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THE APPLICATION OF IR- AND MSS-DATA IN THE RUHR DISTRICT, GERMANY

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ABSTRACT

The Siedlungsverband Ruhrkohlenbezirk (Ruhr Planning Authority - SVR) is a user of remote-sensing data, which are needed for its planning decisions. Since its foundation it has appreciated the value of aerial photography: IR and MS scanners have been in use since 1970. The IR data provide information about the thermal loading of the Rhine, and are also particularly useful for determining the climatology of the urban and surrounding country areas.
The methods used by SVR to interpret the IR pictures are described.
The object of this work is the production of maps indicating the thermal distribution in the conurbation.

INTRODUCTION

The Ruhr District is a polycentric agglomeration with 5.68 million inhabitants. It is well-known as the most important industrial region in Germany. This region also has the most difficult environmental problems.
The Siedlungsverband Ruhrkohlenbezirk, SVR, is a communal umbrella organisation whose job it is to take note of, and solve, problems of the utilization of waste-products, leisure, traffic, landscape planning and the safeguarding of green areas throughout the Ruhr District.
As early as 1926 the aerial photograph was introduced as a basic material. Since this time picture-taking flights have been carried out in regular intervals of a few years. Pictorial plans on a scale of 1 : 5000 are then produced from this material and placed at the disposal of the municipalities as a basis for planning.
Since 1973 a mapping of actual utilization has been carried out with the aid of this pictorial material. It was begun on a scale of 1 : 25000 and is now being continued on a scale of 1 : 10000. This work produces important information about ares balances.
Now is the time, however, to speak in more detail about the employment of IR- and MS-Scanners. These instruments were introduced in the Ruhr District as early as 1970 and have proved themselves especially in water-supervision. An even more important development in the use of scanners was in the scope of the cities, as the IRLS-data produce important information about the "heat-island" of the city, the activity of green areas and the distribution of land-utilization.

Since 1972 the Rhine has been flown over 18 times in sections. In 1973 the entire Ruhr District was photograped 4 times with a scanner, as were a further 8 test areas. In the autumn of 1974, together with the entire Ruhr District, a test area was photographed from various altitudes. In 1975 4 flights in the course of a day produced the thermal behaviour of the earth's surface in the height of summer. As in 1974, an 11-channel scanner was also employed.

The flights over the Rhine between Krefeld and Wesel show clearly the behaviour of warm cooling-water inlets along the river. Their total number is 21. in accordance with the quantity and temperature of the water brought in, cooling-water banners of varying lengths are shown:
3 banners are longer than 5 km, 5 banners are up to 4 km long, 4 banners have a length of about 1 km and 9 of the banners are only a few metres long.

The "heat-island" of the city is especially easy to recognise in the IRLS-photographs. The example of the city of Dortmund can be used to show how the surface-temperature rises with increasing housebuilding.

The individual areas of the city have a varying thermal behaviour in the course of a day. As has been shown in an examination of the city of Essen, above all the degree of sealing can be correlated with the overheating of the city.

Relief plays a large role in a city's climate. The interpretation of IR-photographs must, however, give separate consideration to this, as the work for the city of Wuppertal shows.

The Ruhr District is a polycentric agglomeration whose settlement structures are very complex. Important findings concerning the area-pattern of the settlemnets and the thermal burden on the area can be deduced from the heat-pictures.

A scanning of the data also gives us here the possibility of making quantitative statements about area-sizes and area-behaviour.

Apart from the evaluations of thermal pictures, however, the automatic evaluation of MSS-data is becoming ever more important for mappings of area utilization. It is above all in the inner-city area that there are still difficulties. Preliminary results concerning the distribution of green areas in the city are, however, promising.

