

Assessment of heat stress and tourism bioclimate potential for the selected Polish cities

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Introduction

Weather and climate are not only important natural resources for tourism and recreation, but may very often be limitations, that make leisure activity outdoors impossible or less satisfying. They shape tourist offer, influence choices of time and peoples' place for vacation, as well as affect the type of during holiday. activities undertaken In recent years urban tourism has gained increased popularity in Poland, therefore in this project we decided to focus on bioclimatic determinants of outdoor activities in the five most popular among tourists and most visited Polish cities: Cracow, frequently Gdansk, Poznan, Warsaw and Wroclaw (Fig. 1).



Fig. 1. Location of the selected cities

The aim of this project is to indicate the most favourable seasons for urban tourism in the selected cities and to determine frequency and seasonal variations of unfavourable

Materials and methods

In all calculations in this project, daily meteorological data from standard synoptic stations of national meteorological service (IMGW) was used. The analysed period was 2003-2012.

To determine seasonal variability and intensity of heat stress in tourists during leisure outdoor activities, the Universal Thermal Climate Index (UTCI) [1] was used. Based on physiological criteria, UTCI values were divided into 10 heat stress categories:

< -40°C	- extreme cold stress	9 to 26	- no thermal stress
-40 to -27	 very strong cold stress 	26 to 32	- moderate heat stress
-27 to -13	 strong cold stress 	32 to 38	 strong heat stress
-13 to 0	- moderate cold stress	38 to 46	- very strong heat stress
0 to 9	- slight cold stress	> 46	- extreme heat stress

The incidence of thermal sensations experienced by tourists in different seasons was determined using Missenard's Effective Temperature (TE) with thermal sensation scale modified by Baranowska [2] (Fig. 2). The scale was developed particularly for Polish climate conditions and included

Both UTCI and TE were calculated for 12:00 UTC, because midday hours are typical for the highest outdoor activity of tourists.

quantify frequency То of unfavourable meteorological factors hindering sightseeing and to identify year periods when satisfaction from staying



at different months in Poland, for regions with mean annual air temperature > 8°C

outside could be limited, the modified Climate-Tourism-Information-**0 to** Scheme (CTIS) [3] was applied. Using biothermal and meteorological weather classification of Błażejczyk [4] and calculating Weather Suitability Index (WSI), calendars of bioclimatic conditions' usefulness for various forms of outdoor recreation (sun bathing, sightseeing and mild recreation, active recreation and outdoor sports) were prepared for the selected cities. seasonal changes of weather perception, resulting from the physiological All biometeorological indices values were calculated using BioKlima v.2.6 adaptation and clothing habits. software package.

meteorological factors hindering sightseeing.

Seasonal variability and intensity of heat stress in men

From October to March, at 12 UTC, cold stress of divers intensity was observed in all cities (Fig. 3). In winter on few days very strong cold stress occurred, while in Cracow even extreme cold stress was once recorded (-40.2°C - 1.12.2010). Such biothermal conditions may cause excessive cooling of human organism, if not well protected by highly insulative clothing, and thus reduce possibilities of staying outdoors. From April (in Gdansk from May) mean UTCI values indicated no thermal stress, although in first and second decades of July in all cities except Gdansk very strong heat stress occurred, when all activity should be reduced to protect organism from heat load.



Incidence of thermal sensations experienced by tourists

In all cities in winter at 12 UTC very cold and cold weather prevailed – from 37.7% in Wroclaw to 50.3% in Warsaw (Fig. 4). Comfortable conditions most frequently occurred in Gdansk (27%), with maximum in the third decade of July (44.5%). In other cities comfortable thermal sensations were most common in late March or in April. For tourists in urban areas very hot meteorological conditions are bothersome, but fortunately in all selected cities they occurred very seldom and only from May to September. The frequency of very hot thermal sensations varied from 0.2% in Gdansk to 1.9% in Cracow. Such weather was observed most frequently in the third decade of May and in July.



Climate-Tourism-Information-Scheme



Gdansk	ī		I	1 II	ı	N	1	v		vi	,	VI		/11	I	IX		x		xı		XII	
cloudy days	Ī				Ì																		
foggy days																							
sultry days																							
rainy days																							
windy days																							





Wroclaw

CTIS presents in 10-day intervals the occurrence probability of weather components important for tourists. To make CTIS more legible we limited its content only to adverse meteorological factors hindering sightseeing and outdoor leisure activities. Criteria for the selection of particular day types are as follow:

cloudy days:	mean daily N > 6/8
foggy days:	mean daily f > 93%
sultry days:	occurrence of e ≥ 18.8 hP
rainy days:	daily precipitation > 5 mm
windy days:	mean daily v > 8 m⋅s⁻¹

Cloudy days are the most commonly observed limitation for tourism in the selected cities (Fig. 5). They occur with a probability higher than 50% in winter. They are most frequent in the second decade of November and the last decade of January (in Warsaw), as well as in the second decade of December (in Poznan and Wroclaw). In the summertime, cloudy days are least probable in Warsaw and most probable in Wroclaw.

