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IMPACT OF THE CLIMATE CHANGE ON EVAPOTRANSPIRATION IN THE POIPLIE AREA

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Abstract. This paper is aimed to assess the impact of climate change on water regime of wetland in the area of Poiplie Ramsar site. To simulate the climate change the CGCM3.1 global model (SRES A2 pessimistic scenario and SRES B1 optimistic scenario) and KNMI and MPI regional models were selected as the most appropriate. For the 20-year reference period the years 1977–1996 was chosen, which is within the evaluation compared with the 20-year time horizons 2020, 2050 and 2080. Simulation of soil water regime was carried out using the GLOBAL model. Within the soil water regime evaluation actual evapotranspiration was evaluated in this paper. Actual evapotranspiration has in the future in the studied area also increasing course over the reference period, while the SRES A2 pessimistic scenario expected the increase of 24%, KNMI regional model the increase of 21% and SRES B1 optimistic scenario and MPI regional model the increase of 19%. The development of actual evapotranspiration is derived from the predicted increase in air temperature and precipitation. On the base of these results the ongoing climate change does not cause dramatic changes in Poiplie Ramsar site, thereby this unique wetland ecosystem should be preserved in the future.

Keywords: actual evapotranspiration, climate scenario, wetland, soil water regime, mathematical modelling

INTRODUCTION

The world's population continues to grow constantly. Every year the population increases by at least 80 million people. The UN assumes that the population on Earth in year 2100 will be around 10 billion. The increase of earth's population also determines the

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inhabitants' increase of demands on life (encroachment of villages, towns and demands of the population on drinking water and food). However, we often don't realize that all this is happening at the expense of things important for human existence that we take for granted.

One of them is the devastation and pollution of the surrounding nature. But removing the nature from our surroundings also threatens vital cycles of nature, flora and fauna, which also in these places have their home.

Such parts of nature are precisely wetlands. Their size declined mainly in the 70s and 80s due to the high economic growth, which was important for the creation of large economic exploitation areas (units) and nature protection was last among society's needs. Over time, the society determined the importance of these ecosystems. Through devastation and degradation of wetlands the society found out that the wetlands help to improve the air and water quality, they provide flood protection, are filters that trap pollution from agricultural activities and they fulfil many other functions for the society and the course for nature as such. Therefore, currently the interest in wetlands, their protection, conservation and restoration is increasing.

The climate change, which is currently the most recent and one of the greatest threats of the modern world, also has its share on changes that occur in wetlands. Increasing air temperature, uneven distribution of total precipitation during the year, increasing evapotranspiration and alternation between dry periods without precipitation with periods with intense rainstorms, water regime of wetlands are changing, which in extreme cases can lead to degradation and even to destruction of wetland ecosystems. Therefore, the examination of climatic conditions and water regime of wetlands is justified.

Therefore, the aim of this paper is to evaluate the impact of the climate change on evapotranspiration, as one of the most important components of the soil water balance. Evapotranspiration consists of two components, namely evaporation from the soil surface and transpiration from plant cover.

MATERIALS AND METHODS

The site assessed is a Ramsar site (RS) Poiplie, which represents the last residue of wetland ecosystem in the basin of Ipeľ River. Its importance lies mainly in the occurrence of original and natural streamside vegetation, various types of wetland habitats, floodplain forests, alluvial meadows and pastures. Therefore, this area was on 17 February 1998 officially registered in the list of Wetlands of International Importance especially as a Waterfowl Habitat. RS Poiplie is located on the south of Slovakia in a trans-boundary cross-section as a continuation of extensive wetlands in Hungary, which are part of the Hungarian National Park Duna – Ipoly.

RS Poiplie is located southeast of the Šahy City, in the administrative area of the two cities: Tešmak and Ipeľské Predmostie. The boundary of two districts passes through the site, the district of Levice; Nitra county and the district Veľký Krtíš; Banská Bystrica county [Pásztorová 2013]. The location of RS Poiplie in Slovakia is shown in the Fig. 1.

Geographically, the territory of RS Poiplie is from the north bounded by the southern peninsula of Krupinská planina, from the east by Cerová vrchovina, from the south by

Hungarian Börzsöny Mountains and from west by Podunajská pahorkatina. The altitude ranges between 124 m and 132 m a.s.l., hence the area is typically flat with the relief of lowland river floodplain, which is shaped through terrain depressions, with an average slope of the terrain around 1°. The total area of RS Poiplie is 410.87 hectares [Pásztorová and Skalová 2012].