SURVEY TECHNIQUES

The SVR has used the Type DS-1230 Daedalüs Scanner for IR and MSS flights since 1973. The data recorded on magnetic tape are reproduced on to 12cm film by a DEI 610 Processor. The individual channel data can be reproduced individually or in combination either analogue or by the equi-density technique. SVR processes and interprets the scanner data under contract to the District Councils in the Association Area, and the results must therefore be reproduced in map form for the various planning officials in the towns to use as basic working material. Because geometric rectification of the scanner data is still very expensive, and also as the problem of correcting the radiometric errors is not solved, cartographic conversion of the scanner interpretations still presents great problems. However, one compensation is that aircraft height and time of photography are not so critical.

There are, however, considerations concerning the most favourable time for flying (Lorenz,1973), and the most suitable weather conditions, but these are so rare in the Ruhr area that flying should take place, ideally without delay, during any relatively dry period when the sky however, can be predetermined, depending on the object of the particular task.

Tasks encompassing the whole Ruhr area are flown at 4,500m. It was found that the most suitable height for town analyses was about 2,000m above ground level, while detailed tasks were flown at between 400 and 800m.

As an example, SVR has had produced a map of the surface radiation temperatures of the whole Ruhr area, for which the colour equidensities to a scale of 1 : 110,000, had to be converted manually into a 1 : 50,000 scale chart representing the core zone of the Ruhr area. The area extends some 60km East-West and 30km North-South. The flight pattern flown during the night of 25 April, 1973 consisted of 6 parallel East-West tracks. The Digicolor process covers the temperature range from -3°C to +9°C in 2°C steps.

SURFACE TEMPERATURE BEHAVIOUR

a) Homogeneaus Surfaces: The thermal behaviour of homogeneous surfaces is best determined by radiometer, a device which measures the heat radiation from a surface. As the scanning angle of the device is very small (1°), the measurement taken is very nearly a point reading.

Comparisons of the surface temperatures of varying types of surface and surface-coverage have been made by a large number of authors (viz, inter alia, ALBRECHT,1952, LORENZ,1962,1966,1967, LENSCOW and DUTTON,1964, FUCHS and others,1967, FUJITA and others,1968, KESSLER,1971, GAY,1972, and von HOYNINGEN-HUENNE,1973). Most of these measurements concentrated on the mid-day maximum, and some on the early morning minimum, in all cases under cloudless sky conditions. Fezer,1975, has collated the investigation results of the above authors. The resultant daytime surface-temperature variation curves are shown in Fig. 1. Kessler,1971, also conducted radiometer temperature measurements in Bonn. Some of his results are shown in Fig. 2, which reproduces the daily mean value determined by him of the temperatures of extremely varied surfaces. The "least favourable" high temperatures are produced by stone, concrete and asphalt surfaces. It is apparent from the illustrations that surface temperature variation is at its least at sunrise, after which temperatures begin to rise at varying rates, and cool down again after sunset at varying rates and to different levels.
Urban superheating is generated by the stone, concrete and asphalt surfaces, whose "unfavourably" high mean temperature is clearly shown in the illustra-

tions.

b) Urban Surface Temperature Behaviour: Measurement of the surface temperature of overgrown areas presents us with problems, as the surface itself cannot be accurately defined. It must be remembered that the values recorded during radiometer measurement from vertically overhead are composed of data emanating from subsurfaces located between the surface of the ground and the upper vegetation level.

Measurements by airborne scanner produce the same problems. The surface temperature of large areas is made up of data determined over extremely diverse surface structures with very different thermal behaviour. It is impossible to determine the surface behaviour of every individual, small, homogeneous surface in an area covered: it is therfore necessary to simplify interpretation of the data acquired. This is achieved by using equidensities - average or approximate values - which must be considered in relation to the known thermal behaviour of characteristic homogeneous surfaces such as grass-covered areas, concrete, wooded areas ans asphalt etc.

During the Summer of 1975, SVR organised four survey flights over the Essen area during the 24 hours between 7 and 8 August. From the data acquired, it was possible to determine the temperature behaviour of urban surfaces (Mahler and Stock, 1976).

