Application of GIS and human heat balance in bioclimatic mapping (the case of north-eastern Poland)

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1. INTRODUCTION

Local differentiation of climatic conditions is quite frequently undertaken in bioclimatic studies, especially in tourism and recreation, climatotherapy, urban planing etc. Traditional methods give us information dealing with modifications of individual meteorological elements as well as with the specific micrometeorological phenomena caused by local features of geographical environment, e.g. orography, land use etc. That kind of local climatic conditions is called "topoclimates" (Geiger, 1959; Paszyński 1980).

However general topoclimatic classifications have not any direct relations with the human organism. Thus, there are established typologies of local climates related with their evaluation from the point of view of the human organism (thermal sensations, heat load, severity, pleasant-unpleasant) (Błażejczyk 1990, 1996; Menz 1990). That kind of the local climates units is called "biotopoclimates".

Both, topoclimatic and biotopoclimatic mapping is commonly made within the scale category of 1:10,000 - 1:500,000. The most frequently used scales are 1:25,000 - 1:100,000.

The aim of this paper is to present an application of GIS methods in biotopoclimatic mapping - based on man-environment heat exchange - in the scale of 1:300,000 made for the north-eastern Poland.

2. METHOD

2.1. Principles of the human heat balance

Some general topoclimatic methods base on the analysis of value and structure of the heat balance of a ground active surface (Paszyński 1980; Grzybowski 1983, 1986). The similar background have also some biotopoclimatic classifications (Błażejczyk 1990; Kozłowska-Szczęsna et al 1997; Menz 1990). An active surface in bioclimatic considerations is the human body. The general human heat balance equation has the following form:

$$S = M + R + C + L + E + Res, \text{ (in W m}^{-2}\text{)}$$

where: S - net heat storage (i.e. changes of body heat content - heat expenditure or accumulation), M - metabolic heat production, R - absorbed solar radiation, C - heat exchange by convection, L - heat exchange by long-wave radiation, E - heat loss by evaporation, Res - heat loss by respiration.

In bioclimatic studies *M* value is assumed as constant (70 W m^{-2} for standing, 175 W m^{-2} for walking persons). Respiratory heat loss was not considered due to its small values (5-10 W m^{-2}) and inconsiderable differentiation.

Thus for evaluation of local variability of the human heat balance should be considered the intensity and structure of the main heat loss fluxes (*C, L, E*):

$$\frac{C}{C+L+E} + \frac{L}{C+L+E} + \frac{E}{C+L+E} = 1$$

The various effectiveness of convection, evaporation and long-wave radiation in heat elimination from the body lead to different level of net heat storage in man. Predomination of convection can results in negative *S* values. At intensive evaporation the net heat storage fluctuates about zero. The prevailing of long-wave radiation results in positive net heat storage, i.e. in heat accumulation.

The intensity and structure of absorbed solar radiation, i.e. doses of direct (*R*dir), diffuse (*R*dif) and reflected (*R*ref) solar fluxes in total amount of *R* value are also very important indicators of man-environment heat exchange:

$$\frac{R_{dir}}{R} + \frac{R_{dif}}{R} + \frac{R_{ref}}{R} = 1.$$

All those fluxes of the human heat balance are mostly influenced by meteorological conditions and strongly modified by local features of geographical environment. The intensity of several heat fluxes were calculated with the use of man-environment heat exchange model (MENEX) (Błażejczyk 1994). The simplified option of the model was used (Table 1).

Bioclimatic classification of local climates consists of three levels: groups, types and classes of biotopoclimates. Groups of biotopoclimates characterise predominated way of heat loss from the organism (evaporative, convective, radiative or mixed). In every group there are distinguished 4 types of biotopoclimate (reflexive, insolative, diffusive and variable) which are characterised by the intensity and structure of absorbed solar radiation (Table 2). Classes of biotopoclimate refer to the specific - bioclimaticaly active - local features of the atmosphere, i.e.: special, trees' produced aerosols, air temperature inversions, radiative fogs and air pollution. Occurrence of the various combinations of the local features of the atmosphere represents individual classes of biotopoclimate.

Table 1. Simplified equations for the calculation of particular fluxes of man-environment heat exchange (by Błażejczyk 1994, 1998)

Environmental conditions	Equation
forests, early mornings evenings and nights	$C = 2.36\ Ta - 8.24\ v - 66.20$ $L = 0.77\ Ta + 5.63\ v - 43.02$ $E = -0.32\ Ta - 4.1\ v - 5.51$ $S = 3.34\ Ta - 1.48\ v - 51.16$
non forested areas, daylight hours,	$C = 2.39\ Ta - 2.91\ v - 74.18$ $L = 0.95\ Ta + 3.14\ v - 44.61$ $E = -0.87\ Ta - 1.46\ v - 0.87$ $S = 2.76\ Ta - 4.77\ v - 29.78$
Sun altitude < 4°	$R = 0.294\ (1.388 + 0.215\ h)^2$
Sun altitude ≥4° and N = 0-20%	$R = 0.294\ (-100.43 + 73.98 \ln h)$
Sun altitude ≥4° and N = 21-50%	$R = 0.294 \exp(5.383 - 16.072/h)$
Sun altitude ≥4° and N = 51-80%	$R = 0.294 \exp(5.012 - 11.805/h)$
Sun altitude ≥4° and N = 21-80% and lack of direct radiation, Sun altitude ≥4° and N > 80%	$R = 0.26\ h^{1.039}$

h - Sun altitude, *N* - cloudiness

In *evaporative biotopoclimates* heat is eliminated from the body mainly by evaporation (50-80% of total heat loss). Because of high effectiveness of evaporation in temperature regulation the net heat storage is equal to zero. Evaporative biotopoclimates are typical for the areas with relatively high air temperatures and intensive air movement.

