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The seasonal rainfall variability and a precipitation sufficiency of Norway spruce (Picea abies (L.) Karst) in Western Tatras and surroundings during the period from 1994 to 2013

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Abstract

In our work we processed monthly precipitation amounts from 28 precipitation-gage stations of SHMU (The Slovak Hydro-meteorological Institute) and from one station of UH SAV (The Institute of Hydrology of The Slovak Academy of Sciences). All of these are located in Western Tatras and close surroundings. We used these data for analysing precipitation sufficiency of Norway spruce during years 1994-2013. Secondly, we compared an average annual precipitation during the last two decades with an average from the period of years 1961-1990. Finally, the extremes were analysed; the driest year 2003 and the most humid year 2010. The results show an evident increase of the rainfall in the research area and also strong rain shadow in Liptov-foothills of Western Tatras.

Key words: Rain shadow, annual precipitation, precipitation sufficiency

Introduction

A regular and barrier-free water cycle in a natural environment is a necessity not only for forest ecosystems but for the global one as well. Water is an integral part of all forest ecosystems and can be found in every one of its components: in the air, trees, bushes, plants, mosses and lichens, in soils and deadwoods. The trees and the plants slow down the fall of rain drops on the soil surface and retain water for a gradual release during a whole year (MINĎÁŠ, KONÔPKA, NOVOTNÝ 2006, Holko et al. 2011). The precipitation is indisputably one of the most important factors determining a landscape character. The basic characteristics of precipitation are the amount, the duration and the intensity of the precipitation (TUŽINSKÝ 2002). Under the term “precipitation sufficiency for a plant” we understand the amount of precipitation necessary for avoiding suffering from a lack of water and the water supplies are high enough for a successful growing of the plant within a specific period of time. We could observe a large-scale decline of spruce stands in Slovakia in recent years. The reasons for this are still not sufficiently clarified. A crucial phase of the spruce stand decline has been influenced by a bark beetle infestation (GRODZKI *et al*. 2006; JAKUŠ *et al*. 2008). The climate change could be one of the possible factors, too. In regard of the expected precipitation deficit increase is Norway spruce considered as one of the most endangered wood species, mainly in an area outside of its native extensions (ŠKVARENINA, STŘELCOVÁ, KAMENSKÝ 1995).

Materials and methods

Characteristic of Western Tatras

Western Tatras cover area of 29 177 ha and are the second highest mountain in Slovakia (KŇAZOVICKÝ 1970). They belong from an geological aspect into the outward arc of Western Carpathians. We distinguish two type of base rock here: the acid extrusive granite and metamorphic bedrocks and the alkaline limestone-dolomite Mesozoic sediments (Sivý vrch, Osobitá, Červené vrchy) (TAJBOŠ 2004). Western Tatras belong to a cold climatic region, and into a moderate cool and cool mountainous subregion (LAPIN et al. 2002).

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Metrological stations

The table 1 below shows list of used meteorological stations and their altitudes. 28 stations are owned by SHMU and one by UH SAV. For our calculation were used stations located not only in Western Tatras; for better interpolation we used also stations from outside of the Western Tatras area. The graphical outputs were prepared in ArcMap 10.1 and a “Nearest Neighbour” method was used for an interpolation between stations.

Tab.1 List of station

Station	Altitude [m a. s. l.]
Červenec	1420
Tatranská Polianka	975
Skalnaté Pleso	1778
Štrbské Pleso	1322
Podbanské	972
Pribylina	753
Liptovský Hrádok	640
Konská	749
Žiar	747
Chopok	2005
Luková pod Chopkom	1661
Demänovská dolina-Jasná	1196
Bobrovec	632
Liptovská Ondrašová	569
Lazisko	680
Huty	808
Kvačany	620
Lúčky	616
Liptovská Teplá	509
Tvrdošín-Medvedzie	625
Vitanová-Oravice	853
Vitanová	690
Liesek	692
Trstená	608
Zuberec-Zverovka	1030
Zuberec	763
Oravský B. Potok	646
Dlhá nad Oravou	530
Oravský Podzámok	532

Precipitation sufficiency for Norway spruce (Picea abies (L.) Karst)

We calculated an average rainfall amount for every year of the recent decades at all stations based on monthly totals during the vegetation period (May-August). All stations are located in a native extension areal of spruce. The amount of 300mm was set up as a minimum for successful spruce growing. This value is acceptable for the most of authors (ŠKVARENINA, STŘELCOVÁ, KAMENSKÝ 1995).