First, for 50 selected areas, the type of use, surface-coverage density and the vertical extent of surface coverage were determined. The scanner data were then used to calculate the mean temperature of each surface at all four flight times.

Figs. 3 and 4 show the minimum and maximum surface temperatures. The difference between these produces the temperature-variation shown in Fig.5.

All the examples shown display a rise in temperature with increased surface-coverage and building density, as shown in Fig. 7.

The temperatures for each affected surface were determined with the aid of isolevels: i.e., the distribution of surfaces radiating at the same temperature-level was determined and shown in 1.5°C steps (night) and 3°C steps (day). We therefore had a film record for each temperature step. It was also possible to determine the distribution across the surface and vertically over the temperature profile. In addition the results of the four flights along one profile directly East-West were digitized. The profile was made up of 10 areas, from which the vegetation proportion was determined, as shown in Fig.6. On the other side, the IR channel was used to determine the areas of high thermal radiation. A distinct correlation between vegetation and temperature is apparent: the higher the temperature, the lower being the proportion of vegetation.

THE URBAN HEAT ISLAND

Proof of the existence of the Urban Heat Island has been demonstrated on many occasions (WM O,1974). When installing measurement stations and determining locations, a prior concern is that the different buildings in a town exert different influences on the values recorded. As early as 1885, Hann had already recognised that varying temperaturedifferences between town and country arise not so much from the size of town, but are primarily related to the instrument siting. (Kratzer,1956). The variation between different building layouts, surface contouring and relative building density always produces varying effects on temperature behaviour.

Edmonds also writes (1954): "The validity of my purely mesoclimatic investigations could only be assured by siting (of the measurement equipment) so as to ensure that the area represented was also able to exert its full influence on the equipment." The measurements recorded are therefore determined by the measurement sites selected. The thermal radiation pictures can therefore be drawn on to determine these locations. However, if the detailed thermic composition of a town is known from the radiation pictures, it can be divided into areas of the säme and/or different temperature. It would naturally be difficult to lay down such a division of the town area by absolute air temperature or humidity values, but it is certainly possible to determine the general levels and the climatic balance of the town from thermal radiation pictures. A decisive part is played by the ability to carry out area plotting, as the whole urban area provides readings at the particular instant of recording: we can thus compare different areas of the town with one another. Using conventional measuring techniques, this kind of comparison can only bernade with great difficulty, and lenghty and expensive measurement-sequences are always necessary. From this, methods arise of applying surface-temperature radio-measurement techniques to the problems of urban and inhabited area meteorology and climatology (Lorenz,1973).
The town of Wuppertal, for example, lies in the Wupper Valley, and the effects of surface contour must therefore be taken into account when interpreting the thermal radiation readings.

In thematic charts of the urban area, we have attempted to weight the individual factors and to summate them, choosing the figures 1 to 3, where 1 represents favourable, 2 is neutral and 3 unfavourable.
The thermal distribution pattern noted during one night IR overflight divided the city into cold (1), warm (2), and very warm (3) zones. The contouring was divided into hilly (1), inclined (2), and valley-bottom (3) areas. The usage map distinguished between wooded (1), grassy (2), and built-up (3) areas, while the latter were further sub-divided into scattered (1), closely-spaced (2), and central (3) area building-densities. It will be seen from Fig.7 that the highest radiation temperatures were produced by the areas where the building density was highest. Heatemitting heavy industrial installations also make their presence clearly apparent (Stock,1975).

The Ruhr Heat Islands are shown in Fig.8, and it can clearly be seen how close they are to each other in the West. The towns of Duisburg, Oberhausen, Mülheim and Essen almost form one single Heat Island. The area becomes somewhat less densely-packed towards the East. Only the town of Dortmund is again apparent as a major Heat Island. Classification of this area with the aid of IR photographs and MSS data by the methods indicated above certainly produces important basic material for planning purposes. A first step is the recently-printed surface radiation temperature distribution chart of the Ruhr Area (Stock,1976).