In *convective biotopoclimates* heat expenditure by convection predominates (50-80% of total heat loss). Intensive heat elimination from the body can lead to negative values of net heat storage. Convective biotopoclimates are typical for the areas with relatively low air temperature and intensive air movement.

In *radiative biotopoclimates* the fraction of long-wave radiation range from 30 to 60%. Due to small effectiveness of long-wave radiation in temperature regulation there can be observed heat accumulation in the organism. Radiative biotopoclimates are typical for the areas with relatively high air temperatures and small air movement.

In the *mixed biotopoclimates* the intensity of *C, L* and *E* heat fluxes is similar each other or there are observed their frequent temporal and spatial changes.

Reflexive biotopoclimates refer to relatively high fraction of solar radiation reflected from the ground (albedo > 20%). It causes that total *R* amount reaches 110-120 W m^{-2} (in ordinary dressed persons). *Insolative* biotopoclimates is connected with predomination of direct solar radiation (50-70% of *R* which can reach 90-100 W m^{-2}). In *diffusive* biotopoclimates solar radiation diffused by trees, buildings etc. predominates (50-90% of *R*). Absorbed solar radiation can reach 30-60 W m^{-2} only. In *variable* biotopoclimates frequent temporal and spatial changes of solar radiation intensity and structure are observed

Every, individual type of biotopoclimate has its own, specific characteristic of man-environment heat exchange, thermal conditions and physiological response of an organism on atmospheric stimuli (Table 3).

2.2. Construction of biotopoclimatic maps

In local climate studies the most useful method of digital presentation of environmental data is raster analysis. The vector orientated methods are less useful due to the problems with spatial delimitation of the various components of geographical environment; each of them influence in different ways local characteristics of air temperature, solar radiation, wind speed etc. Thus the base of topoclimatic mapping is the network of pixels. The size of pixel should depend on the scale of the used maps, e.g.:

- 50x50 m - for the scale of 1:10,000
- 100x100 m - for the scale of 1:25,000
- 250x250 m - for the scale of 1:50,000
- 500x500 m - for the scale of 1:100,000
- 1000x1000 m - for the scale of 1:200,000
- 3000x3000 m - for the scale of 1:300,000

Table 2. Classification of biotopoclimates based on the structure of the human heat balance (Błażejczyk 1990)

	Groups of biotopoclimates			
Types of biotopoclimate	**Evaporative** (50-80% of heat is loosed by evaporation)	**Convective** (50-80% of heat is loosed by convection)	**Radiative** (30-60% of heat is loosed by radiation)	**Mixed** (frequently changes of the heat loss structure)
Reflexive (*R* reaches 120 W m.$^{-2}$; fraction of reflected radiation is > 20%)	1.1. Evaporative-reflexive biotopoclimate	2.1. Convective-reflexive biotopoclimate	3.1. Radiative-reflexive biotopoclimate	4.1. Mixed-reflexive biotopoclimate
Insolative (*R* reaches 100 W m.$^{-2}$; fraction of direct radiation is 60-80%)	1.2. Evaporative-insolative biotopoclimate	2.2. Convective-insolative biotopoclimate	3..2. Radiative-insolative biotopoclimate	4.2. Mixed-insolative biotopoclimate
Diffusive (*R* reaches 30-60 W m.$^{-2}$; fraction of diffuse radiation is >80%)	1.3. Evaporative-diffusive biotopoclimate	2.3. Convective-diffusive biotopoclimate	3.3. Radiative-diffusive biotopoclimate	4.3. Mixed-diffusive biotopoclimate
Variable (*R* changes from 30 to 120 W m.$^{-2}$; frequent spatial changes of *R* structure)	1.4. Evaporative-variable biotopoclimate	2.4. Convective-variable biotopoclimate	3.4. Radiative-variable biotopoclimate	4.4. Mixed-variable biotopoclimate

Table 3. Thermophysiological characteristics of individual biotopoclimates (by Błażejczyk 1990)