The Results

Precipitation distribution in research area in period 1961-1990

The figures 1 and 2 show precipitation distribution and also precipitation increase in relation to altitude and exposition in the research area. We can see that at an altitude of 1000 m a. s. l. is the difference of annual average in between the SE and NW exposition circa. 300mm. KončEk et al (1974) in an analysis of data from stations in Tatras stated a difference of circa 450 mm at the same altitude.

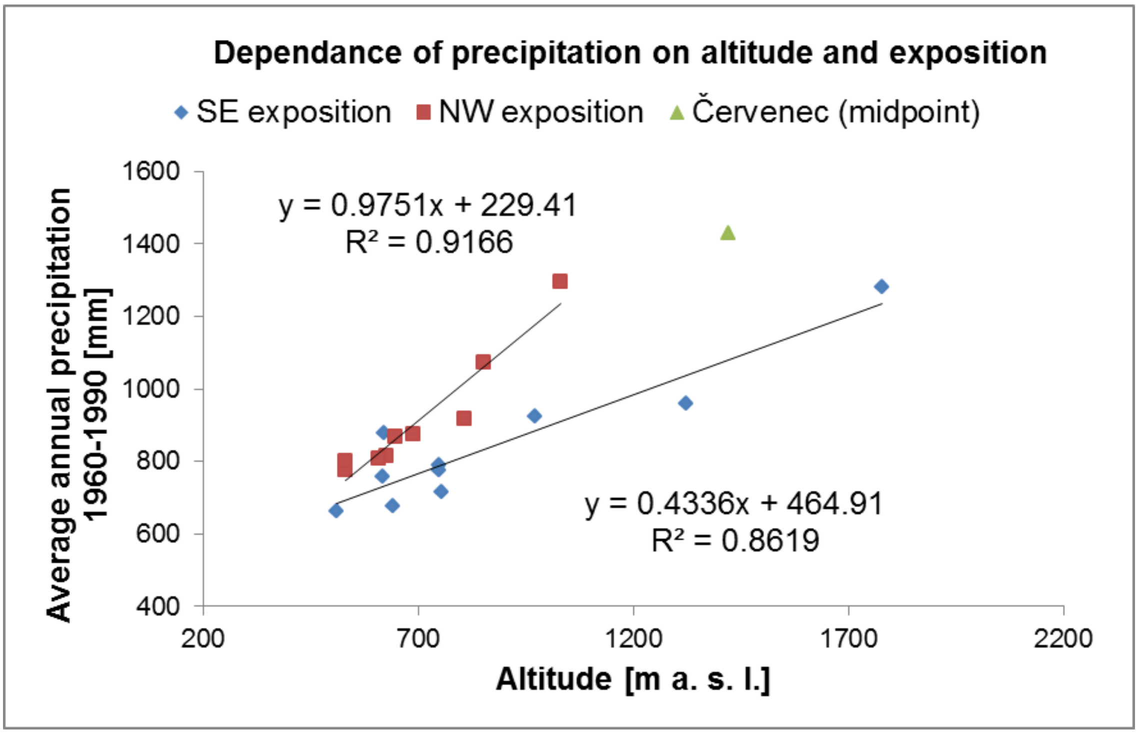

Fig. 1 Average annual precipitation in relation to altitude and exposition

Precipitation sufficiency of Norway spruce (*Picea abies* (L.) Karst.) during the period 1994-2013

Figure 3 shows number of years, when the limit of 300mm of precipitation was not achieved. Although all the stations are located in a native extension areal of spruce, we can see that this limit was not achieved at several of them. The highest number of years with the rainfall amount below the limit was recorded in Pribilina, Liptovský Hrádok, Konská, Bobrovec, and Liptovská Ondrašová. All these stations are located on the leeward side of Western Tatras, with a strong rainfall shadow effect. At other stations, mainly at higher altitude and on a windward side we can see a sufficient level of precipitation for spruce during vegetation period. There are very good conditions for spruce growth in this area. On the other hand, at the stations where the precipitation sufficiency wasn't achieved the growth could have been slowed down or the spruce could have become weaker due to stress.

