CLIMATE ATLAS OF A METROPOLITAN REGION IN GERMANY BASED ON GIS

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Abstract

The Climate Atlas of the Region Stuttgart includes the total area of the Region of Stuttgart with around 2.7 million inhabitants on a surface area of 3.654 km². The part with the maps is arranged in basic maps, maps with results and climate analysis maps. In the basic maps facts are presented which are important for the examination and valuation of the climate, for example the height level, the land use and the position of measuring points. Other maps give information on the surface temperature, the mean annual air temperature, nocturnal cold air production and the velocity and volumes of cold air flow. All is included in a GIS project.

Key words: Urban Climate Atlas, Urban Planning, GIS, Region Stuttgart

1. INTRODUCTION

Sustainable spatial development aims at durably preserving important ecological protective goods and balancing functions in order to guarantee an environmentally friendly development of housing estates and infrastructure. Large-scale studies on the functions of open space were carried out in the context of the updating of the regional plan in combination with an environmental impact assessment in order to gain essential current information and to account for the planning legislation requirements. For the Region Stuttgart a GIS-based digital information and management system for all relevant protective goods is developed.

Climatic balancing functions like the production of cold air and the transport of cold and fresh air are of great importance for people's health and well-being. The necessity for the working up of climatic concerns in the context of the updating of the Regional Plan is not least the compelling result of the new legal demands of the Strategic Environmental Impact Assessment (EIA). A qualified analysis of the implications of the Regional Plan for the protective good Climate is a major requirement for the legal security of the planning.

There is an important new aspect that adds to the legal requirements: global climate change. The annual amount of precipitation and its distribution changes. Increasing temperatures lead to a higher number of hot days and more heat stress. This can have particularly negative implications for the health of the resident population in the agglomerated areas of the Region Stuttgart. Against this background a forward-looking consideration of climatic balancing functions within spatial planning is of special meaning.

2. CLIMATE ATLAS OF THE REGION OF STUTTGART 2008: MAJOR CONTENTS AND INNOVATIONS

The Digital Climate Atlas of the Region of Stuttgart from 2008 covers the whole area of the region (3.654 km²), i.e. that this version provides climatic evaluations for all 179 towns and municipalities in the region with 2.67 millions of inhabitants.

The Region of Stuttgart is one region of the federal state Baden-Württemberg in the southern part of Germany. Data acquisition and processing was realized with the help of a geographic information system (GIS). It allows for a modern utilization and the coordination with other digital data and guarantees an easy way to update the data. The digitization allows for further analysis steps thanks to special software, e.g. wind field calculations, cold air drainage as well as the intersection with other relevant environmental data. This is a significant functional improvement compared with the analog climate atlas from 1992 (Baumueller et.al, 1992).
An agreement was reached between the Association Region Stuttgart and the city of Stuttgart on a close cooperation and a joint further development of the climate atlas.

Fig. 1: Location of the Region Stuttgart in Germany

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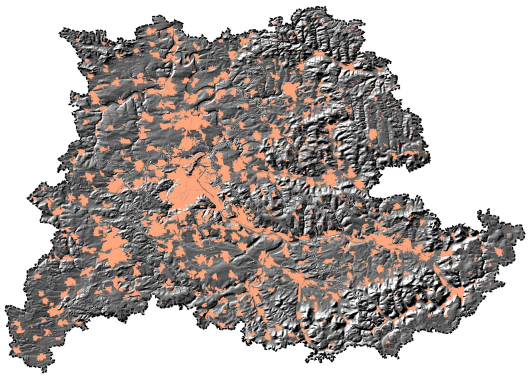
The Department of Urban Climatology of the city of Stuttgart contributed its outstanding specialist knowledge. An important basis for the preparation of the climate atlas were the thermal maps developed thanks to measuring flights in the summer of 2005. The evaluation and processing of the data for the drawing up of the basic material for planning maps was realized by an external specialist office. Data from the State Institute for Environment, Measurements and Nature Conservation Baden-Württemberg (LUBW) and from the German Meteorological Service was also used. The data was brought together by the Department of Urban Climatology of the city of Stuttgart.



The basic information within the climate atlas contains a general climatic classification of the region for factors like wind, solar radiation, temperature and precipitation. Resulting from this the regional situation of the air and the climatic concerns relevant for the planning are worked up and presented in texts or maps.

2.1. Thermal maps

The thermal maps illustrate the results from the measuring flights (infrared thermography) which allow for a snapshot of the temperature distribution on a radiation day and for the identification of differences in the temperature structures of a city or a landscape in the context of settlement.

Fig. 2: Relief and Settlement areas of the Region Stuttgart

For an interpretation of the maps it is essential to be aware of the interaction between the meteorological parameters within the air in the ground layer and of the relation to other meteorological data (climate maps) and to include the local topographic conditions and vegetation. The purpose of the analysis is to know more about local cooling and air exchange processes through the principles of topographic climatology and to determine those areas within the city which play an important role in the formation of local wind systems.