Symbol of biotopo-climate (see Tab. 2)	Physiological reactions of the human organism	Thermal state of an organism	Predominated thermal sensations	Heat load of an organism	Example of an occurrence (over the territory of Poland)
1.1.	Very intensive peripheral blood flow as well as sweat secretion and evaporation. Skin temperature (*Tsk*) considerably higher and blood pressure - lower then the "average" ones *.	sufficient, physiological regulation of the heat balance	from "warm" to "very hot"	slight or average heat stress	dunes, cemented squares, forest glades, sand planes, fresh meadows in wide valleys
1.2.	Intensive peripheral blood flow as well as sweat secretion and evaporation. Skin temperature (*Tsk*) higher and blood pressure lower then average.	like in type 1.1.	from "warm" to "hot"	thermoneutral or slight heat stress	sunny exposed slopes
1.3.	Slight increase of peripheral blood flow. Sweat secretion and its evaporation as well as *Tsk* slightly over the average.	like in type 1.1.	from "neutral" to "warm"	thermoneutral or slight cold stress	dry coniferous forests, settlements inside forests
1.4.	Frequent changes of blood pressure and sweat secretion. *Tsk* lower then average.	like in type 1.1.	from "neutral" to "very hot"	varied, from moderate cold to moderate hot stress	forest parks, villa settlements
2.1.	Blood pressure, blood flow, sweat secretion equal to average. *Tsk* slightly lower then average.	slight reduction of heat loss by more insulating clothing can be necessary	from "cool" to "neutral"	thermoneutral conditions or slight cold stress	beaches, wide sandy areas
2.2.	Blood pressure higher then average. Behavioural increase of metabolic production. *Tsk* lower then average.	more insulating clothing or additional heat gains necessary	from "cold" to "cool"	moderate cold stress	wide fields and another open areas covered by grass
2.3.	Blood pressure considerably higher then average. Behavioural increase of metabolic production.	like in type 2.2.	from "very cold" to "cool"	great and even very great cold stress	not dense forests on the sea or lake shores

2.4.	Frequent changes of blood pressure. Temporary shivering and behavioural increase of metabolism. *Tsk* lower then average.	like in type 2.2.	from "neutral" to "very cold"	varied from slight to great cold stress	forest parks on the sea and lake shores
3.1.	Peripheral blood flow, sweat secretion and *Tsk* considerably higher then average. Great disorders in sweat evaporation.	great hazard of organism overheating, additional air ventilation necessary	from "hot" to "very hot"	great and even very great heat stress	downtown and industrial settlements, fresh meadows in the bottoms of narrow valleys
3.2.	Peripheral blood flow, sweat secretion and *Tsk* slightly higher then average. Slight disorders in sweat evaporation.	small hazard of of organism overheating, additional air ventilation necessary	from "warm" to "hot"	moderate heat stress	village settlements, fields in the bottoms of narrow valleys
3.3.	Peripheral blood flow, sweat secretion and *Tsk* equal to average.	additional air ventilation temporally necessary	from "neutral" to "warm"	thermoneutral conditions	coniferous and mixed forests
3.4.	Slight fluctuations of physiological parameters.	like in type 3.3.	from "neutral" to "hot"	varied from thermoneutral to moderate hot stress	no dense coniferous and mixes forests, suburban settled areas
4.1.	Frequent changes of *Tsk* and another physiological parameters on the level higher then average.	technical regulation of heat gains and losses necessary	from "cool" to "very hot"	varied from thermoneutral to moderate hot stress	dense settled urban areas
4.2.	Frequent changes of *Tsk* and another physiological parameters on the level equal average.	sufficient, physiological regulation of the heat balance	from "cool" to "hot"	varied, from moderate cold to moderate hot stress	no dense settled urban areas, fields with tree belts
4.3.	Frequent changes of *Tsk* and another physiological parameters on the level lower then average.	like in type 4.2.	from "cold" to "warm"	varied, from great cold to moderate hot stress	orchards
4.4.	Frequent, great changes of *Tsk* and another physiological parameters.	behavioural and technical heat balance regulation necessary	from "cold" to "very hot"	varied, from great cold to great hot stress	block build-up areas

Each pixel should contain digital information dealing with various components of geographical environment. The additional benefit of raster analysis is the possibility to use the actual data obtained from the space images of studied area.

The main problem in biotopoclimatic mapping is to define spatial distribution of essential meteorological elements in the local scale: air temperature, wind speed and intensity of global solar radiation. There can be used two sources of data: generalised results of standard meteorological measurements performed in various type of geographical environment as well as remote sensing images (Błażejczyk 1996).

The results of standard meteorological measurements performed in various type of geographical environment can not be generalised for different climatic zones. Only some universal qualitative relationships between some components of geographical environment and air temperature, solar radiation intensity as well as wind speed can be pointed as follows.

<u>Orography</u>:

- in deep, narrow valleys and depressions wind speed is lower then on uplands,
- on the tops of hills and mountains air movement is very intensive,
- on sunny exposed slopes the air temperature is higher then on lowlands.

<u>Land use</u>:

- in downtown and industrial areas decrease of wind speed and increase of air temperature are observed,
- in parks and suburban areas (with high trees) great spatial variability of solar radiation intensity as well as air temperature and wind speed is observed,
- over the fresh grass, sandy areas and cemented squares increased amount of reflected solar radiation occurs,
- on lake and sea shores the wind speed increases considerably,
- inside woods and dense parks the great decrease of solar radiation income and wind speed is observed; there are occurs also decreasing of air temperature,
- lakes and water areas characterise by increase of reflected solar radiation and wind speed and by decrease of air temperature.

<u>Type of soil</u>:

- on dry - mainly sandy - soils the tendency to air temperature increasing is observed,
- on wet - mainly fluvial - soils air temperature is relatively low.

The construction of digital biotopoclimatic map has some steps: preparing basic environmental layers, calculating basic topoclimatic as well as biotopoclimatic layers and finally - resultant biotopoclimatic map and evaluation maps (Fig. 1).

