THE CONTRIBUTION OF URBAN CLIMATE STUDIES TO A NEW URBANITY

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ABSTRACT

The city development of Germany follows three main directions, which are influenced by the demographically development. Conversion of industrial, military and non used train track areas to housing and service centres, the economical concentration and more densely built up inner cities are named as new urbanity. Climatologically speaking this development leads to an increase of heat island, air pollution and a reduced ventilation of the cities. At the example of Kassel it can be seen that this development has positive and negative factors. Urban climate studies can be used to support ideas of architects and planners without destroying thermal and air quality comfort. Especially the importance of open spaces and the thermal conditions there are taken as example to create a climatologically approved urban design. From the definition of an ideal urban climate the different planning levels and climatic scales are combined.

1 INTRODUCTION

In Germany one can observe different developments. One is that inner cities gets more densely built up areas with spare vegetation and less open spaces; the second one is the conversation non used open areas like military fields, large old factories and railway tracks into building sites. This new urban development leads to an increasing roughness with reduced ventilation and higher air pollution and also to an increased heat island situation with thermal stress conditions. Urban climate studies have to meet these subjects in order to give help for urban planners and architects. The basic knowledge about urban climate has to be evaluated and transferred to planning practice and to answer their urgent questions.

But there is also a third aspect, which tend to be the opposite and occurs mainly in eastern Germany. Due to loss of people and industry there the population decreases and many houses and factories were destroyed. Here new areas become free and can be climatologically used for ventilation and for an improvement of the open space climate.

In all these developments it is important that urban climate studies help to bring the thermal and air pollution aspects into discussion and not to see an open pace as a potential area for buildings. For this urban climate investigations have to meet the urgent questions of planners. Which areas may be free for development, is there a limit in density of buildings, which gaps have to be maintained. To answer these questions links between climatological and planning scales together with evaluation criteria are needed. The paper shows how the linkage between scales and levels of urban climate and planning aims. Moreover it is shown that urban climate only can work with an areal information set, which combines planning trends, thermal comfort and air pollution.

Finally coming to very concrete proposals, mainly what is of concern for the behaviour of people, interviews showed the important role of microclimate in the neighbourhoods. The more densely built up cities in the mid latitude climates create an optimum of thermal comfort conditions in short walking distances, which is judged as positive, while ventilation is rather seen as negative (Katzschner 2004).

The objective here is to discuss in which circumstances this situation can be accepted and when the situation turns to negative in warmer climates. Warm climates therefore need generally wider gaps, while in moderate climate density can be even increased in some situations.

2 URBAN DEVELOPMENT CONCEPTS RELEVANT TO URBAN CLIMATE

Urban development plans and concepts like a master plan have some more principle aims, which later on get a spatial implementation like:

- Development of inner cities with living, working and shopping together with a reorganisation of the city and the suburban structure
- Development of an improvement of the living situation (the social city)
- Regaining of open spaces through pull down of buildings and a convert of land use (the renewal of cities)
- Service centres in the inner city like hospitals, administrations or service companies
- Development of the infrastructure including traffic
- Near by recreation (development of green spaces)
- Development of cultural consciousness

At the example of the city Kassel (figure 1) the implementation of these general aims in a spatial pattern is seen. Figure 1 is a cut showing the plans for the inner city of Kassel/Germany.