2.2. Production and drainage of cold air, wind field calculations

The Digital climate atlas of the region of Stuttgart was not only spatially extended but it took up new technical and content-related aspects. Region-wide calculations of the thickness and drainage of cold air were carried out on the basis of the digital elevation model, the land use and infrared thermography. As areas producing cold air and cold air catchment areas during inversion weather conditions bring about fresh air supply during the night, they have a substantial function for the aeration of settlement areas. The Digital climate atlas also provides detailed information on the wind conditions. Synthetic wind field calculations also allow for an evaluation of the local wind conditions in the region. As the wind (characterized by wind speed and wind direction) determines the spreading of air pollutants, it plays a major role for air hygiene. The knowledge on the aeration situation within the settled areas gained from the factors wind and cold air is an important assessment foundation for spatial planning on both the regional and the municipal level.

2.3. Climate analysis maps

Just as within the climate atlas from 1992, climate analysis maps represent a substantial result of the analysis. The climate analysis maps, which are now available in digital form for the whole region and therefore for all towns and municipalities, show the local climatic features as an areal outline. On the one hand the map gives a differentiated depiction of areas with a particular suitability, like areas producing cold air, cold air catchment areas or climate-relevant ventilation lanes. These areas are of great significance for the balance of climate and air hygiene. On the other hand the climate map shows settled areas which are defined as climatopes with certain microclimatic characteristics. They are basically determined by the actual land use and especially by the type of development. Climatopes range from unpolluted to climatically polluted spaces.
The Digital climate atlas of the region of Stuttgart gives different types of climatopes with their characteristics)

Climatic compensation areas and climatopes can be influenced by a change in the land use, especially by sealing and development. This is especially important in the case of planning designations in the spatial and functional context of climatically polluted areas. Climate-relevant open land with a direct connection to polluted settlement areas is highly sensitive towards changes of use.
The climate analysis maps give an outline of the climatopes distribution in the region of Stuttgart.

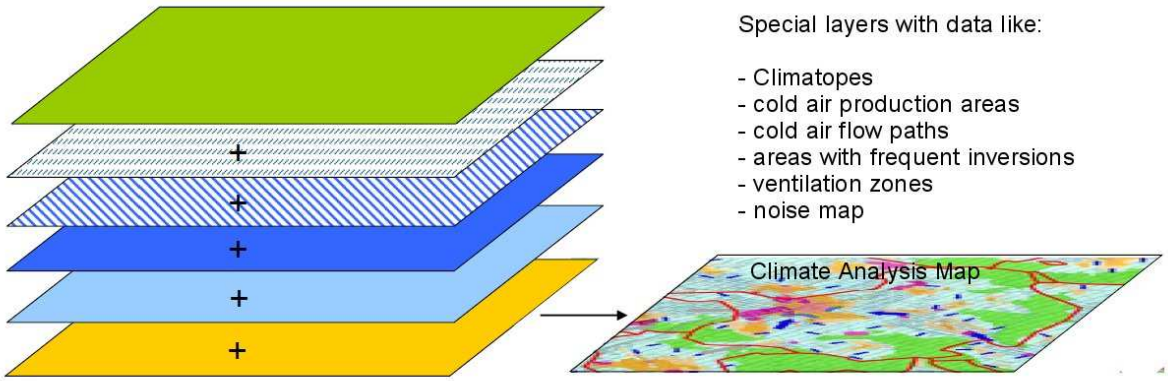


Fig. 3: Scheme how to get the climate analyse map

2.4. Planning reference maps

The climate atlas serves as technical support of the regional plan and land use planning. This is why there are maps for the assessment of aspects relevant for planning containing area classifications with different indications for changes of use or the requirements to take particular steps. The indications are summarized in eight categories. They refer to undeveloped free spaces as well as to structurally used areas. The indications refer to the effects of structural uses and changes of use on the climatic situation.

2.5. Prognosis of the implications of climate change: average annual temperature and bioclimate

What is studied in more detail apart from the climatic situation are the changes resulting from global climate change. The prognosis examines the change of the average annual temperature and the resulting implications for the bioclimate. What we can see is an expected area of about 5 % with more than 30 days with heat stress resulting from high perceived temperatures in this region. Numerous epidemiological studies prove that the adaptability of sensitive people will be overstrained more quickly in these cases - especially in the case of a predisposition for cardiovascular and respiratory diseases. This may lead to an increasing number of fatalities.

With regard to the temperature increase as a result of the climate change we try to look further ahead and go beyond the current situation. This is realized through a prognosis basing on the assumption that the number of days with heat stress will double in the case of climate warming till 2100. The result is that large parts of Greater Stuttgart (57 % of the territory) would have to expect more than 30 days with heat stress, in the valleys more than 60 days, i.e. that a significantly higher percentage of people would be exposed to heavy heat pollution in the summer. The alongside map legend of the following maps shows the number of days for 1971-2000 and 2071-2100.

The maps compare the actual situation determined by the German Meteorological Service with the prognosis expecting.