Basic environmental layers should consist of orography, land use as well as type of ground maps. Space image of surface can be also used. On every layer the most important -from the climatic point of view - elements of relief (e.g. valleys, ridges, slopes with various orientation), land use (e.g. urbanised areas, meadows, forest of various types) and ground surface characteristics (e.g. sands, clays, water bodies) should be distinguished. The quantitative analyse - made individually for particular studied areas - should lead to find coefficients modifying *Ta*, *K*glob and *v* values by particular types of relief, land use and type of soil in the reference to standard conditions represented by local meteorological station.

As basic topoclimatic layers the maps of relative values of global solar radiation, air temperature and wind speed should be calculated. They are made by reclassification of initial, environmental maps with the use of modifying coefficient. If the space image of surface temperature is available the map of relative air temperature can be obtained from the surface temperature map.

Bioclimatic evaluation of ambient conditions should also consider the specific local features of the atmosphere, i.e. trees' produced aerosols, air temperature inversions, radiative fogs and air pollution. The qualitative analyse and reclassification of initial, environmental layers lead to prepare the layer containing those information.

The basic, biotopoclimatic layers consists of three maps: of absorbed solar radiation, net heat storage and heat load in man. The simplified option of the MENEX model (Table 1) can be used for the calculations. The additional maps of the intensity of several heat loss fluxes (*E*, *C* and *L*) must be also calculated to achieve its structure. They can be made for various thermal, insolative and windy conditions.

The resultant biotopoclimatic map should contain information dealing both, with human heat balance structure (Table 2) as well as with specific features of the atmosphere (Table 4). The full description of biotopoclimatic units consists of two elements. The first one indicates type of biotopoclimate (e.g. 1.1., 3.4. etc.) and the second one - printed in the subscript - its class. In digital scheme of biotopoclimate classes 0 points to the absence and 1 to the occurrence of specified atmospheric feature in the order mentioned above and in Table 4. So, for example, $1.1._{0.0.0.0.}$ indicates evaporative-reflexive type of biotopoclimate without any specific atmospheric features, $2.3._{0.1.0.1.}$ points to convective-diffusive type of biotopoclimate with air temperature inversions and air pollution, etc.