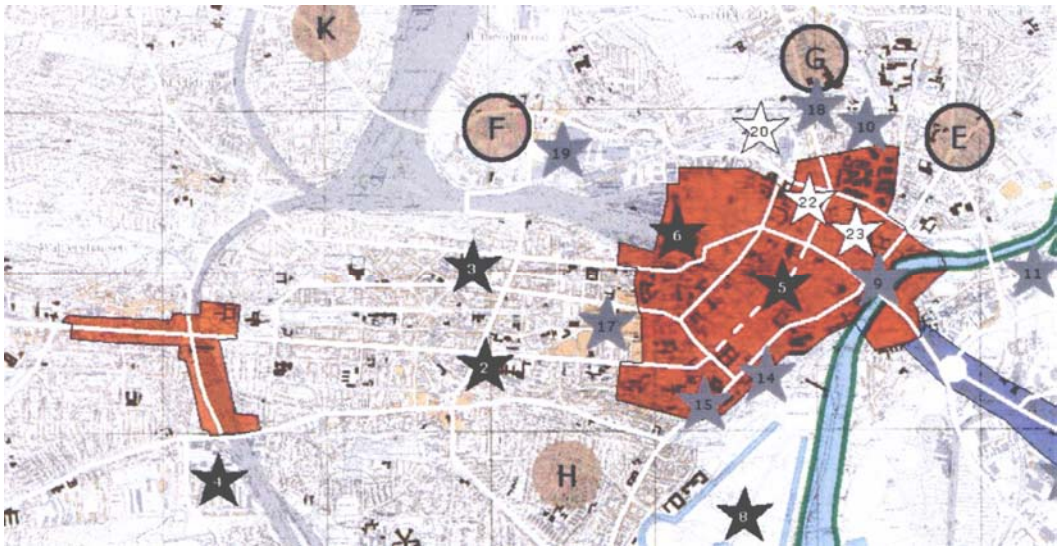


Figure 1 Urban development plan of Kassel; red areas with high priority of building developments, blue and green areas for more vegetation, reconstruction and recreation, stars mark punctual developments

The concept out of figure 1 is an urban development separated in with two main areas and with punctual densities. (Gogo et al. 2003). The general aim was to have an inner city development with increased density at two areas, which are the existing city centre and a second one near a new train station and to regain open spaces along the outgoing streets, including pulling down houses, and with an extension of an inner city park area.

For further planning discussions this concept has to be brought into connection to the urban climate aspects. To which extent do dense building sites effect heat island and thermal conditions of the open spaces and what potentials does the concept have to improve thermal conditions and air mass exchange for example along roads and parks.

The punctual developments, which are conversion areas from military places to service centres and from not longer used industrial places to residential buildings, are dealt and urban climatically evaluated in chapter 4.2 on a microclimatic level.

Before discussing some conflicts between planning and urban climate it is important to see the interactions between climate and use of spaces. Investigations with interviews from previous studies (Katzschner 2002) showed very clearly the need of certain microclimates in neighbourhoods. At the example of Kassel the ideal thermal conditions could be derived as follows:

- the use open spaces is more frequent in the centre of the heat island and increases with high values of the thermal indices,
- street are seen as comfortable for pedestrians if thy have the choice between sun and shadow,
- ventilation areas have to be judged in the frame of the city as such and should be classifies as important yes or no. Otherwise there will be no influence on planning,

The definition of the ideal urban climate by Mayer et al. (1990) considers the areas and time concept as important evaluation criterion: *The "ideal urban climate" is an atmospheric situation within the UCL with a high variation in time and space to develop inhomogeneous thermal conditions for man within a distance of 150 m. It should be free from air pollution and thermal stress by means of more shadow and ventilation (tropical areas) or wind protection (moderate and cold climates)*

Evans and others (Evans et al. 2001) have already developed some proposals for architects and planners on how to achieve this situation on a micro scale level. These general proposals have to be devoted to concrete urban places as seen before:

Planning possibilities	thermal effect
• Width of streets	using shadow and sun in a daily and annual variation
• Pergolas and arcades	sun protection in summer, using winter radiation
• Vegetation	sun and wind protection, long wave radiation
• Colours	reflection and daylight
• Materials	heat storage, dust

3 METHOD

The principle underlying methodology is an areal evaluation of urban climate conditions. This is based on land use from digital grid data sets together with topographical data in 200 m grids. The meteorological input parameters were mean air temperatures and humidity, wind speed and wind directions from near by meteorological stations or from recorded data in existing analysis like in the Environmental Atlas Hessen (HLUG 1999) and measured data.