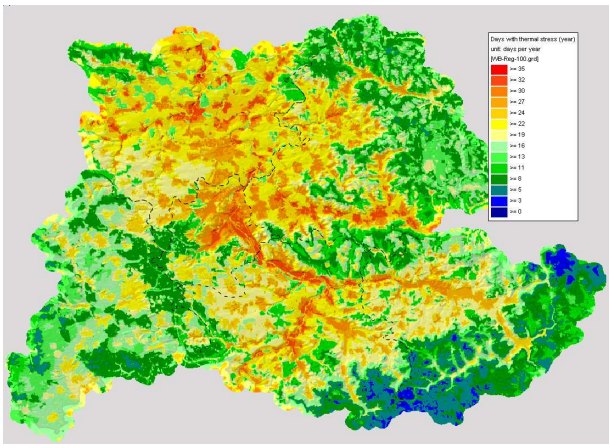


Fig. 3 Bioclimate Days with heat stress 1971-2000

The prognosis shows that this will be a big challenge for regional planning. What plays a major role in this context is the preservation of climatic compensation areas on which fresh and cold air is produced and the guaranteeing of sufficient aeration.

2.6. Air pollution

Besides information on the bioclimate and the climatic situation of settlements, the Digital climate atlas of the region of Stuttgart depicts current air pollution levels in the Stuttgart region. The data from the LUBW emission inventory from 2004 was analyzed and broke down into the region. The data now contains summaries of the concentration of particulate matter (PM_{10}) unlike in 1992.

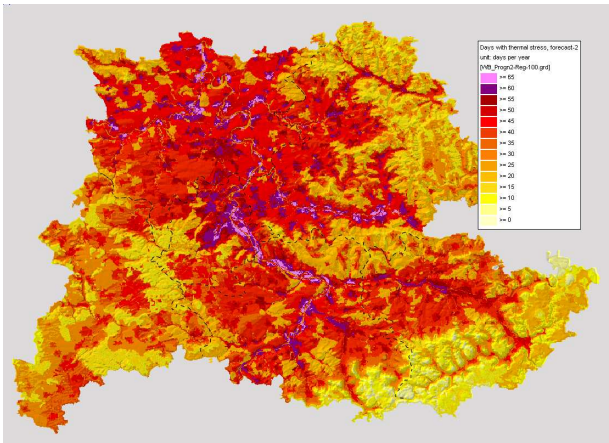


Fig. 4: Bioclimatic Days with heat stress 2071-2100

2.7. Further information

Further factors influencing the population like noise are also taken up and presented in synoptic maps. If this information is connected with the topographic situation, remaining quiet areas emerge for example, which can be used for the assessment of recreation areas with a particularly pronounced regeneration suitability.

3. CONSIDERATION OF THE RESULTS OF THE CLIMATE ATLAS IN REGIONAL PLANNING, LANDSCAPE STRUCTURE PLANNING AND URBAN LAND USE PLANNING

3.1. Draft of the regional plan

The green corridors and caesuras included in the draft of the regional plan contain substantial climatic compensation areas determined on the basis of climatope maps and of information on the production and drainage of cold air. Especially green caesuras often preserve locally relevant ventilation lanes, which are of importance for the aeration of adjacent settlements. The Digital climate atlas of the region of Stuttgart provides important basic information on the assessment of the climatic situation in the Stuttgart region. The presentation of the current environmental situation with regard to the protective goods is an essential part of the environmental report. Only the determination of the current situation allows for the deduction and assessment of possible changes and significant effects of regional planning designations. So the contents of the climate atlas were included into the environmental report:

This way the environmental impact assessment of the draft of the regional plan clearly meets the requirements of considering the protective goods People/Health and Climate/Air.

The landscape structure plan is a major information basis for the designations of free spaces within the regional plan. It shows the current situation of free spaces and indicates necessary measures for the protection and improvement of the basic conditions for natural life. The landscape function map illustrates the overlapping high-quality functions of natural space like soil, species and biotopes or climate. This allows for the determination of areas where the precious aspects of free space, like ventilation lanes or climatic compensation areas, are preserved through regional green corridors and caesuras. Especially the results from the climate analysis maps and climate indication maps are used for the designation of requirements, targets and measures in favour of the protective good Climate.

Especially climatope maps and planning reference maps provide appropriate data for the drawing up of land use plans which towns and municipalities in the region can use in order to consider climatic aspects in the process of drawing up these plans pursuant to the Federal Building Code. The Digital climate atlas from 2008 can also be used as for the Strategic Environmental Impact Assessment, which is to be realized for the land use plans. The Digital climate atlas represents a uniform data set which can be used in the future by all municipalities in the region. The climate data will be available for all towns and municipalities, first inquiries were received and could be responded. In the context of a further development of the climate atlas attempts are made to improve the functionality of the data by means of interactive elements. We would like to point out that the Digital climate atlas can provide first indications for development plans but detailed analyses will still be necessary in order to correctly assess the local situation.

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