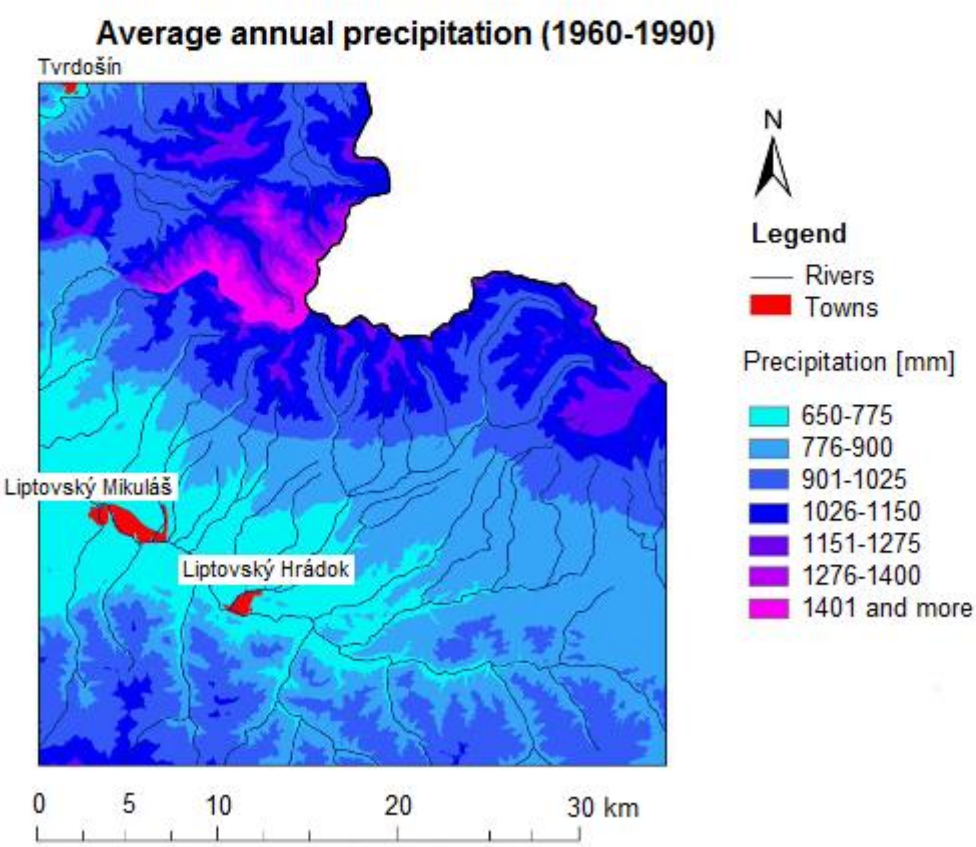

Fig. 2 Precipitation distribution

Changes in average annual precipitation between 1961-1990 and 1994-2013

Figures 4 and 5 show how an average annual precipitation changed in between 1961-1990 and 1994-2013. We can see slightly increased average annual precipitation in years 1994-2013 in compare with a period of years 1961-1990 at all stations. The only exceptions are the rainfall-gauge station Konska with a 6 % decrease and Žiar (without difference). At this point stations Červenec, Tatranská Polianka, Bobrovec, Liptovská Ondrašová, Liesek and Zuberec were disregarded due to a lack of figures from years 1961-1990.