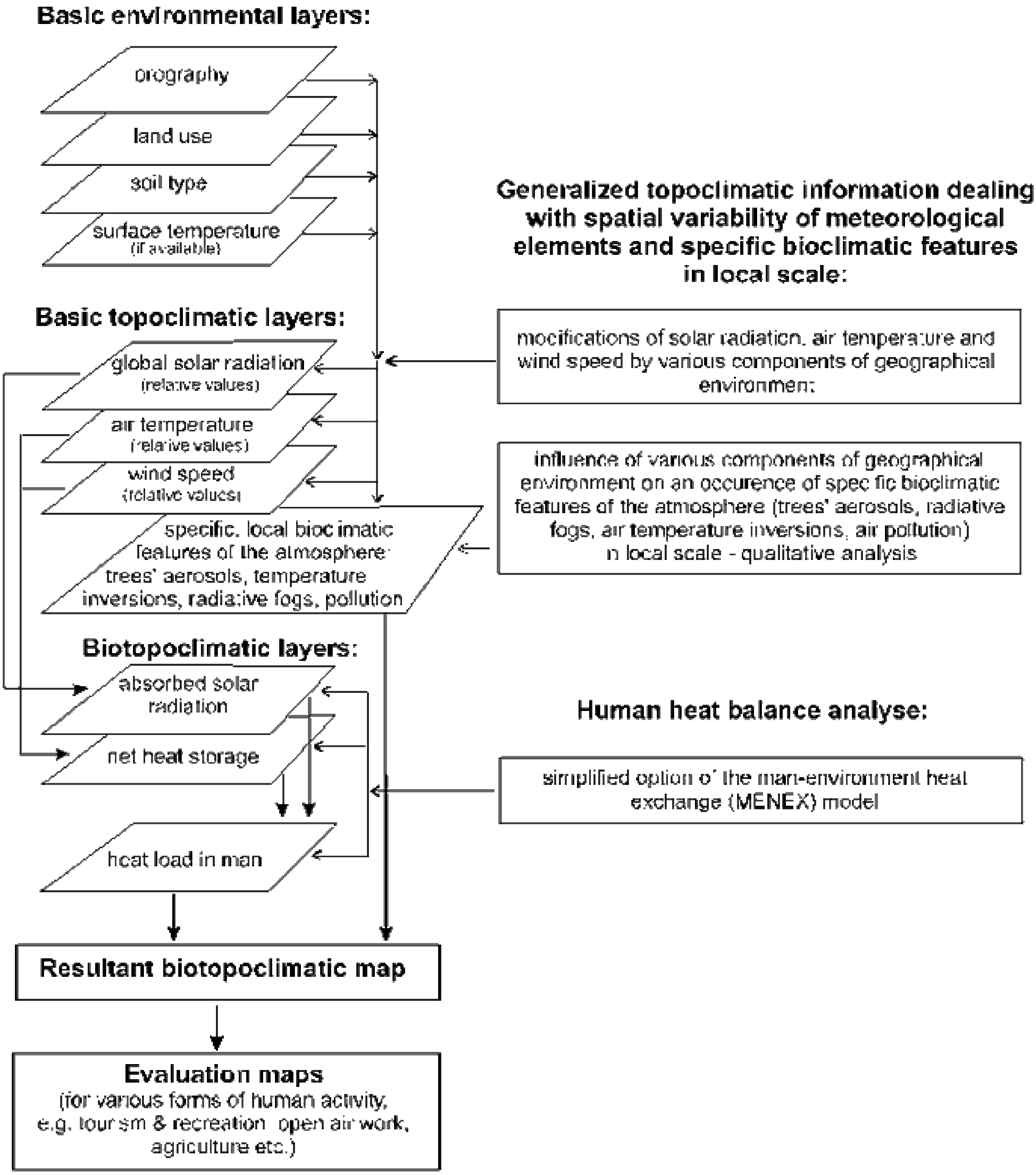

Fig. 1. The scheme of the several steps in biotopoclimatic mapping

3. BIOTOPOCLIMATIC MAPS OF NORTH-EASTERN POLAND

In the present paper there is done an example of biotopoclimatic map of north-eastern Poland. The map was made as GIS application with the use of IDRISI 4.0. software package. The system bases on the network of 2588 pixels with the size 3x3 km. Every pixel contains digital information dealing with various components of geographical environment. The topographic and thematic background maps had the scale of 1:300 000. To obtain basic, environmental layers of relief, land use and soil type (Fig. 2-4) the following thematic maps were digitised: geological, types of landscape, geomorphological, vegetation cover, swamps and water bodies (Atlas województwa białostockiego 1968).

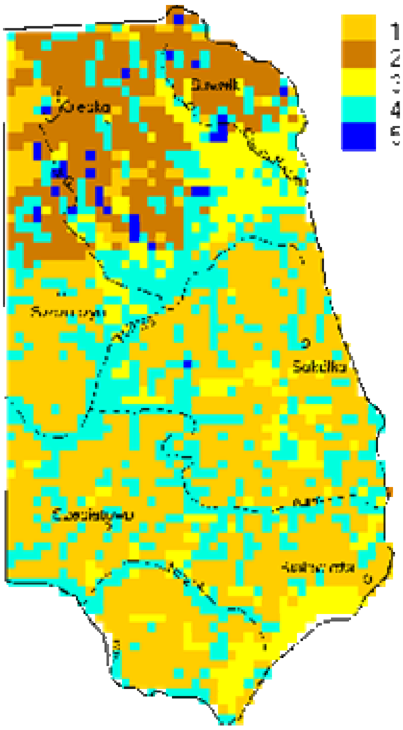

Fig. 2. Digital map of relief
1 - post glacial lowlands,
2 - post glacial hill uplands,
3 - sander lowlands,
4 - valleys,
5 - lakes

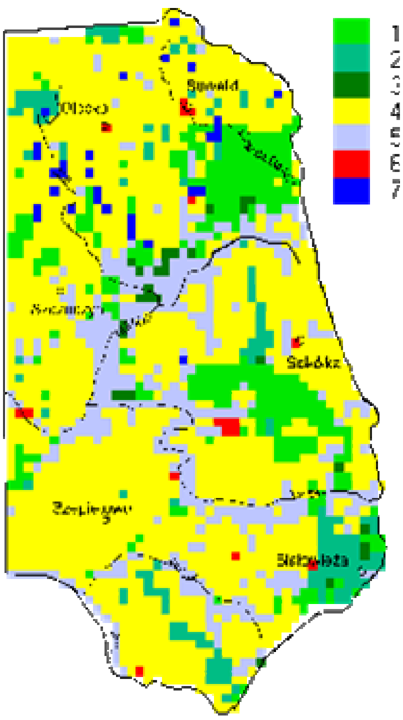

Fig. 3. Digital map of land use
1 - coniferous forests,
2 - mixed forests,
3 - wet forests,
4 - rural areas,
5 - meadows,
6 - urbanised areas,
7 - lakes

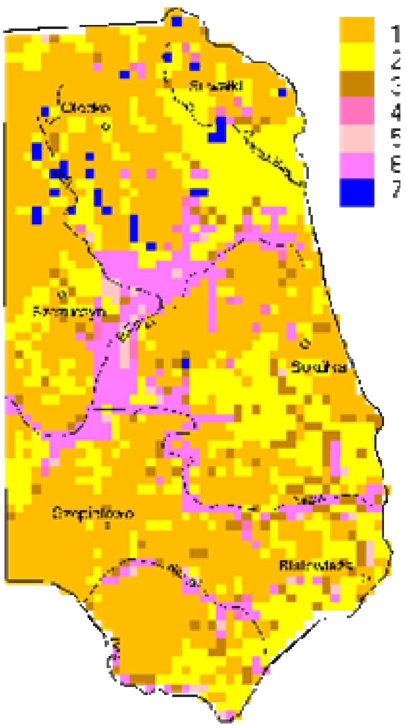

Fig. 4. Digital map of soil types
1 - dry clays,
2 - dry sands,
3 - dry alluvials,
4 - wet clays,
5 - wet sands,
6 - wet alluvials,
7 - lakes

Next, basing on generalised results of various topoclimatic investigations modifying coefficients of global solar radiation (zr), air temperature (zt) and wind speed (zv) typical for different types of relief, land use and soil were defined:

- <u>relief</u>:

- post glacial lowlands - zr, zt and zv = 1.00,
- post glacial uplands - zt = 0.95; zr and zv = 1.00,
- sander lowlands - zr, zt and zv = 1.00,
- valleys - zr = 1.00; zt and zv = 0.95;