In July and August, sultry days may cause some limitation for tourism, exceeding the 50% probability in the third decade of July in Gdansk, Warsaw

Weather suitability for outdoor recreation

Weather Suitability Index (WSI) is a numerical measure which evaluates if a given weather type is pleasant and enables maintenance of thermal balance of human organism or not. Final assesment of weather suitability for different types of tourism activities is defined in particular decades on the basis of WSI average values, where:

< 0.49	unfavourable weather
.50 – 1.19	moderate favourable weather
.20 – 1.99	favourable weather
> 2.00	very fevery able weether

0

≥ 2.00 very favourable weather

In all cities, meteorological conditions in winter are unfavourable for sun bathing, but very favourable for active outdoor recreation (Fig. 6). The most favourable weather for sun bathing is in the first decade of September in Gdansk, as well as in the last decade of April in Poznan and Warsaw. The best conditions for sightseeing and mild recreation are in all cities in the second and third decades of April. Moreover, September and first two decades of October in Gdansk and Warsaw are also very favourable for this kind of activities. In Gdansk and Wroclaw during the whole year the weather is at least favourable for active recreation and outdoor sports.

SB:	Cracow	Gdansk	Poznan	Warsaw	Wroclaw	MR:	Cracow	Gdansk	Poznan	Warsaw	Wroclaw	AR:	Cracow	Gdansk	Poznan	Warsaw	Wroclaw
	0.00	0.00	0.00	0.00	0.00		0.98	0.86	0.92	0.81	0.86		2.23	2.49	2.39	2.34	2.22
I	0.03	0.00	0.00	0.00	0.00	I	1.19	0.92	0.99	0.99	1.00	I	2.34	2.56	2.23	2.43	2.22
	0.00	0.00	0.00	0.00	0.00		1.22	1.14	1.16	1.09	1.25		2.37	2.59	2.47	2.43	2.39
	0.03	0.00	0.03	0.00	0.00		1.25	1.37	1.40	1.23	1.41		2.42	2.64	2.46	2.48	2.62
Ш	0.09	0.00	0.00	0.00	0.00	II	1.13	1.46	1.32	1.25	1.23	II	2.31	2.66	2.52	2.42	2.52
	0.16	0.00	0.07	0.00	0.11		1.57	1.73	1.60	1.63	1.45		2.39	2.71	2.41	2.45	2.47
	0.35	0.06	0.09	0.08	0.15		1.66	1.97	1.79	1.83	1.69		2.42	2.76	2.62	2.66	2.66
III	0.49	0.15	0.47	0.47	0.36	III	1.38	1.77	1.57	1.69	1.28	III	2.28	2.52	2.42	2.33	2.48
	1.22	0.85	1.26	1.06	1.22		1.90	2.17	2.03	2.08	1.95		2.14	2.58	2.19	2.34	2.36
	1.38	0.95	1.17	1.17	1.14		2.03	1.89	1.96	1.97	1.81		2.37	2.46	2.34	2.43	2.37
IV	1.61	1.48	1.72	1.66	1.49	IV	2.16	2.32	2.25	2.29	2.04	IV	2.13	2.51	2.39	2.23	2.27
	1.75	1.79	2.15	2.03	1.65		2.14	2.38	2.32	2.26	2.21		1.99	2.14	2.23	2.19	2.27
	1.43	1.51	1.48	1.69	1.25		1.66	2.04	1.83	1.97	1.89		1.54	1.92	2.11	2.02	2.07
V	1.53	1.68	1.34	1.54	1.01	V	1.83	2.06	1.72	1.90	1.68	V	1.70	2.04	2.02	1.81	1.88
	1.32	1.79	1.67	1.52	1.08		1.37	2.06	1.87	1.60	1.60		1.37	1.78	1.81	1.64	1.91
	0.99	1.82	1.39	1.66	0.84		1.25	1.93	1.59	1.64	1.38		1.33	1.63	1.67	1.61	1.54
VI	1.08	1.73	1.25	1.57	1.26	VI	1.33	2.00	1.69	1.74	1.82	VI	1.31	1.72	1.85	1.50	1.70
	1.19	1.65	1.41	1.51	1.14		1.45	1.87	1.68	1.60	1.73		1.44	1.68	1.79	1.59	1.75
	0.98	1.68	1.15	1.49	0.93		1.14	1.75	1.33	1.44	1.33		0.97	1.30	1.23	1.17	1.27
VII	0.86	1.30	1.21	1.22	0.80	VII	1.05	1.62	1.37	1.34	1.40	VII	0.97	1.53	1.18	1.18	1.36
	0.80	1.53	1.06	1.25	0.89		1.03	1.71	1.33	1.27	1.33		1.02	1.40	1.25	1.06	1.34