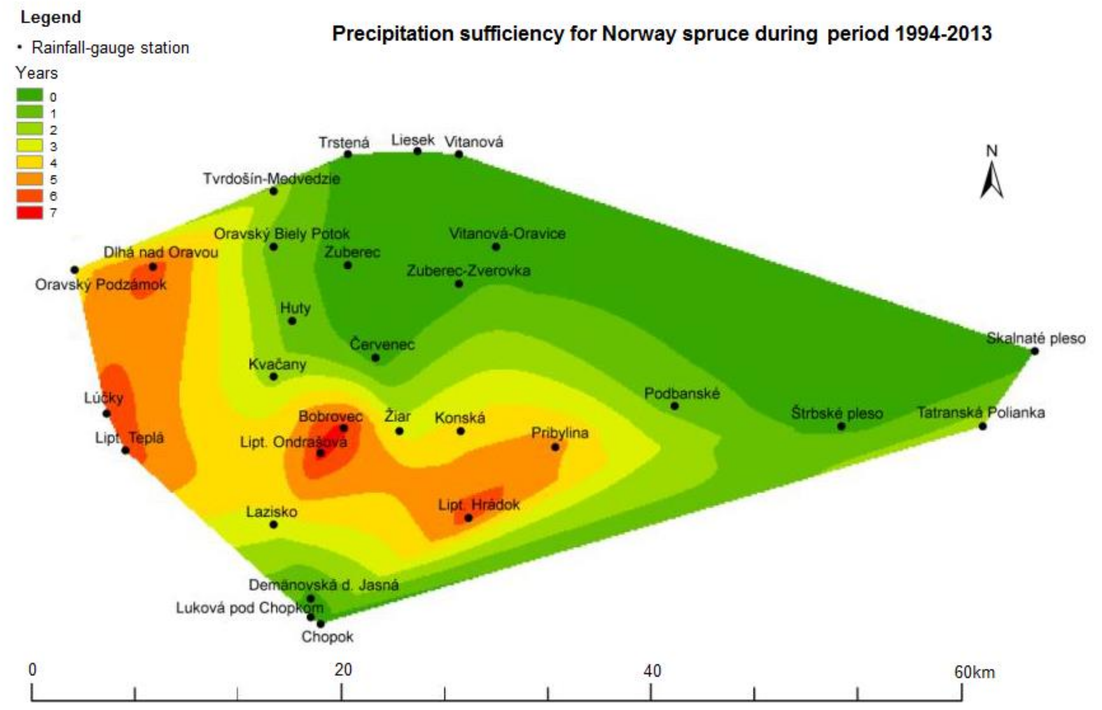

Fig. 3 Number of years, when precipitation sufficiency was not achieved

Extreme years in precipitation during last two decades

In last two decades the driest year was the year 2003 and the most humid one was the year 2010. We used annual precipitation sums from the years (2003 and 2010) and calculated differences in between them and the average annual precipitation in 1961-1990. In the year 2003 (Fig.6) the decrease went up to -40% (Konská -39,2 %) of the average annual precipitation in 1961-1990. In the year 2010 an increase of almost 70% (Luková 68, 4%) of the average was recorded (Fig. 7).