- <u>land use</u>:

- coniferous forests - zr = 0.30; zt = 0.90; zv = 0.20,
- mixed forests - zr = 0.40; zt = 0.80; zv = 0.30,
- wet forests - zr = 0.30; zt = 0.75; zv = 0.20,
- rural areas - zr, zt and zv = 1.00,
- meadows - zr = 1.10; zt = 0.95; zv = 1.00,
- settled areas - zr = 0.80, zt = 1.25; zv = 0.6,
- lakes - zr = 1.20; zt = 0.85; zv = 1.20;

- <u>soil type</u>:

- dry, post glacial residuals - zr, zt and zv = 1.00,
- dry sands - zr and zv = 1.00; zt = 1.10,
- dry alluvials - zr, zt and zv = 1.00,
- wet, post glacial residuals - zr and zv = 1.00; zt = 0.95,

- wet sands - zr and zv = 1.00; zt = 0.95,
- wet alluvials - zr and zv = 1.00; zt = 0.90.

Using the above modifying coefficients the basic environmental maps were recclassified to the maps of relative values of global solar radiation, air temperature and wind speed (Fig. 5-7). In every pixel zr, zt and zv represent their mean values produced by relief, land use and soil type.

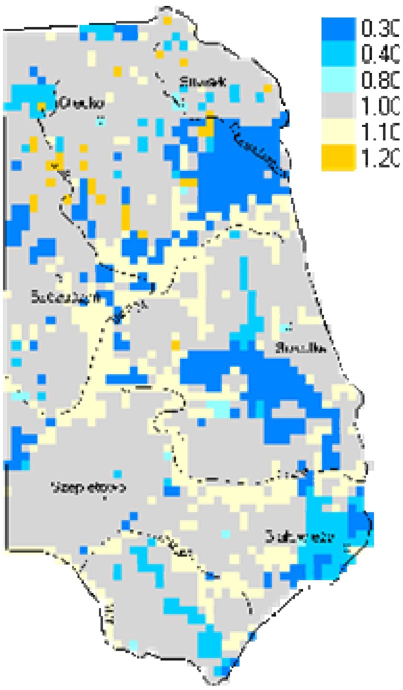

Fig. 5. Digital map of the relative values of global solar radiation

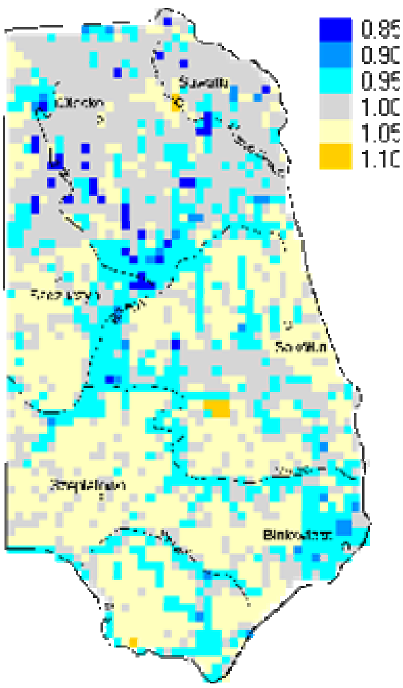

Fig. 6. Digital map of relative values of air temperature

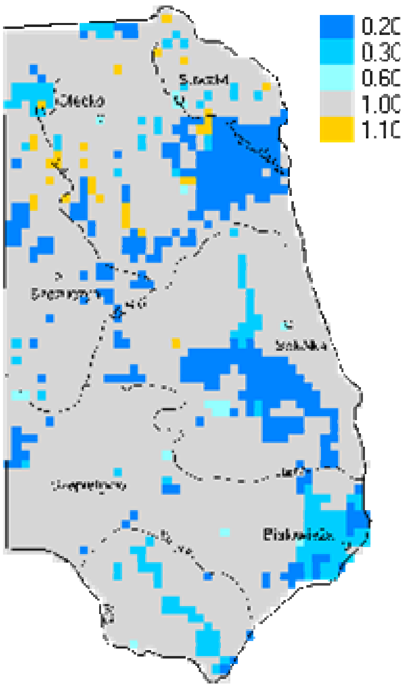

Fig. 7. Digital map of the relative values of wind speed

Using simplified equations of the MENEX model (Table 1) the components of the human heat balance were calculated taking into account 20°C as a basic level of *Ta*, 4 m s^{-1} as a basic level of *v*. It was also assumed solar radiation conditions typical for cloudiness of 21-50% and Sun altitude of 50°. As an example the map of net heat storage is presented (Fig. 8). The analysis of the values of the human heat balance components were made (using standard LOTUS worksheet) and every pixel was classified to appropriated type of biotopoclimate.