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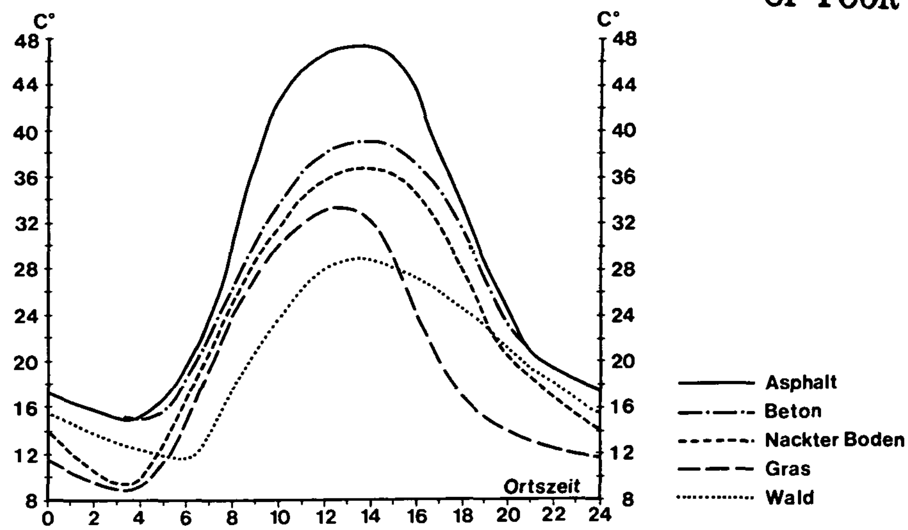

Figure 1: Radiation temperatures of different homogeneous areas (Fezer 1975).