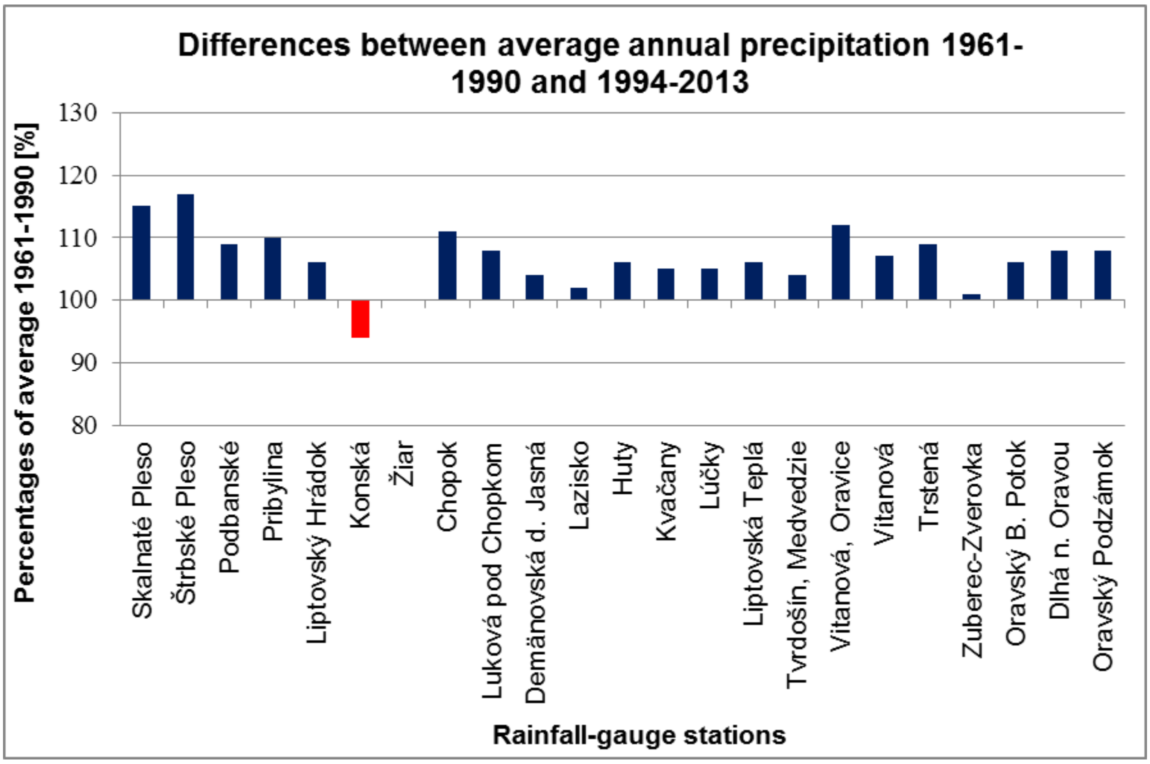

Fig. 4 Comparison of average annual precipitation 1961-1990 with 1994-2003

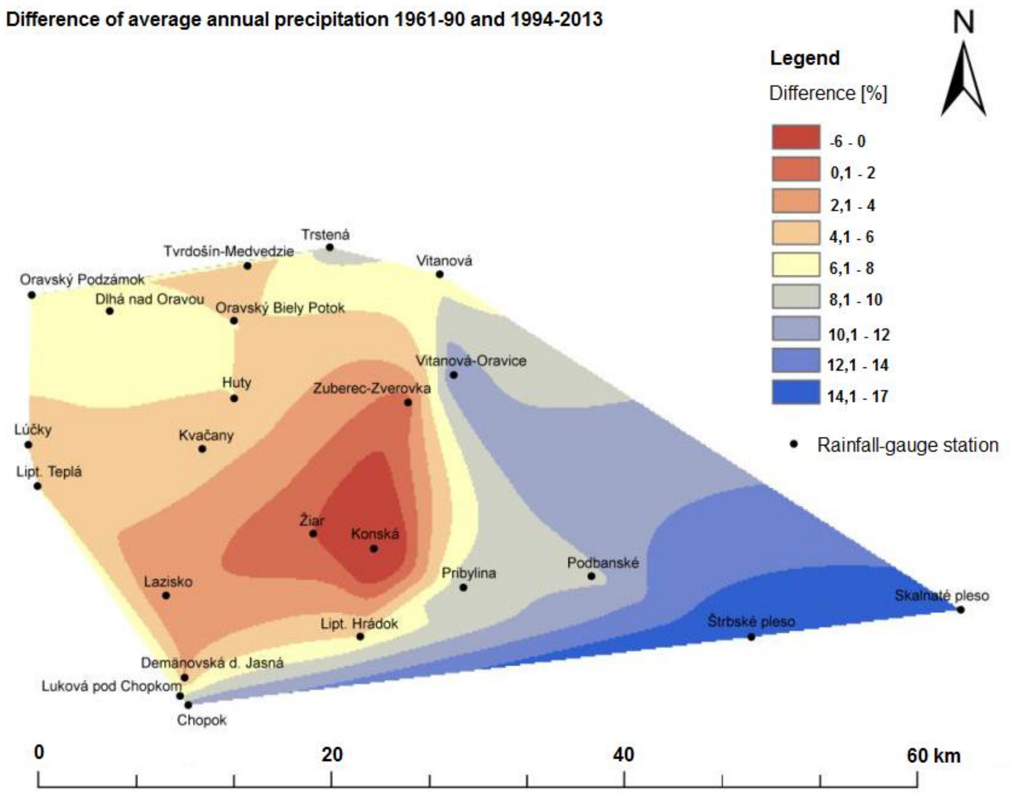

Fig. 5 Graphical result of comparison

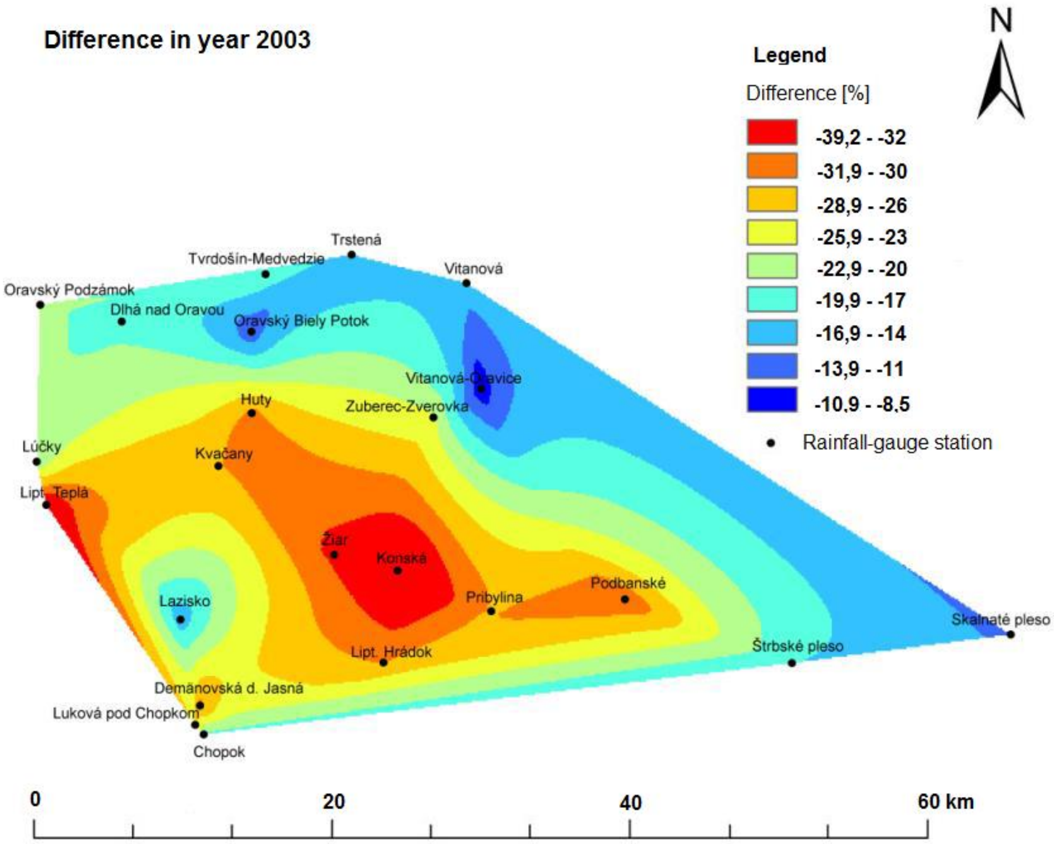

Fig. 6 Comparison of annual precipitation in the driest year 2003 and average annual precipitation 1961-1990

Conclusion

This work was aimed on an evaluation of the annual and seasonal precipitation regime in Western Tatras and the surroundings. Our target was also to analyse what impact this mountain range has on the rainfall distribution on the windward (Orava) and on the leeward (Liptov) side of it. The results can be summarized into the following points:

- The leeward side of Western Tatras is located in a strong rainfall shadow. The average annual precipitation difference at an altitude of 1000 m a. s. l. is about 300mm in compare with the windward side.
- In several years the precipitation sufficiency of Norway spruce was not achieved. The rainfall totals in a vegetation period (May-August) were lower than 300mm; more often at leeward foothills of Western Tatras (Bobrovec,

Liptovská Ondrášová, Liptovský Hrádok, and Pribilina). At several stations the sufficiency was not achieved in 7 year during the last two decades.

- By comparing the average annual precipitation in year 1994-2013 and during 1961-1990 we recorded an increase of precipitation in the research area (in average by 7 %, 63 mm)
- The driest year in the last two decades was the year 2003 when annual precipitation sum was 77% of an average annual precipitation in 1961-1990.
- The most humid year was the year 2010 when annual precipitation was higher by 46% than the average annual precipitation in 1961-1990.