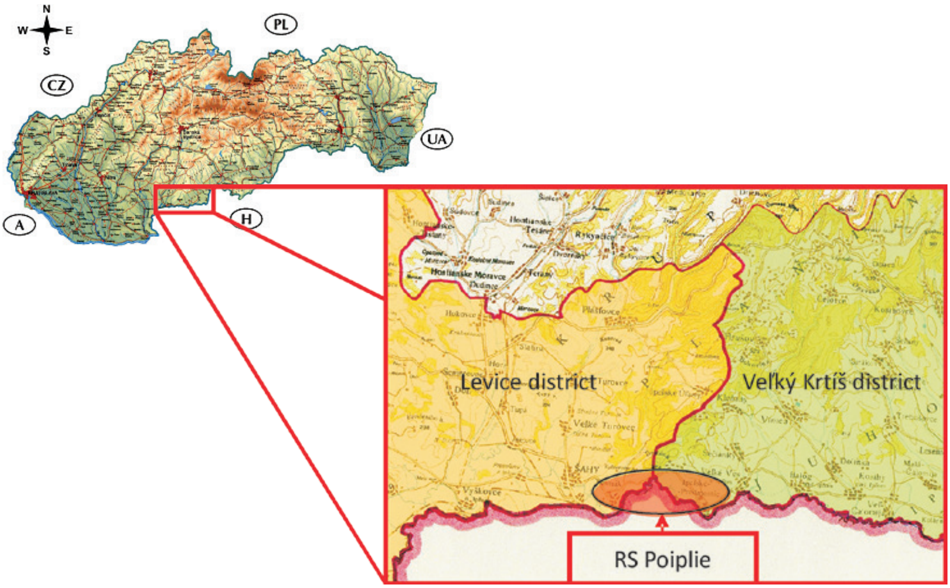

Fig. 1. Localization of the Ramsar Site Poiplie in Slovakia

According to the Landscape Atlas of the Slovak Republic [Kolektív autorov 2002] the Krupinská planina intervenes into the area from the S-NW direction and the whole eastern part is covered by Juhoslovenská kotlina. Therefore the RS Poiplie in geomorphological terms belong to the Alpine-Himalayan system, subsystem Carpathians and Western Carpathians province.

Impact of the climate change on evapotranspiration

To evaluate the impact of the climate change on evapotranspiration in the Poiplie area a modification of meteorological elements using climate models and scenarios is required. Three models were chosen as most suitable – Canadian CGCM3.1 global model, the regional German MPI model and the regional Dutch KNMI model. All models have a daily output value of more elements since the year 1951 (1950) until 2100. After selecting a suitable climate models the emission scenarios were chosen according to the studies and recommendations of the Intergovernmental Panel on Climate Change (IPCC). For the global CGCM3.1 Canadian model was the pessimistic emission scenario SRES A2 and the SRES B1 optimistic scenario the most suitable for our area. The regional German MPI model and the Dutch KNMI model used the medium pessimistic SRES A1B emission scenario. On the basis of these climate scenarios the meteorological characteristics until the year 2100 from meteorological station of the Slovak hydrometeorological Institute (SHMI) Dudince have been modified.

The 20-year period from 1977 to 1996 was chosen as the reference period. In order to compare the modified meteorological characteristics of the reference period were time periods of the same duration 2011–2030 (time horizon 2020), 2041–2060 (time horizon 2050) and 2071–2090 (time horizon 2080) selected.

For the modelling of water regime the model GLOBAL [Majerčák and Novák 1994] is most commonly used. It is an one-dimensional variable saturated flow model including root water uptake, evapotranspiration structure, corn yield, interception of precipitations. It is a mathematical simulation model which is used as a tool for diagnosis and prognosis of water regime of the soil profile with plant cover. Hydrophysical soil characteristics, meteorological data, vegetation parameters, the lower boundary condition (ground water level) and initial condition belong to the main input data. One of its standard outputs is the actual evapotranspiration in daily step. Daily values of the average monthly and annual evapotranspiration values for the reference period of 1977–1996 and for the time horizons 2020, 2050 and 2080 according to the climate scenarios SRES A2 and SRES B1 and the regional models KNMI and MPI were for better estimation converted.

RESULTS AND DISCUSSION

Average monthly and annual totals of actual evapotranspiration during the reference period of 1977–1996 and also time horizons of 2020, 2050 and 2080 according to the pessimistic scenario SRES A2 are shown in the Tab. 1, which is supplemented by the difference between the reference period and time horizons.