In order to use planning aims and combine them with possible changes in urban climate the maps have to be linked to each other so that conflict immediately can be recognized. For example where future buildings will effect ventilation and how air pollutions is distributed. The climatic functions then were translated to an evaluation with means for planning.

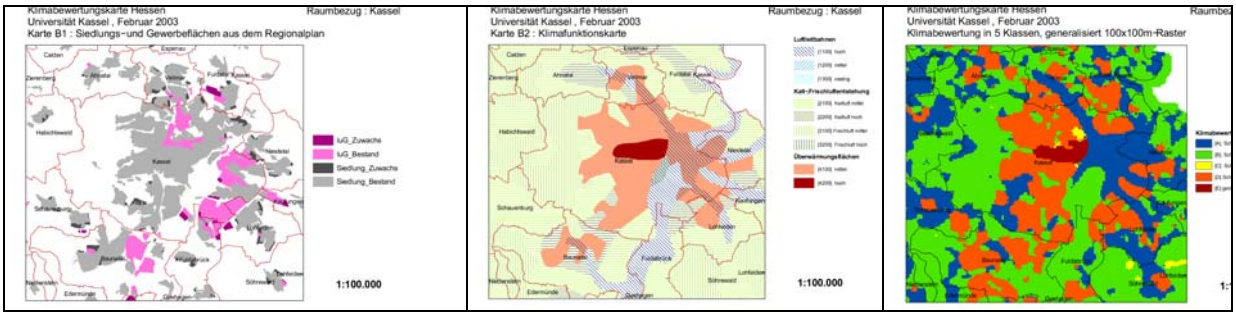


Figure 2 Spatial development plan, urban climate and evaluation in the city of Kassel

Through the Geographical Information System (GIS Arc.Info) geographical data and land use data were classified and transformed to urban climate functions like, thermal aspects (i.e. heat and cooling rates), a wind classification with ventilation paths and topographically influenced downhill movements. The building fabric was classified through roughness length and thermal radiation processes.

The following factors were used:

- Land use classifications for thermal and radiation with categories of city structures, industrial areas, gardens and parks, forests, greenland and agricultural areas. Water was only used from lakes while train tracks got a special classifications as they have a large daily variation in surface temperature and therefore radiation differences,
- topographical and geographical data which influence the local circulation pattern,
- ventilation through an analysis of the roughness length.

Evaluation was carried out through a GIS based calculation method, which calculated weighting factors for every grid with a result for thermal and dynamic map. This then was combined to the urban climate function map with an evaluation to the urban climate map for planning use.
Due to this methodology the climate map has two levels: one is dealing with the thermal and the second one with the dynamical aspect. Therefore it is possible to have a classification in the final map, which can differ between the advices for heat island effects and the well ventilated areas or weak ventilated areas for improvement. The method of a GIS based urban climate calculation can be used at all different scales with various grids in order to get answers on different planning levels.

Table - 1 Urban climate and planning scales

Administration level	Planning level	Urban climate issue	Climatic scale
city 1:25.000	urban development; master plan	heat island effects; ventilation paths	meso scale
neighbourhood 1: 5.000	urban fabric system	air pollution	meso scale
block 1: 2.000	open space design	thermal comfort	micro scale
single building 1:500	building design	radiation and ventilation effects	micro scale