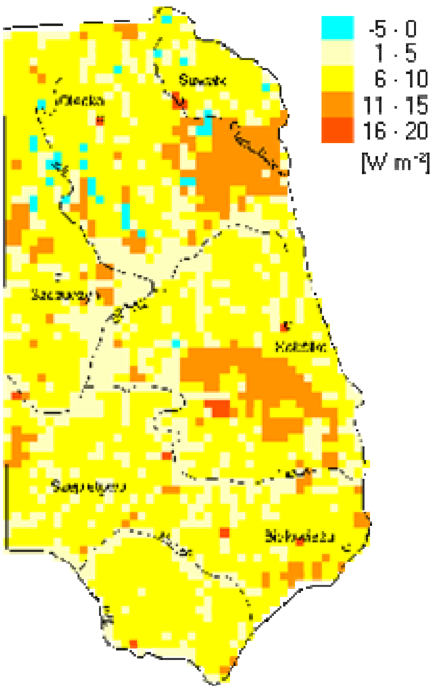

Fig. 8. Digital map of net heat storage in man at air temperature of about 20°C, wind speed - 4 m s^{-1} as well as small and moderate cloudiness

The resultant biotopoclimatic map of north-eastern Poland (Fig. 9) consists of 4 types of biotopoclimate: (1.2., 2.1., 2.2. and 3.3.).

- **evaporative-insolative (1.2.)** where heat loss due to sweating predominates; absorbed solar radiation can reach in the summer 100 W m^{-2}; net heat storage has slight, positive values
- **convective-reflexive (2.1.)** where intensive convective heat loss predominates; absorbed solar radiation can reach even 120 W m^{-2} thanks to high albedo of the ground and/or plant surface; net heat storage points to slight cooling of an organism
- **convective-insolative (2.2.)** were moderate convective heat loss predominates; absorbed solar radiation can reach in the summer 100 W m^{-2}; net heat storage points to thermoneutral conditions
- **radiative-diffusive (3.3.)** where moderate heat loss by long-wave radiation predominates; absorbed solar radiation has small intensity (30-60 W m^{-2}) because of diffuse radiation predomination; net heat storage points to thermoneutral conditions

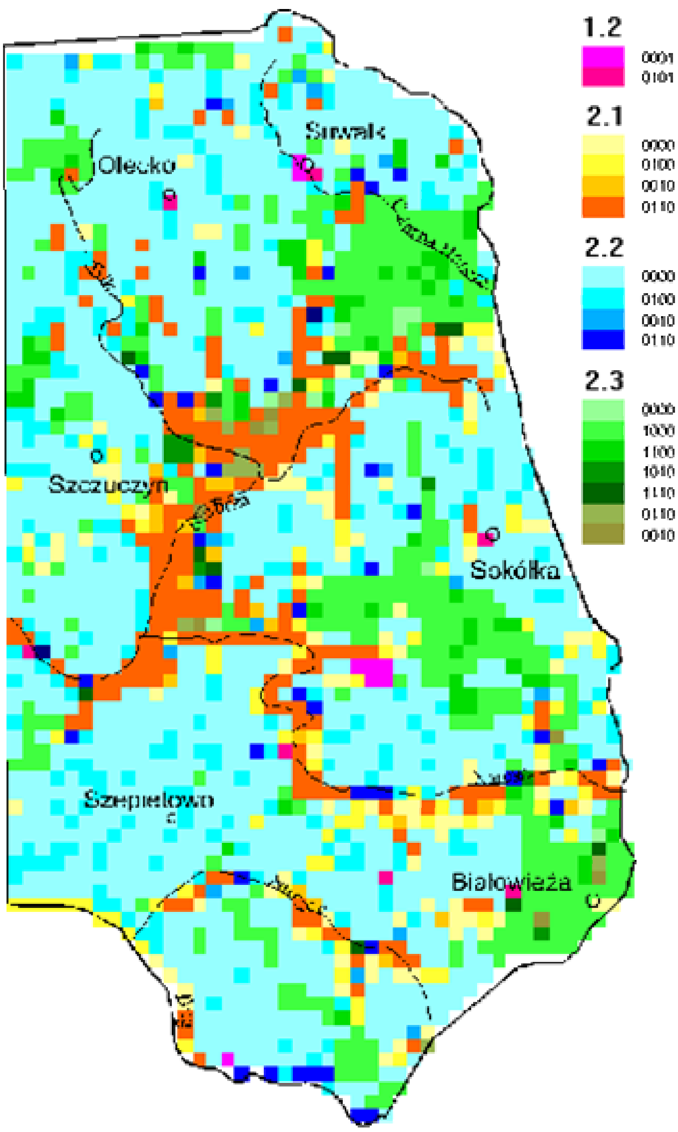

Fig. 9. Resultant biotopoclimatic map of north-eastern Poland; explanations in the text and in Table 4.

In each type 2-7 classes of biotopoclimate were distinguished (Table 4). The most frequently air temperature inversions and radiative fogs are observed in the near ground atmosphere layer.

Table 4. Types and classes of biotopoclimate of north-eastern Poland

Type of biotopoclimate	Class of biotopoclimate	Local features of the atmosphere			
		trees' produced aerosols	air temperature inversion	radiative fogs	air pollution
1.2.	0.0.0.1.				x
	0.1.0.1.		x		x
2.1.	0.0.0.0.				
	0.1.0.0.		x		
	0.0.1.0.			x	
	0.1.1.0.		x	x	
2.2.	0.0.0.0.				
	0.1.0.0.		x		
	0.0.1.0.			x	
	0.1.1.0.		x	x	
3.3.	0.0.0.0.				
	1.0.0.0.	x			
	1.1.0.0.	x	x		
	1.0.1.0.	x		x	
	1.1.1.0.	x	x	x	
	0.1.1.0.		x	x	
	0.0.1.0.			x	

x indicates the occurrence of specified feature of the atmosphere

Both, types and classes of biotopoclimate refer to main types of landscape of this part of Poland, i.e. post glacial, rural lowlands, wide, wet valleys and old forests. Some, small urbanised areas (e.g. Bialystok, Suwalki, Augustow) are also marked on the map by specific type and class of biotopoclimate.