The courses of the average monthly actual evapotranspiration according to the climate scenario SRES A2 for time horizons 2020, 2050 and 2080 are shown in the Fig. 2 compared with the course during the reference period. From the Fig. 2, it is apparent that during all time horizons, the average monthly actual evapotranspiration was higher than during the reference period. The largest increase in the actual evapotranspiration compared to the reference period occurs in January (5 mm) and December (4 mm) over the time horizon of 2020 and in December (4 mm) for time horizons 2050 and 2080. On the contrary, the lowest increase in actual evapotranspiration compared to the reference period occurs in June during horizons 2020 (6 mm – 9%), 2050 (8 mm – 12%) and in May during time horizon 2080 (10 mm – 16%).

The courses of the actual evapotranspiration according to the climate scenario SRES A2 for time horizons 2020, 2050 and 2080 are shown and compared with the course of the reference period in the Fig. 3. The picture shows that during the different time horizons are the annual totals of actual evapotranspiration higher than during the reference period. The exceptions are the years 2024, 2026 and 2056, when there is a decrease of annual actual evapotranspiration compared to the reference period. From the comparison of the calculated averages for each time horizon with the average during the reference period, it is apparent that in the time horizon 2020 there will be an increase of the average annual actual evapotranspiration by 74 mm (19%), in the time horizon 2050 by 77 mm (20%) and in time horizon 2080 by 93 mm (24%). This means that in the future a gradual increase in actual evapotranspiration is expected. This fact is confirmed by the Fig. 4, which shows the course of the average daily cumulative actual evapotranspiration for the reference period and the different time horizons. The gradual increase of the actual evapotranspiration in the future depends on the forecasted increase of the air temperature and the precipitation.

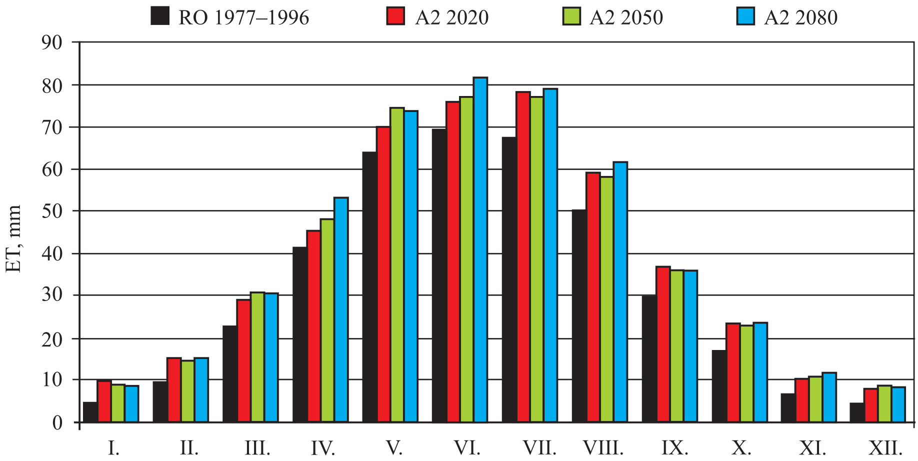

Fig. 2. Course of the average monthly totals of actual evapotranspiration for the reference period of 1977–1996 and time horizons 2020, 2050 and 2080 according to the SRES A2 scenario

Table 1. Average monthly and annual totals of actual evapotranspiration according to the SRES A2 scenario and the differences compared to the reference period (RP)

Month	RP	A2 2020			A2 2050			A2 2080		
	mm	mm	Difference A2-RP mm	Difference A2-RP %	mm	Difference A2-RP mm	Difference A2-RP %	mm	Difference A2-RP mm	Difference A2-RP %
I	5	10	5	100	8	3	60	8	3	60
II	9	15	6	67	14	5	56	15	6	67
III	22	29	7	32	30	8	36	30	8	36
IV	41	45	4	10	48	7	17	53	12	29
V	63	69	6	10	74	11	17	73	10	16
VI	69	75	6	9	77	8	12	81	12	17
VII	67	78	11	16	76	9	13	78	11	16
VIII	50	59	9	18	58	8	16	61	11	22
IX	29	36	7	24	35	6	21	35	6	21
X	17	23	6	35	22	5	29	23	6	35
XI	7	10	3	43	10	3	43	11	4	57
XII	4	8	4	100	8	4	100	8	4	100
Σ per year	383	457	74	19	460	77	20	476	93	24