4 RESULTS

4.1 Urban climate and planning on a city level

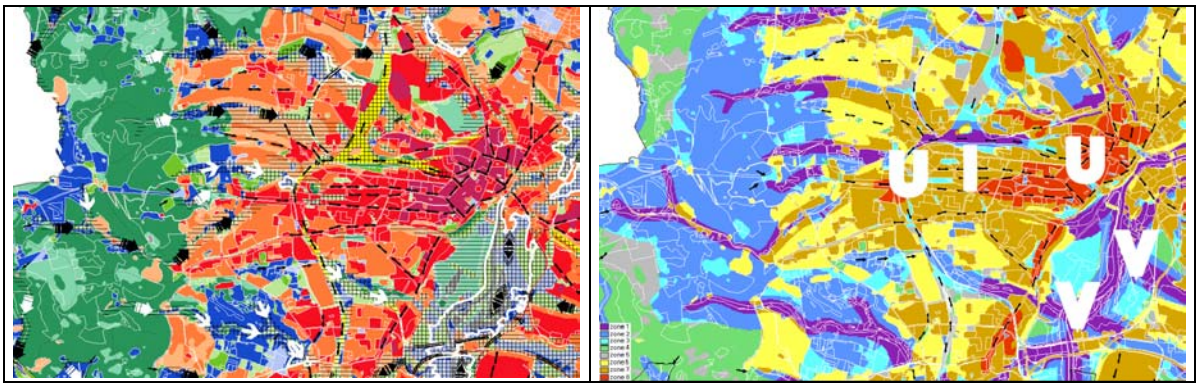


Figure 3 Urban climate map (left) and the derived urban climate evaluation map (right) for Kassel (1:10.000), U (urban development areas), I (connecting zones), V (reorganisation through vegetation)

For the city level urban climate analysis of the region are needed. In figure 3 the spatial approach of urban climate investigations and the derived planning proposals can be seen. From the urban climate analysis the evaluation takes the climatic characteristic and transfers it to a climatically based evaluation with planning advises. This is done in 8 steps with important ventilation areas (dark blue), cold air production areas with downwind streams (blue) as the most important spaces for air mass exchange up till the red areas which mark the heat island with reduced ventilation. While in the blue and green areas the planning advice is not to extend buildings here, in the yellow areas a more dense building structure is allowed and in the red areas planners should look to the microclimatic conditions of the open spaces. The urban climate map is linked to planning aims. Urbanity (U) is developed in the maximum heat island with good thermal conditions for the use of open space, intermediate or connecting zones (I) were situated in moderate climates with fairly high ventilation, while recreation and leisure areas (V) are in green areas with good cooling during evenings

The investigation result shown on figure 3 is an example of the meso scale level with urban climate as fundament for the urban development plan. It is important to mention, that different urban planning levels need different climatic scales. Urban development is devoted to the meso scale f.e. 1.25.000; open space planning with thermal comfort analysis have to be done in a mirco scale level of 1:2.000 or larger, which can be seen in the next chapters.

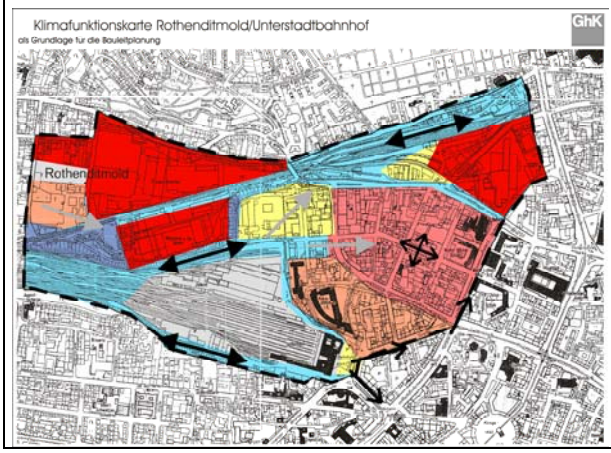
Urban planning needs qualitative and quantitative spatial results on which they can rely on. GIS gives grids which later can be transferred to vector data. The results from the investigation areas are shown in a spatial evaluation and a directly devoted planning advice, where the urban climate function is explained with the outcome for planning. The main classifications are: ventilation areas, improvement areas against thermal stress, fresh air production zones and rules for density and heights of buildings.

4.2 Urban climate and planning on a city quarter level

In the frame of the urban climate situation of Kassel as result in the meso scale one comes to a more micro scale analysis as seen in figure 4 in a scale of 1:5.000 as background information for a master plan. Reason here was the conversion of non used old train tracks and industry into building sites for residential buildings. The area is situated near the city centre and so it would fit to the inner development plan from the overall concept. The old train station is not longer intensively used and areas become free for further building development. The intention was to reorganise an old train station with new constructions of residential buildings and create open space for recreation. The master plan should also include a detailed urban climate study to evaluate the meso- and microclimate in terms of ventilation and thermal conditions. Within these city structures a climatological inhomogeneous situation occurs with high heat islands effects, air paths and vegetation sites.