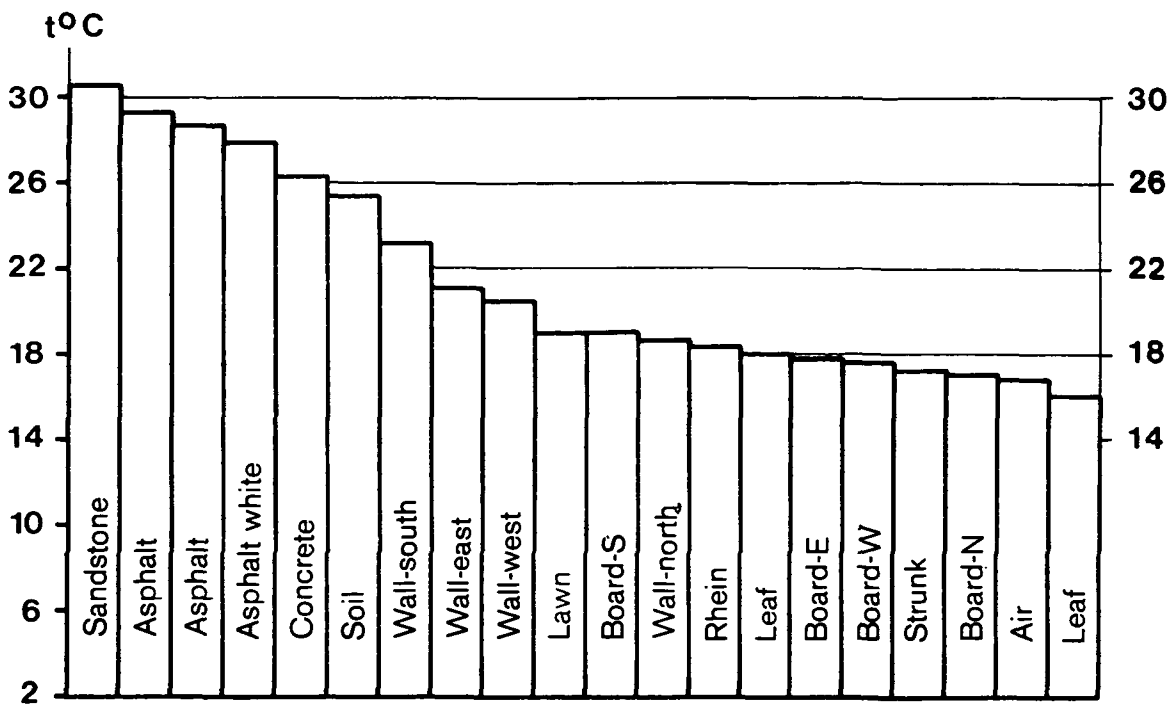

Figure 2: Daily mean of air - and surface radiation temperatures (Kessler 1971)

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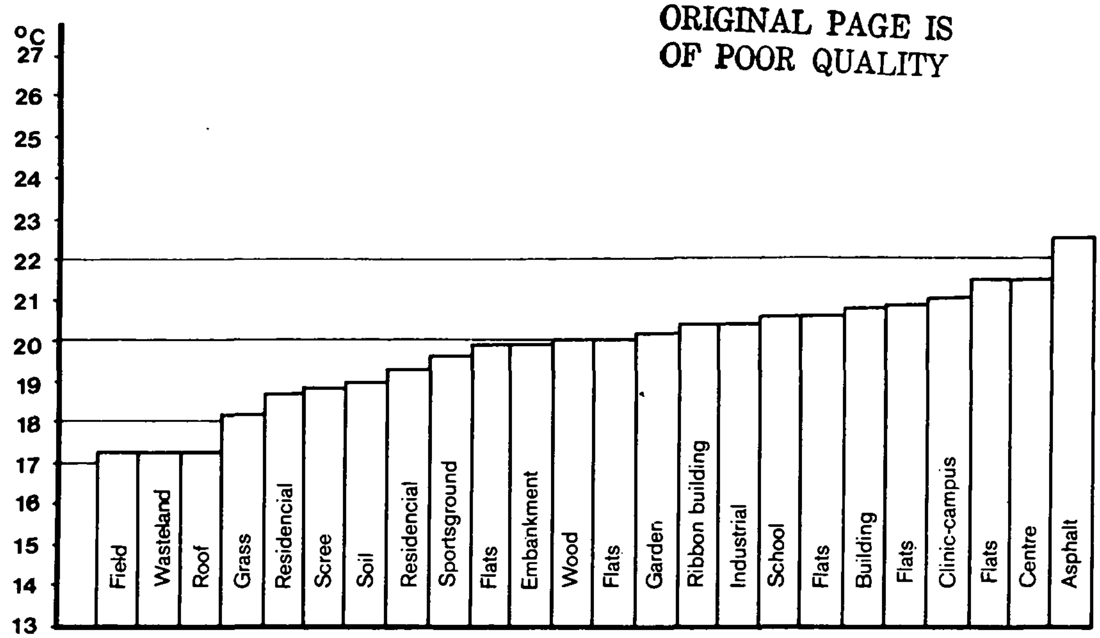

Figure 3: Radiation temperatures over different areas in Essen at night 8.8.1975, 4^{00} h.