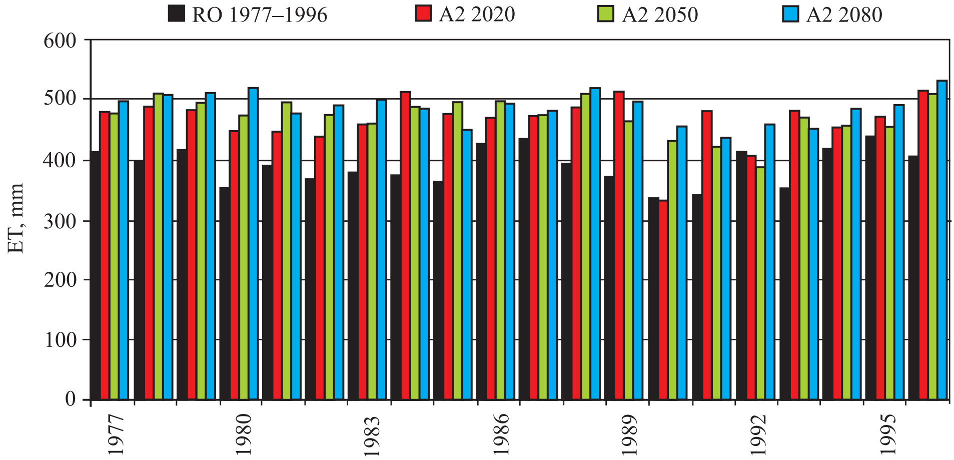

Fig. 3. Course of the average annual totals of actual evapotranspiration for the reference period of 1977–1996 and time horizons 2020, 2050 and 2080 according to the SRES A2 scenario

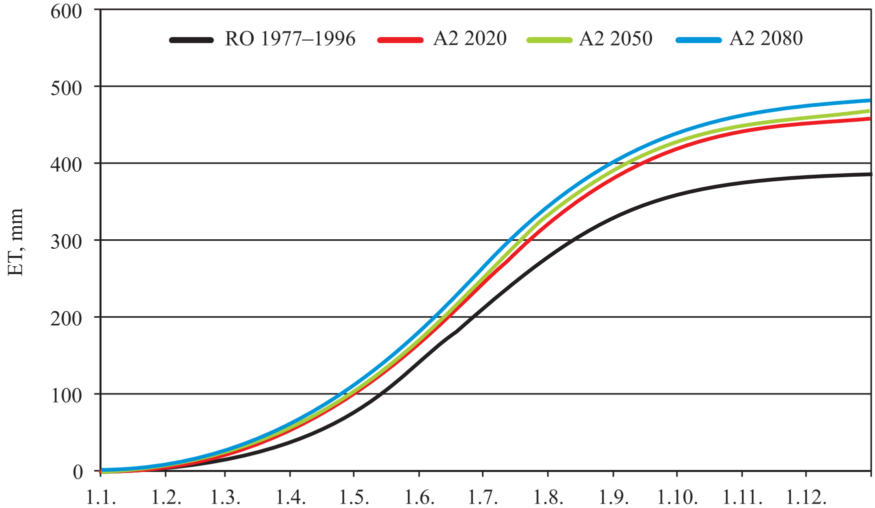

Fig. 4. Course of the average daily totals of cumulative actual evapotranspiration for the reference period of 1977–1996 and time horizons 2020, 2050 and 2080 according to the SRES A2 scenario

Average monthly and annual totals of actual evapotranspiration during the reference period of 1977–1996 and time horizon 2020, 2050 and 2080 according to the optimistic scenario SRES B1 are shown in the Tab. 2, which is supplemented also by the differences between the reference period and time horizons.

The largest increase in the actual evapotranspiration compared to the reference period is expected in December (4 mm) during time horizons 2020 and 2080 and 3 mm during the time horizon of 2050. On the contrary, the lowest increase in the actual evapotranspiration compared to the reference period occurs in May 2020 during the time horizons 2020 (4 mm – 6%), 2050 (7 mm – 11%) and in June during the time horizon 2080 (7 mm – 10%).

The courses of the annual actual evapotranspiration according to the climate scenario SRES B1 for time horizons 2020, 2050 and 2080 are similar as according to the climate scenario SRES A2, so an increase in actual evapotranspiration is assumed. When comparing the calculated averages for each time horizon with the average during the reference period, it can be said that the time horizon 2020, a rise in the average annual actual evapotranspiration by 64 mm (17%) is expected, in the time horizon 2050 by 77 mm (20%) and in time horizon 2080 by 71 mm (19%).