Therefore more detailed investigation was carried out with measurement and calculations of thermal index PET in order to make recommendations for the construction of buildings and open spaces, as for any open space planning discussion where the different thermal conditions in an area play an important role. This is can not be done by average values. More important for any planning evaluation is the variation of the thermal conditions in time and space. Here the physiological equivalent temperature PET with a spatial variation was used. Each value then was directed to an urban classification (figure 4).

One can see that highest values PET occurs in the industrial outdoor places without any vegetation. The spatial variety is low. Residential areas can be warm, but it is always possible to choose cooler places there (i.e. backyards and tree shadow).



Legend:

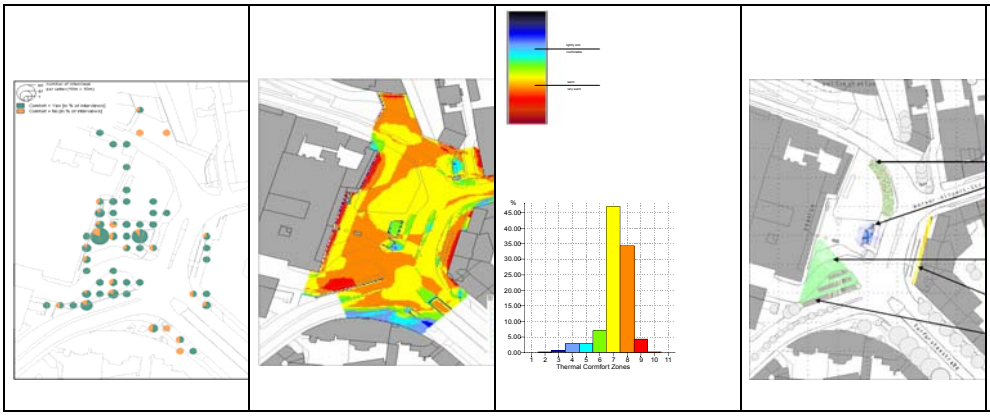
colours	classification	PET (°C) (typical summer day 12 o'clock)	ΔPET(spatial °C)
dark red (industry)	warm	42	5
red (residential 5 fl)	very warm	39	10
brown (residential 3 fl)	warm	35	15
yellow (open structured)	moderate	30	6
grey (train tracks)	warm, ventilated	34	2
blue (vegetation, tracks)	moderate	33	5
dark blue (vegetation)	cool	25	2

Figure 4 Urban climate map of the investigation area in a scale of 1:5.000

From these investigations for ventilation a thermal comfort following proposals were derived:

- the blue areas should be kept free for ventilation,
- the yellow areas can be built under respect of the air flow as drawn in the map,
- for the residential areas with a good ventilation and a high variety of thermal comfort zones, no recommendation is given,
- wide streets with high wind speed need more vegetation against cold stress during autumn to spring,
- the very small vegetation site has very different thermal comfort conditions, this should be kept.

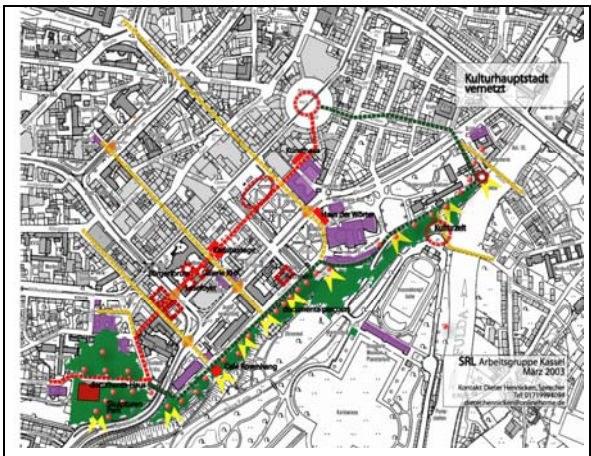
4.3 Urban climate and planning of open spaces