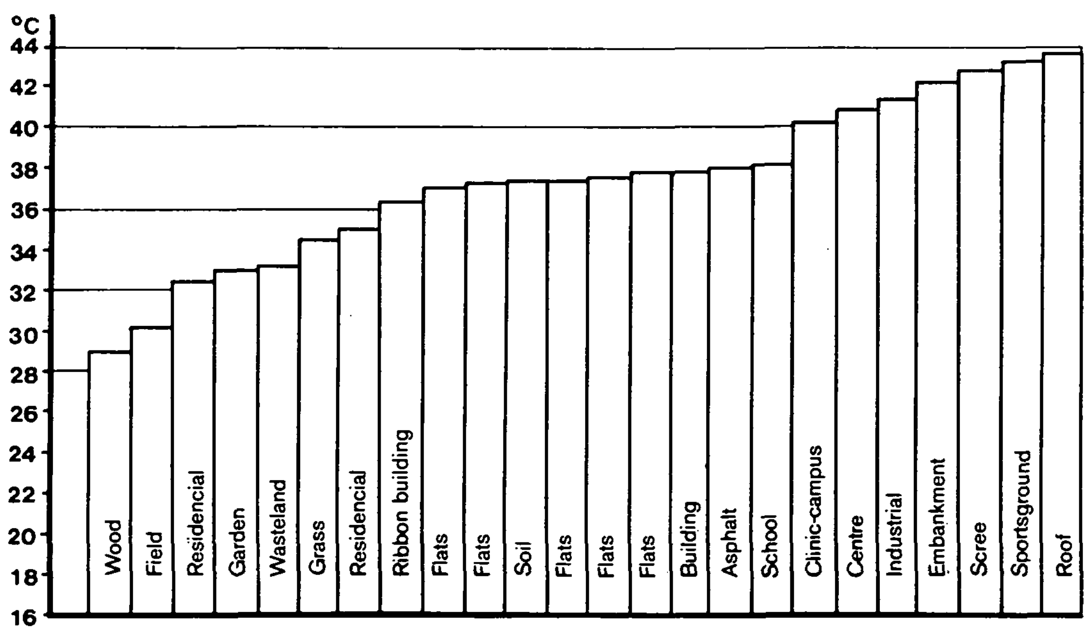

Figure 4: Ratiation temperatures over different areas in Essen at day 8.8.1975, 10^{00} h.

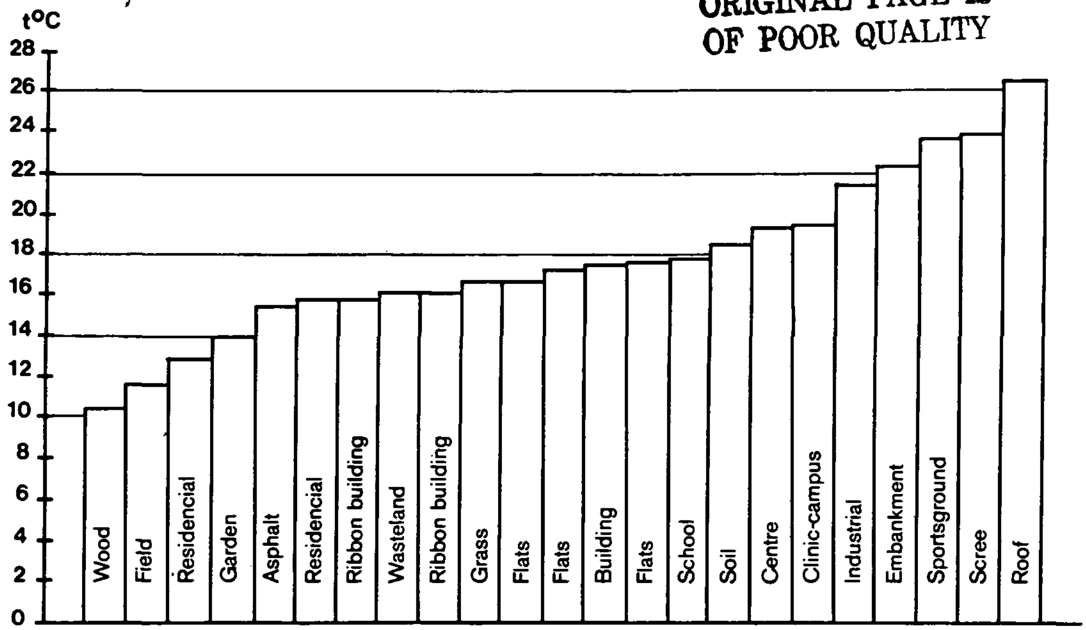

Figure 5: Increase of radiation temperature over different areas in Essen from night 8.8.1975, 4^{00} h to day 8.8.1975, 10^{00} h.