	1.15	1.63	1.28	1.46	0.95		1.36	1.71	1.35	1.56	1.37		1.32	1.50	1.14	1.20	1.31
VIII	1.09	1.68	1.42	1.30	1.11	VIII	1.18	2.04	1.55	1.42	1.57	VIII	1.12	1.84	1.35	1.36	1.45
	1.21	1.66	1.65	1.82	1.05		1.43	1.87	1.88	1.78	1.65		1.30	1.68	1.83	1.58	1.66
	1.44	2.02	1.77	1.93	1.26		1.55	2.22	1.96	2.21	1.79		1.49	1.87	1.76	1.88	1.89
IX	1.47	1.85	1.62	1.87	1.33	IX	1.88	2.23	1.97	2.14	1.95	IX	1.99	2.13	2.21	2.03	2.16
	1.76	1.94	1.73	1.89	1.43		1.89	2.24	2.02	2.11	1.92		1.61	2.27	2.08	2.07	2.16
	1.28	1.53	1.30	1.57	0.93		1.82	2.09	1.96	2.05	1.61		2.08	2.27	2.37	2.37	2.21
Х	1.13	1.02	1.13	1.00	1.11	Х	1.80	2.16	2.03	2.13	1.99	Х	2.35	2.38	2.41	2.43	2.55
	1.10	0.28	0.65	0.67	0.65		2.01	1.80	1.88	1.89	1.72		2.38	2.51	2.58	2.65	2.60
Na	0.68	0.09	0.47	0.37	0.54	N/I	1.63	1.49	1.58	1.47	1.45		2.36	2.48	2.45	2.32	2.38
XI	0.32	0.00	0.10	0.15	0.24	XI	1.55	1.26	1.33	1.34	1.50	XI	2.33	2.26	2.48	2.44	2.50
	0.10	0.00	0.00	0.00	0.12		1.35	0.81	1.26	1.17	1.32		2.46	2.43	2.55	2.49	2.58
170	0.06	0.00	0.00	0.00	0.03	201	1.27	0.90	0.99	0.90	1.22	2/11	2.52	2.53	2.37	2.44	2.50
XII	0.00	0.00	0.00	0.00	0.00	XII	1.00	0.89	0.81	0.82	0.94	XII	2.44	2.51	2.38	2.48	2.52
0.00 0.00 0.00 0.00 0.00 1.21 0.90 0.83 0.78 0.90 2.43 2.50 2.41 2.44 2.47													2.47				
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	unfavourable moderate fav										favo	urable		verv fav	<i>i</i> ourable		
							mode										



10 20 30 40 50 60 70 80 90 100%



Fig. 5. Modified Climate-Tourism-Information-Scheme (CTIS) for the selected Polish cities in consecutive decades of the year, 2003-2012

and Cracow.

Foggy days occur mainly in winter, with the highest probability in Poznan (over 40% from November to January), while rainy days that limit outdoor activities (> 5 mm), are observed seldom in selected cities – mainly from May the to early September (with maximum of 20% probability). Windy days are registered only in Gdansk, with less than 20% probability.

Conclusions

The main limitations for outdoor leisure activities in Polish cities are associated with biothermal conditions. In winter, frequently occurring cold stress, can be particularly disturbing to non-acclimatized tourists from warmer countries.

Thermal sensations associated with very cold and cold meteorological conditions occur often in winter at 12 UTC, with maximum in the first decade of March in Gdansk and the second decade of February in Warsaw.

In the selected urban areas very hot meteorological conditions occurred very seldom and only from May to September.

The main limitation for tourism in these cities are cloudy days. They are most probable from November to February.

Weather in the selected cities is most suitable for active recreation and sports. The best time of the year for sightseeing and mild recreation are second and third decades of April.

Fig. 6. 10-day averages of weather suitability indices (WSI) for various forms of recreation in the selected Polish cities: sun bathing (SB), sightseeing and mild recreation (MR), active recreation and sports (AR)

References

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