Middle high vegetation against wind;
Water fountain for cooling and masking of traffic noise;
planting of trees for shadow and wind reduction near a bus stop;
creeping plants at the facade against long wave radiation and glaring;
shadow areas with sitting possibilities;

Figure 5 Percentage of people in comfort, thermal conditions, evaluation criteria and a design proposal at an open space

Coming into more details of the open space planning the microclimatic scale should be investigated and evaluated. This can be shown at an open space Hauptbahnhof in Kassel. First step were measurements with parallel interviews. From that figure 5 shows the local spots (yellow) were thermal comfort never could be reached, while others have a high percentage of thermal comfort throughout a year. The thermal calculation in figure 5 (right) shows that the non comfort places correspond to cool places while the comfort ones are not the hottest points but fairly warm places. The evaluation criteria climate variability shows in a yearly average the frequency of occurrence of a certain thermal comfort situation.



Suitable climate conditions for use in accordance to the corresponded optimal PET value

1. Red lines as walking space within the heat island suitable for cultural events and exhibitions and cafes (PET 22°C)
2. Open places in the heat island near buildings (lilac); too much ventilated for calm activities music events proposed (25 °C)
3. Green area near slopes windy and cold stress no open activities possible; a proposal for walking and sightseeing (18 °C)
4. Green vegetation areas; warm but good cooling in summer; proposal for pubs and social events during daytime, wind reduction through plantings proposed (20 °C)

Figure 6 Cultural concept Kassel for open air activities with suitable climates

4.4 Application of urban climatology with the cultural concept Kassel

The union of architects and urban planners (SRL) had developed a concept for an application to become cultural capital. Within this concept they advised different cultural activities in the open spaces of the inner city and towards a park area. Figure 6 shows the connection between the concept and suitable thermal conditions for the planned activities. As said before the use of open space is also depending from climate, therefore the concept in its spatial pattern has to be considered in the microclimatic varieties. The main concept of a walking line between the important cultural events is situated in the maximum heat island with reduced ventilation. This warm areas are adopted well for cultural activities, while a t the slope situation towards the park high winds occur with cold stress most of the time therefore this areas are only suitable for walking and not for sitting outside to have coffee etc. These planned activities were background for the PET values, which should be achieved in that typical situation during summer, when open space activities have their highest frequency.

5 EXAMPLES SALVADOR AND JOAO PESSOA

With an equivalent GIS methodology urban climate studies were carried out in the Brazilian cities of Salvador and Joao Pessoa. For Salvador land use data and topographical data were combined with a wind classification. Result is an urban climate map right in figure 7.

Analysing the climate of Salvador, as a first approach, Andrade et al. (2002) stated that "the climatic condition of the city promote positive thermal stress during the whole year, attenuated during winter season (June, July and August). This was correlated by a calculation of the thermal index PET together with measured climatic data. Main heat stress situation occur in summer all day and during afternoons in winter. From this situation only areas with dense and high buildings were effected. These outcomes

emphasize the need to provide shading through vegetation and to preserve ventilation paths for thermal comfort in tropical cities, as expected (ANDRADE et al, 2002). With a data base of topographical and land use an areal distribution of the thermal comfort could be derived.

For Joao Pessoa the final result is shown, where the different layers already were combined. From that map planning proposals can be derived. Areas for building restrictions are green marked and areas which suitable for urban development red, orange or pink. To each colour a separate proposal can be directed.