Table 2. Average monthly and annual totals of actual evapotranspiration according to the SRES B1 scenario and the differences compared to the reference period (RP)

Month	RP	B1 2020			B1 2050			B1 2080		
	mm	mm	Difference B1-RP mm	Difference B1-RP %	mm	Difference B1-RP mm	Difference B1-RP %	[mm]	Difference B1-RP mm	Difference B1-RP %
I	5	9	4	80	8	3	60	8	3	60
II	9	15	6	67	15	6	67	14	5	56
III	22	27	5	23	27	5	23	27	5	23
IV	41	45	4	10	48	7	17	47	6	15
V	63	67	4	6	70	7	11	70	7	11
VI	69	74	5	7	77	8	12	76	7	10
VII	67	76	9	13	78	11	16	78	11	16
VIII	50	58	8	16	60	10	20	59	9	18
IX	29	36	7	24	37	8	28	35	6	21
X	17	22	5	29	23	6	35	22	5	29
XI	7	10	3	43	10	3	43	10	3	43
XII	4	8	4	100	7	3	75	8	4	100
Σ per year	383	447	64	17	460	77	20	454	71	19

The average monthly and annual totals of actual evapotranspiration during the reference period of 1977–1996 and time horizon 2020, 2050 and 2080 according to the KNMI regional model are shown in Tab. 3, which is supplemented by a difference between the reference period and time horizons. The largest increase in the actual evapotranspiration compared to the reference period is expected in December (4 mm) for all the time horizons. On the contrary, the lowest increase in the actual evapotranspiration compared to the reference period is assumed to be in June for all time horizons 2020 (3 mm – 4%), 2050 (6 mm – 9%) and 2080 (7 mm – 10%).

The courses of the annual actual evapotranspiration according to the KNMI regional model for time horizons 2020, 2050 and 2080 are in the Fig. 5 compared with the course of the reference period. From the picture, it is apparent, that in each year during the time horizons are the annual totals of actual evapotranspiration higher than during the reference period. The exceptions are the years 2056 and 2086, when there is a reduction of the annual total actual evapotranspiration compared to the reference period. When comparing the calculated averages for each time horizon with the average during the reference period, it can be said that during the time horizon 2020 an increase in the average annual actual evapotranspiration is expected by 67 mm (17%), in the time horizon 2050 by 68 mm (18%) and in the time horizon 2080 by 80 mm (21%). This means that in the future a gradual increase in actual evapotranspiration is expected according to the SRES A2 scenario. This fact is confirmed by the Fig. 6, on which are shown the courses of the daily cumulative actual evapotranspiration for the reference period and the different time horizons.

Table 3. Average monthly and annual totals of actual evapotranspiration according to the KNMI model and the differences compared to the reference period

Month	RP	KNMI 2020			KNMI 2050			KNMI 2080		
	mm	mm	Difference KNMI-RP mm	Difference KNMI-RP %	mm	Difference KNMI-RP mm	Difference KNMI-RP %	mm	Difference KNMI-RP mm	Difference KNMI-RP %
I	5	8	3	60	7	2	40	9	4	80
II	9	13	4	44	13	4	44	14	5	56
III	22	27	5	23	26	4	18	28	6	27
IV	41	46	5	12	48	7	17	50	9	22
V	63	71	8	13	73	10	16	73	10	16
VI	69	72	3	4	75	6	9	76	7	10
VII	67	75	8	12	77	10	15	77	10	15
VIII	50	59	9	18	56	6	12	57	7	14
IX	29	39	10	34	37	8	28	38	9	31
X	17	21	4	24	21	4	24	22	5	29
XI	7	11	4	57	10	3	43	11	4	57
XII	4	8	4	100	8	4	100	8	4	100
Σ per year	383	450	67	17	451	68	18	463	80	21

Average monthly and annual totals of actual evapotranspiration during the reference period of 1977–1996 and each time horizon 2020, 2050 and 2080 according to the MPI regional model are shown in Tab. 4, which is supplemented by a difference between the reference period and time horizons. The largest increase in the actual evapotranspiration compared to the reference period is expected in December for all the time horizons: in the time horizons 2020 and 2080 by 4 mm and in the time horizon 2050 by 5 mm. On the contrary, the lowest increase in the actual evapotranspiration compared to the reference period is expected in June during the time horizon 2020 (4 mm – 6%), 2050 (5 mm – 7%) and 2080 (7 mm – 10%), while in the time horizon 2080 the lowest increase can be also observed in May (6 mm – 10%).