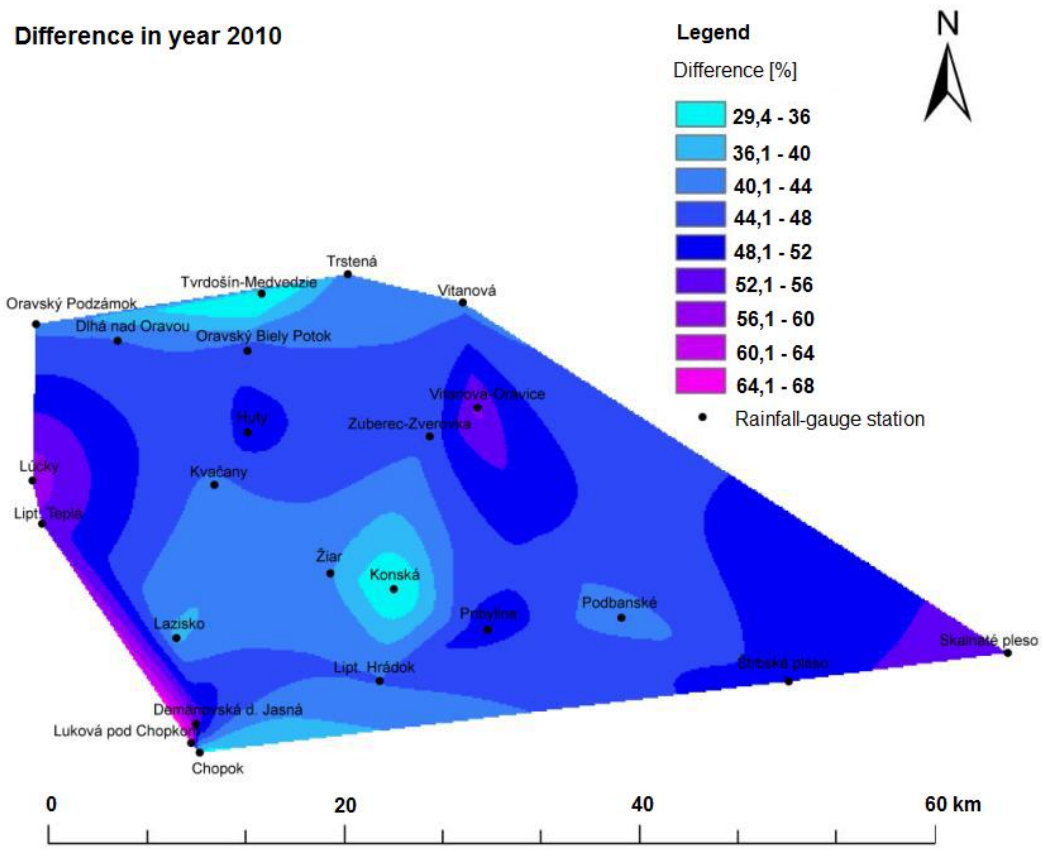

Fig. 7 Comparison of annual precipitation in the most humid year 2010 and average annual precipitation 1961-1990

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Summary

Príspevok sa venujeme problematike rozloženia a medziročnej variability zrážok v Západných Tatrách a ich okolí. Predmetom výskumu bola zhodnotenie zrážkovej zabezpečenosti smreka obyčajného (Picea abies (K.) Karst) počas posledných dvoch dekád. V práci sme taktiež porovnávali dlhodobý normál z rokov 1994-2013 so zrážkovým normálom 1961-1990. Ďalej sme sa zamerali na vizualizáciu a zhodnotenie zrážkovo extrémnych rokov (2003 a 2010) v danej oblasti.

Z výsledkov je zrejmý zrážkový tieň na liptovskom predhorí Západných Tatier, pričom v nadmorskej výške 1000 m n. m. zaznamenávame rozdiel v zrážkovom normály 1961-1990 cca 300 mm. Aj keď všetky sledované stanice (28 staníc SHMU, 1 stanica UH SAV) ležia v areály prirodzeného výskytu smreka, na niektorých nebola naplnená jeho zrážková zabezpečenosť počas 7 rokov z posledných dvoch dekád. Väčšina staníc, kde k tomu dochádzalo, je lokalizovaná na liptovskom predhorí Západných Tatier. Pri zhodnotení množstva zrážok počas obdobia 1994-2013 so zrážkovým normálom 1961-1990 pozorujeme takmer na všetkých staniciach ich nárast. Výnimkou je len stanica Konská (6% pokles) a Žiar (bez zmeny). Priemerne množstvo zrážok za rok sa zvýšilo o 63 mm (7%). Počas najsuchšieho roku posledných dvoch dekád, roku 2003 ročný úhrn na pozorovaných staniciach predstavoval 77% zrážkového normálu. Počas na zrážky najbohatšieho roku 2010 sme zaznamenali 46 % nárast zrážok.

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