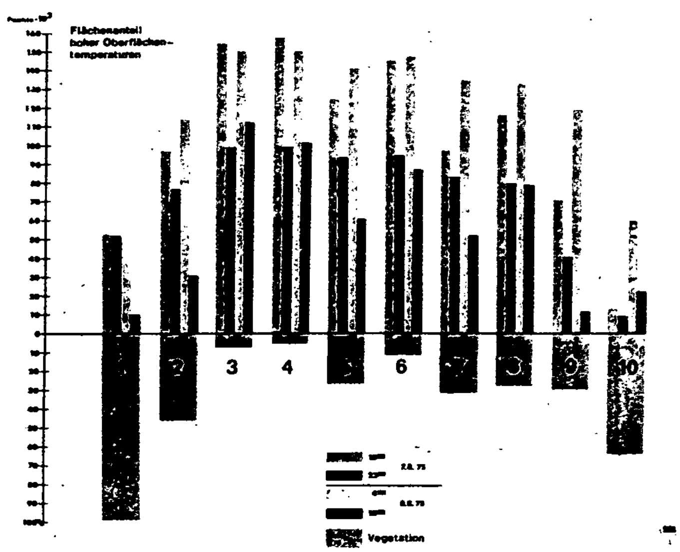

Figure 6: Relation between vegetation and radiation temperatures in 10 areas along a W-E-profil in Essen at 7. and 8.8.1975.

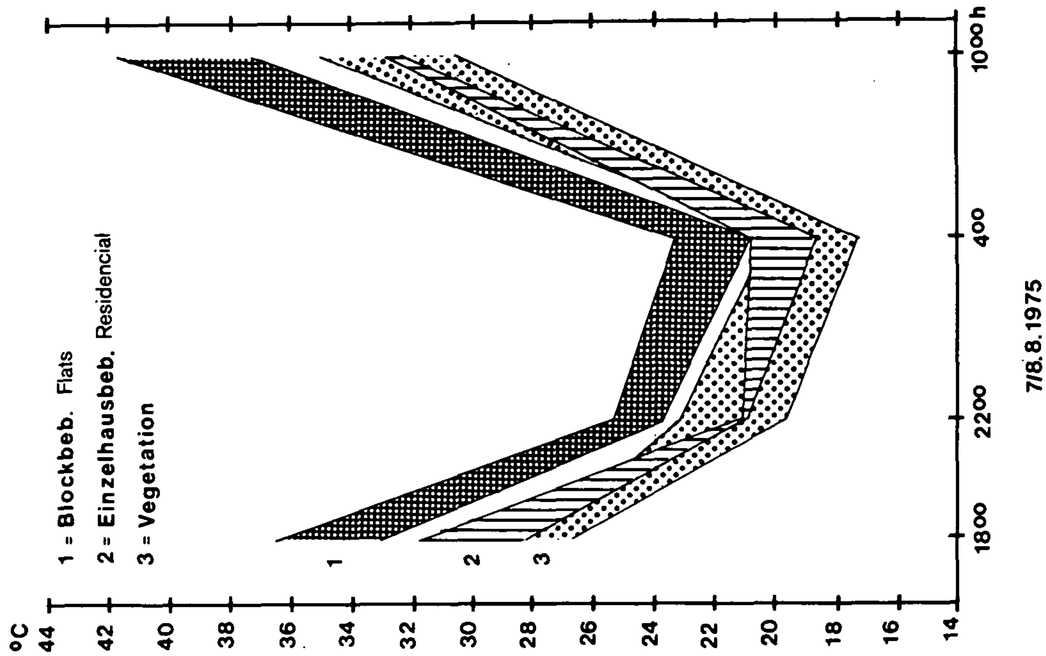

Figure 7: Radiation temperatures in Essen.

Figure 8: Heat-Islands in the Ruhr-District. Max. radiation temperatures at night 25.4.1973.