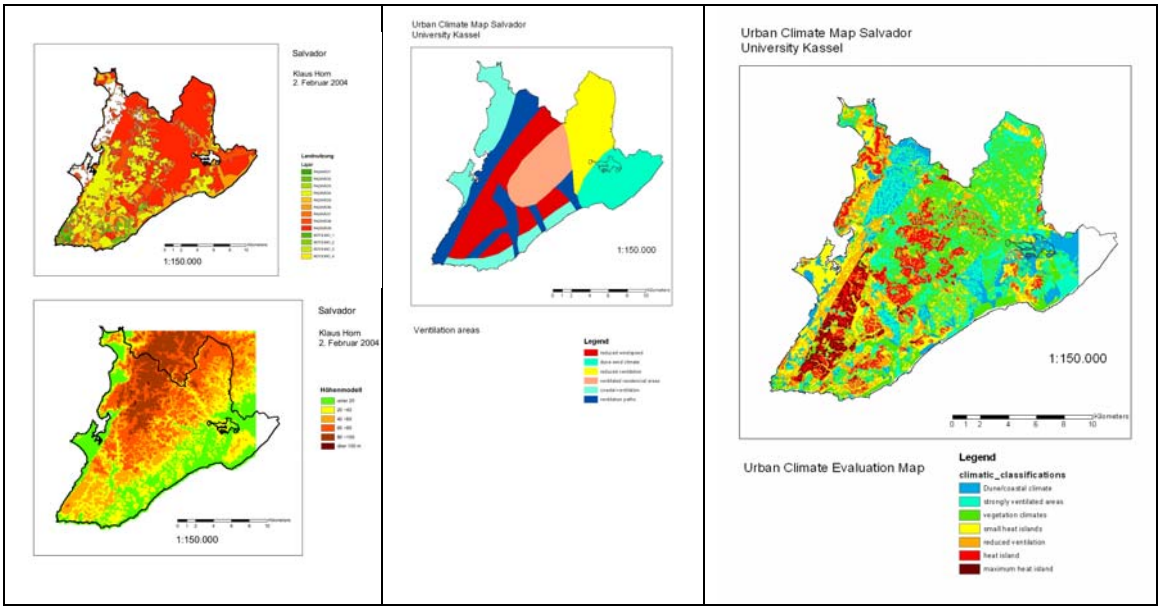


Figure 7 Spatial distribution of attributes for GIS calculation urban climate of Salvador

The results can be better explained with the urban climate map of Joao Pessoa. In figure 8 you will see green and blue areas, which are well ventilated parts of the city due to advection or channelling effects. The hatched areas are even more important as here a high wind penetration into the city is observed, whereas in the grey areas winds are blocked.. For planning purpose this means that in the grey areas it will be most problematic to develop new buildings, while in the green and blue areas urban development has no important effect on urban climate. With the urban climate map every area is described in a climatologically way and translated towards a planning proposal.

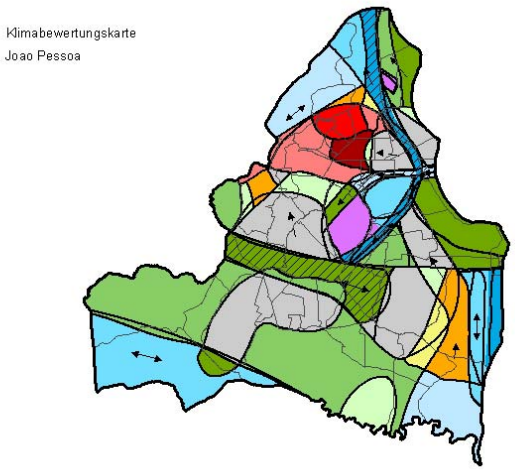


Figure 8 Urban climate map Joao Pessoa

5 CONCLUSIONS

For any urban plan, concept or master plan urban climate maps are important to evaluate thermal comfort for the use of open spaces and ventilation for air pollution problems. One can see that these aspects were separated in different planning levels to which climatic investigations has to be devoted to.

Following the aim of planners to revitalise cities the use of open spaces are in the centre of discussion and here the thermal comfort play an important role. Heat island in this sense can also be seen as positive for mid European cities. Higher varieties of microclimatic situations having the air pollution problem in mind can be good criteria for urban climate. In general it is important to compare the climate pattern with city structures and the use of open spaces at the same levels.

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