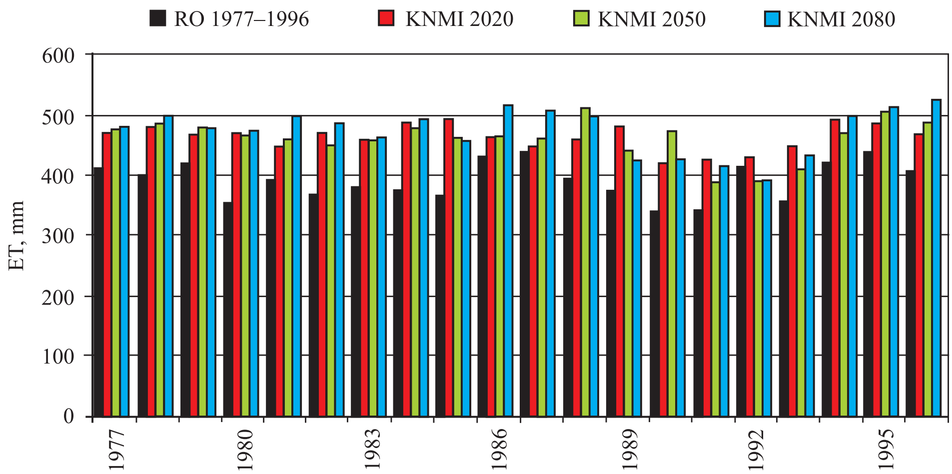

Fig. 5. Course of the average annual totals of actual evapotranspiration for the reference period of 1977–1996 and time horizons 2020, 2050 and 2080 according to the KNMI model

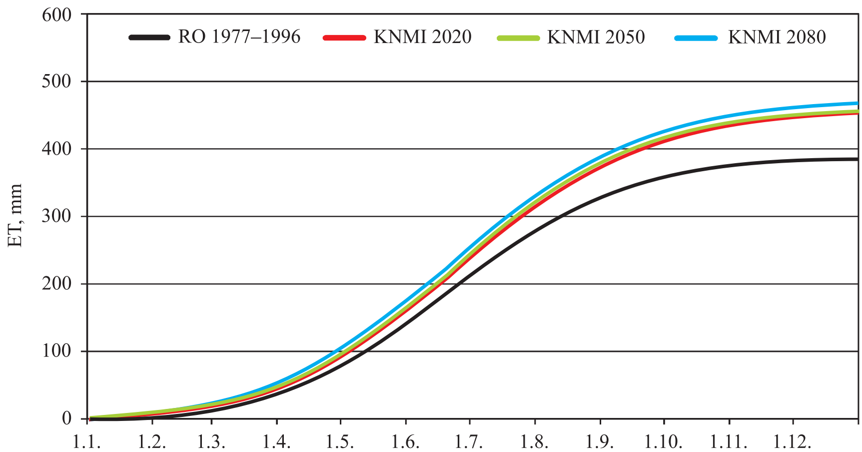

Fig. 6. Course of the average daily totals of cumulative actual evapotranspiration for the reference period of 1977–1996 and time horizons 2020, 2050 and 2080 according to the KNMI model

The courses of the annual actual evapotranspiration according to the MPI regional model for time horizons 2020, 2050 and 2080 are in the Fig. 7 compared with the course of the reference period. This figure shows that in each year during the different time horizon are the annual totals of actual evapotranspiration higher than during the reference period. The exceptions are the years 2056 and 2086, when there is a decrease of the annual total actual evapotranspiration compared to the reference period. When comparing the calculated averages for each time horizon with the average during the reference period, it can be said that in the time horizon 2020 the increase in average annual actual evapotranspiration by 66 mm (17%), in the time horizon 2050 by 55 mm (14%) and in the time horizon 2080 for 74 mm (19%) is expected. This means that in the future the increase in actual evapotranspiration is expected, although the increase was not gradual with the increasing years. This fact is confirmed by the Fig. 8, which shows the course of the average daily cumulative actual evapotranspiration for the reference period and different time horizons. Higher values of average daily cumulative actual evapotranspiration during the time horizon of 2020 compared to the time horizon of 2050 are caused by higher precipitation during the time horizon of 2020 compared with the time horizon of 2050.

