10.1016/j.enggeo.2004.07.002

BROOTHAERTS, N., KISSI, E., POESEN, J., VAN ROMPAEY, A., GETAHUN, K., VAN RANST, E., DIELS, J. (2012): Spatial patterns, causes and consequences of landslides in the Gilgel Gibe catchment, SW Ethiopia. Catena 97, 127–136. https://doi.org/10.1016/j.catena.2012.05.011

CLERICI, A., PERGEO, S., TELLINI, C., VESCOVI, P. (2002): A procedure for landslide susceptibility zonation by the conditional analysis method. Geomorphology 48, 349–364. https://doi.org/10.1016/S0169-555X(02)00079-X

GALANG, J. S. (2004): A comparison of GIS approaches instability zonation in the central Blue Ridge mountainof Virginia. Master Thesis, State University, Blacksburg, 99 p.

KLIMEŠ, J. (2003): Statistické metody tvorby modelů náchylnosti území ke vzniku svahových deformací, Geomorfologický sborník 2 ČAG, ZČU v Plzni, 279–286.

KLIMEŠ, J. (2007): Hodnocení sesuvného ohrožení a metody tvorby map náchylnosti území ke vzniku svahových deformací. Miscellanea Geographica 13, Katedra geografie, ZČU v Plzni, 23–28.

MAERKER, M., HOCHSCHILD, V., VILIMEK, V., MACA, V. (2016): Stochastic assessment of landslides and debris flows in the Jemma basin, Blue Nile, Central Ethiopia, Geografia Fisica e Dinamica Quaternaria, 2016, In print.

MANTOVANI, F., SOETERS, R., VAN WESTEN, C. J. (1996): Remote sensing techniques for landslide studies and hazard zonation in Europe. Geomorphology 15, 213–225. https://doi.org/10.1016/0169-555X(95)00071-C

NECHYBA, M., KROPÁČEK, J., VAŘILOVÁ, Z., KOTVA, P., ZVELEBIL, J. (2016): Combined methods for risk assessment of mass movement and erosion susceptibility in the Ethiopian highlands. AUC Geographica 51(1), 17–28. https://doi.org/10.14712/23361980.2016.2.

SOETERS, R., VAN WESTEN, C. J. (1996): Slope instability recognition analysis and zonation. In: TURNER, K. T., SCHUSTER, R. L. (eds). Landslide: investigation and mitigation. Spec Rep 47. Transportation Research Board, National Research Council, Washington, DC, 129–177.

SUMMERFIELD, M. (1991): Global Geomorphology: an introduction to the study of landforms. Longman Scientific & Technical, 537 p.

ŠÍMA, J., ZVELEBIL, J., KRUPIČKA, J. et al. (2009): Water resources management and environmental protection studies of the Jemma River basin for improved food security. Czech Republic Development Cooperation, Aquatest a.s., Ministry of the Environment of Czech Republic, Prague, 224 p.

VAN WESTEN, C. J. (1997a): Prediction of the occurrence of slope instability phenomena through GIS-based hazard zonation. Geol Rundsch 86, 404–414. https://doi.org/10.1007/s005310050149.

VAN WESTEN, C. J. (1997b): Statistical landslide hazard analysis. ILWIS 2.1 for Windows application guide. ITC Publication, Enschede, 73–84.

VARNES, D. J. (1978): Slope movement types and processes. In: Special Report 176: Landslides: Analysis and Control (Eds: Schuster, R. L., Krizek, R. J.). Transportation and Road Research Board, National Academy of Science, Washington D. C., 11–33.

WOLDEAREGAY, K. (2013): Review of the occurrences and influencing factors of landslides in the highlands of Ethiopia: With implications for infrastructural development. Momona Ethiopian Journal of Science (MEJS) 5(1), 3–31.

ZVELEBIL, J., ŠÍMA, J., VILÍMEK, V. (2010): Geo-risk management for developing countries – vulnerability to mass wasting in the Jemma River Basin, Ethiopia. Landslides 7(1), 99–103. https://doi.org/10.1007/s10346-009-0191-2

RESUMÉ

Analýza významnosti předběžných faktorů v modelování náchylnosti ke svahovým pohybům: Případová studie povodí Jemmy, Etiopie

Článek podrobně popisuje metodiku stanovení významnosti jednotlivých předběžných faktorů v modelování náchylnosti ke svahovým pohybům. Jako zkoumaná oblast byla vybrána lokalita Portugalský most, která je svahovými pohyby významně postižena. V první části jsou v krátkosti popsány jednotlivé vstupní vrstvy a jejich vliv na stabilitu svahu. Většina práce se věnuje rešerši dalších metodik používaných k těmto modelům a návrhu vlastní metodiky. Tato metodika je na rozdíl od většiny používaných metodik čistě objektivní, tedy není do výsledků nijak možno zasahovat. V článku jsou dále popsány všechny vstupy a výstupy metodiky, je představen popis jednotlivých fází výpočtu. Výsledky jsou ilustrovány na konkrétních příkladech. Ve zkoumané oblasti je nejvýznamnějším faktorem sklonitost naopak nejméně významný je vliv land coveru. V samotném závěru jsou tyto výsledky použity pro vytvoření samotné mapy náchylnosti ke svahovým pohybům. Součástí článku je též diskuse dosažených výsledků včetně možných vylepšení.

Vít Maca, Jana Smolíková
Charles University, Faculty of Science
Department of Physical Geography and Geoecology
Albertov 6
128 43 Prague 2
Czechia
E-mail: vitek.maca@gmail.com