4. BIOCLIMATIC EVALUATION MAP FOR THE NEEDS OF RECREATION

For the various practical purposes bioclimatic evaluation map can be constructed. However, north-eastern part of Poland is the region predestined for recreation because of very clean air as well as great amount of old forests, lakes and rivers. Thus bioclimatic evaluation map for the needs of recreation was derived from resultant biotopoclimatic map (Fig. 10). Five classes of terrain was distinguished:

I. very favourable for all forms of recreation,
II. favourable for most forms of recreation,
III. moderately favourable for some forms of recreation,
IV. less favourable for recreation,
V. unfavourable for recreation.

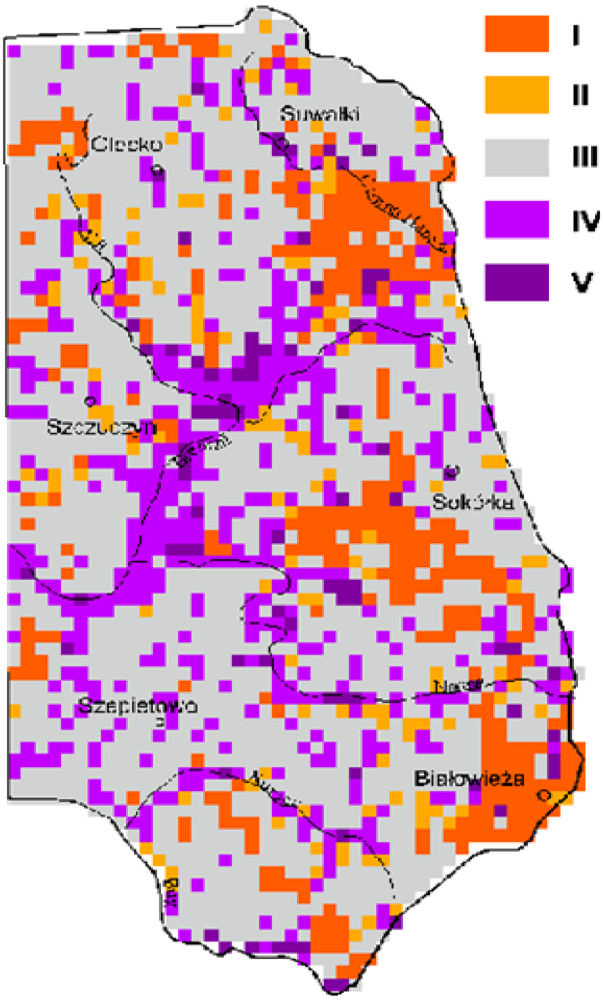

Fig. 13. Bioclimatic evaluation map for the needs of recreation
I - very favourable,
II - favourable,
III - moderately favourable,
IV - less favourable,
V - unfavourable

Very favourable areas characterise with very mild thermal conditions (small range of the human heat balance and its temporary fluctuations). There is also very slight risk of air temperature inversions and radiative fogs. Great amount of trees' produced aerosols is very friendly for man.

Favourable areas characterise rather with mild (equilibrated man-environment heat exchange) or with hardened thermal conditions (intensive and temporally fluctuated heat exchange typical for the lakes). In the second case recreation use by children and elderly people can be limited.

Moderately favourable areas characterise with mild thermal conditions. However the risk of temperature inversions or radiative limit their recreational ability.

In less favourable areas the man is liable to intensive cooling of an organism. Additionally temperature inversions and radiative fogs make this areas unfavourable for residential recreation.

Unfavourable areas characterise rather with great heat load of an organism and great air pollution or with very deep air temperature inversions and radiative fogs as well as great air and ground humidity make this areas unfavourable for any form of recreation.

In general, very favourable and favourable areas compose almost 20% of the studied territory, moderately favourable areas - about 58%, less favourable areas - about 19% and unfavourable areas - only about 3%. Thus, we can find that the north-eastern Poland has the area of great bioclimatic potential for the needs of recreation.

5. CONCLUSIONS

The paper presents the original way of the construction of topoclimatic and biotopoclimatic maps in regional scale gathering two recent methods of studies: Geographical Information System and human heat balance model.

The GIS bases on raster network with 3x3 km resolution. Environmental data of relief, land use and type of soil were derived from traditional, printed maps of that region. It seems that for regional scale this resolution give satisfying spatial image of the territory. Topoclimatic maps were calculated with the use of IDRISI 4.0 software package basing on general relationships between environmental components and climatic parameters in local scale. This method of spatial analyse of local climates gave very good results.

Biotopoclimatic maps were constructed thanks to the combination of GIS IDRISI procedures and the human heat balance model. The resultant biotopoclimatic map and evaluation map are comfortable to the results of various, detail studies performed in particular parts of the territory.

While the method works quite good in the area with small orographical differentiation it seems necessary to undertake analytical studies in more complicated landscapes, like mountains or urbanised areas.

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