Table 4. Average monthly and annual totals of actual evapotranspiration according to the MPI model and the differences compared to the reference period

Month	RP	MPI 2020			MPI 2050			MPI 2080		
	mm	mm	Difference MPI-RP mm	Difference MPI-RP %	mm	Difference MPI-RP mm	Difference MPI-RP %	[mm]	Difference MPI-RP mm	Difference MPI-RP %
I	5	8	3	60	7	2	40	9	4	80
II	9	12	3	33	13	4	44	14	5	56
III	22	26	4	18	25	3	14	28	6	27
IV	41	46	5	12	45	4	10	46	5	12
V	63	69	6	10	70	7	11	69	6	10
VI	69	73	4	6	74	5	7	76	7	10
VII	67	75	8	12	73	6	9	76	9	13
VIII	50	62	12	24	58	8	16	60	10	20
IX	29	38	9	31	33	4	14	38	9	31
X	17	21	4	24	21	4	24	22	5	29
XI	7	11	4	57	10	3	43	11	4	57
XII	4	8	4	100	9	5	125	8	4	100
Σ per year	383	449	66	17	438	55	14	457	74	19

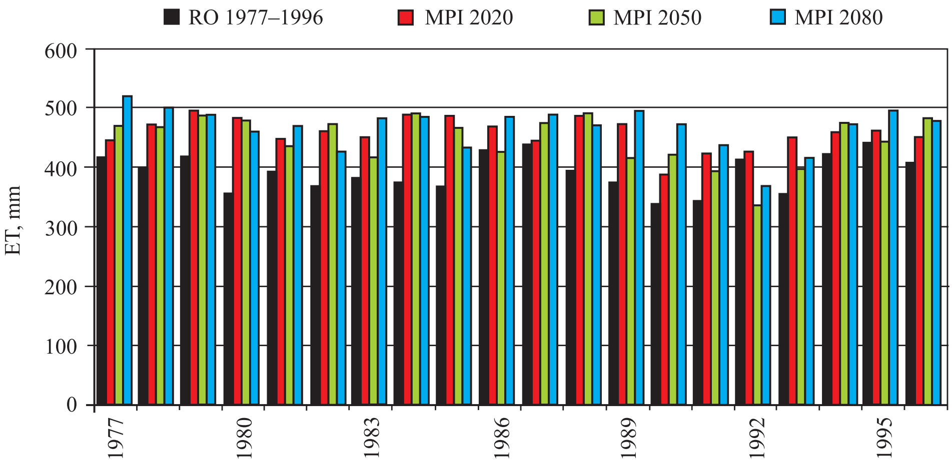

Fig. 7. Course of the average annual totals of actual evapotranspiration for the reference period of 1977–1996 and time horizons 2020, 2050 and 2080 according to the MPI model

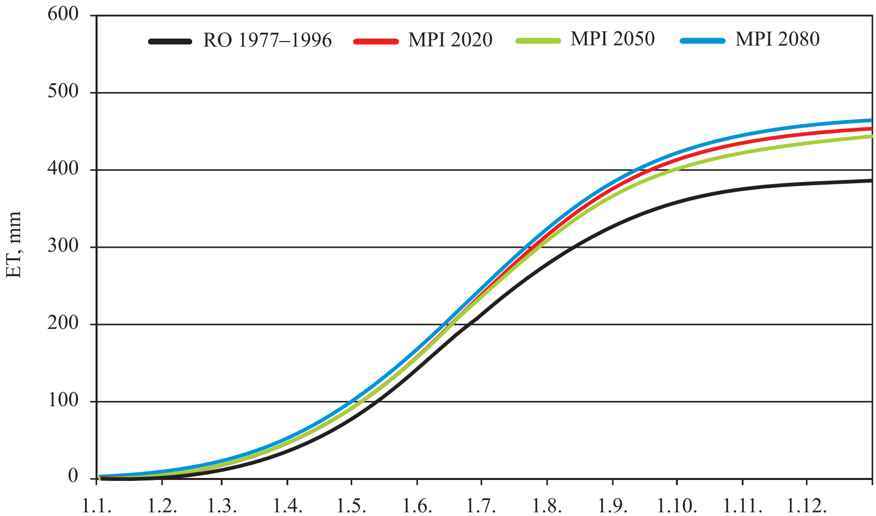

Fig. 8. Course of the average daily totals of cumulative actual evapotranspiration for the reference period of 1977–1996 and time horizons 2020, 2050 and 2080 according to the MPI model

The average annual totals of actual evapotranspiration by the different climate scenarios and models during the selected time horizons 2020, 2050 and 2080 are shown and compared with the average annual actual evapotranspiration during the reference period in the Tab. 5. On the basis of these results, we can conclude that in the future a gradual increase of total actual evapotranspiration is prognosed. The largest increase of evapotranspiration compared to the reference period is expected in the time horizon 2080 compared to the reference period, assumed by the pessimistic scenario SRES A2 (24%). Then the regional model KNMI follow (21%), while the lowest increase in total actual evapotranspiration is assumed by the optimistic scenario SRES B1 and the MPI regional model (about 19%). This development of actual evapotranspiration depends on the prognosis of increase in air temperature and the precipitation.

Table 5. Comparison of average annual totals of actual evapotranspiration [mm] of reference period and the various climate models and scenarios

RP 1977–1996	Time horizons		SRES A2	SRES B1	KNMI	MPI
383 mm	2020	ET, mm	457	447	450	449
		Δ, %	19	17	17	17
	2050	ET, mm	460	460	451	438
		Δ, %	20	20	18	14
	2080	ET, mm	476	454	463	457
		Δ, %	24	19	21	19

RESUME

The values of evapotranspiration in the area of interest should, in the future, show an increase compared to the reference period (the pessimistic scenario SRES A2 expected an increase by 24%, the KNMI regional model by 21% and the optimistic scenario SRES B1 and the MPI regional model by 19%). This increase in actual evapotranspiration is based on the prognosed increase of air temperature and precipitation.

On the basis of these results, the ongoing climate change shouldn't have drastic impacts on the Ramsar site Poiplie, thus this unique wetland ecosystems should be preserved for the future.

REFERENCES

Kolektív autorov (2002). Atlas krajiny Slovenskej republiky. 1. vyd. Ministerstvo životného prostredia SR – Slovenská agentúra životného prostredia, Bratislava – Banská Bystrica, 344 pp.

Majerčák, J., Novák, V. (1994). GLOBAL: One-dimensional variable saturated flow model including root water uptake, evapotranspiration structure, corn yield, interception of precipitations and winter regime calculation. In: Research Report. Institute of Hydrology, Slovak Academy of Sciences, Bratislava, 75 pp.

Pásztorová, M. (2013). Dôsledky klimatickej zmeny na vodný režim mokrade. Edícia vedeckých prác, Zošit č.129. STU, Bratislava, 155 pp.

Pásztorová, M., Skalová J. (2012). Prognóza zrážok a teplôt pre oblasť Poiplia. Acta hydrologica Slovaca, 13(2), 314–323.

Velebný, V. et al. (2000). Vodný režim pôdy. STU, Bratislava, 208 pp.

www.sws.org (10.01.2011).

WPŁYW ZMIANY KLIMATU NA PROCES PAROWANIA TERENOWEGO W OBSZARZE POIPLIE

Streszczenie. Celem pracy było dokonanie oceny wpływu zmian klimatu na reżim wodny terenów podmokłych na obszarze Poiplie Ramsar. W celu symulacji zmiany klimatu użyto modelu globalnego CGCM3.1 (SRES A2 jako scenariusz pesymistyczny i SRES B1 jako wersja optymistyczna) oraz modeli regionalnych KNMI i MPI wybranych jako najbardziej odpowiednie. Jako 20-letni okres referencyjny wybrano lata 1977–1996, który w trakcie ewaluacji był porównywany do 20-letniego okresu z górną granicą lat 2020, 2050 i 2080. Symulacja reżimu wody w glebie była przeprowadzona przy użyciu modelu GLOBAL. W trakcie oceny reżimu wód ziemnych oceniono rzeczywisty proces parowania terenowego. Prognozuje się, że proces ten na badanym terenie wzrośnie w okresie sprawozdawczym; scenariusz pesymistyczny SRES A2 określa oczekiwany wzrost na poziomie 24%, model regionalny KNMI prognozuje wzrost na poziomie 21%, a scenariusz optymistyczny SRES B1 oraz model regionalny MPI – wzrost na poziomie 19%. Rozwój rzeczywistego procesu parowania terenowego wywodzi się z przewidywanego wzrostu temperatury powietrza i opadów atmosferycznych. Na podstawie tych wyników trwające zmiany klimatyczne nie powodują dramatycznych zmian na obszarze Poiplie Ramsar, tym samym ten unikalny ekosystem terenów podmokłych powinien w przyszłości podlegać ochronie.

Słowa kluczowe: rzeczywisty proces parowania terenowego, scenariusz klimatyczny, teren podmokły, reżim wód w glebie, modelowanie matematyczne

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