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CLIMATIC INFLUENCES OF THE GREENS AND CITY PLANNING[1]

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The green spaces of our cities are being exposed to growing pressure. It is not so much the expansion pressure of traffic and built-up areas, though their influence should not be underestimated, as the pressure exercised by propaganda that makes itself felt. Green spaces, we are told, have no influence on the climate of the city; they just favor crime, as a widely circulated article published first in America tries to make us believe. German sociologists insist that today "in areas with blocks of flats frequently far too large green spaces are being laid out, although one should imagine that a society so fully aware of the value of real estate might have learned to make more economical use of so rare a commodity." Green spaces are said to be green waste land, costing time and money for which there is no return; they are more or less empty, we are told, and at their best they might be considered as future building reserves.

Let us remember that in the years immediately after the end of the war the Green Center to be laid out on the ruins of the cities was highly advertised everywhere and widely acclaimed; there were to be no more of those dreary masses of blocks of flats; a modern city should expand into space. And, accordingly, one family houses with small gardens began to eat deeper and deeper into the open country. No wonder that at present the pendulum swings back. Salvation, we are now invited to believe, is to be found in densely built-up cities. How long, or how short a time it will take until counteraction again sets in, nobody can tell.

Again we watch the ancient law of dialectics — thesis calling for antithesis — at work. And yet, are there no certain facts based on a sound foundation and therefore beyond all influences of fashion, short-lived tastes and temporary tendencies to guide us? This question leads us to an examination of the essentials of man, city, nature, and culture, component parts whose joint action is especially conspicuous in a city. Although there is as yet no final answer to all the questions arising in these connections, in spite of computers and other technical gadgets, one point appears to be clear, namely that also in a city, culture can only be a function of man's relation and attitude to nature, whereby nature is not to be considered as mere raw material for man. For man in his physical and psychic being is still subject to nature and to the process of natural functions.

A city is not just a vast mass of buildings, streets, vehicles, and people. A city transforms everything that nature has provided and the final result is even a climate of its own making, different from the climatical conditions of the immediate surroundings. One becomes aware of this change through the natural senses of feeling, smelling, and tasting, and yet no city planner gives this fact the attention that it deserves. Nevertheless, this is the basis on which to build up our case answering the charges of those who claim that green spaces in a city are nothing but waste.

Although in research work good progress has been made in recent years, the findings of the research workers and especially the factors producing climatical changes in our cities, with all their deleterious effects, are far too little known to the city planners. "In the cities departure from the ways of nature and denaturalization in culture have reached their highest degree . . . even

[1] Reprinted from ANTHOS, the official organ of the International Federation of Landscape Architects (IFLA), Volume 5, Number 1, 1966.

climate itself becomes artificial in the cities" (Hellpach). This denaturalization is illustrated by the following findings.

The air in a city is impregnated with a large number of particles which become the nuclei about which such matter as exhaust gases and radioactive substances gather; eventually they will get into the respiratory organs where they will work havoc. (The particles which we refer to here are particles of pollution of a size measuring from one millionth to one five-thousandth of a millimeter.)

Number of particles in one cm^3:

	Average	Max. of average	Min. of average	absolute Maximum
Big cities	147 000	379 000	49 100	4 000 000
Small towns	34 300	114 000	5 900	400 000
Country places	9 500	66 500	1 050	336 000
Coastal areas	9 500	33 000	1 560	150 000
Mountains:				
500–1000 m	6 000	36 000	1 390	155 000
1000–2000 m	2 130	9 830	450	37 000
above 2000 m	950	5 830	160	27 000
Ocean	940	4 680	840	39 800

(A. Landsberg)

Average values of air pollution have been found by Reifferscheldt in Germany shortly after the end of the war to be

	Big cities	Country
Kernels	200 000	8000 per cm^3
Dust particles	270	7–10

We have to remember that findings may vary according to the accuracy of the measuring instruments; their principal value lies in the fact that they allow for comparisons to be made.

The number of dust particles found in sedimentation is stated by Liesegang to be 104 g/m^2 on an average for the years 1933-1940 in the city of Berlin. Today dust sedimentation in Western Germany has reached twice this amount already. These particles are, however, not so dangerous to health. They are normally kept back by the mucus membrane so that they do not find their way into the respiratory organs, whereas the tiny particles suspended in the air do get into the lungs along with all the injurious elements attached to them. Of this polluted air man inhales on an average 12 m^3 per day; it may be two to ten times this amount for hard-working people.

Air pollution varies according to hours of the day and to the seasons of the year as well as to the height above ground. We may distinguish three levels — just above ground, roof level (domestic heating), and level of factory chimneys.

This means that high blocks of flats which are much higher than other houses might easily reach with their upper stories into zones that are polluted to a far greater extent and where the amount of pollution is continually kept on a certain level by the factory chimneys as well as by the smoke from the houses. The content of particles and dust particles leads to the formation of a dust dome which is responsible for UV poorness and dimness of sunlight (loss of 20%) in the cities.

The higher the buildings of a city, they more do they counteract the natural flow of air. To overcome friction energy is used up, the draught action slows down and thus an air cushion is formed above the city. Oncoming air currents have to rise above this cushion and the result is poor ventilation of the city.

Furthermore, the masses of the buildings of a city form an artificial rock that stores up heat during the daytime. Not only with the ground surface, but with all the walls of the buildings as well, and they make up a total far greater than the area itself. And as the masses of the buildings reduce the effects of air currents, the process of carrying off this stored-up heat is slowed down. In addition to this, the amount of heat, which on plant-covered areas is absorbed by the process of assimilation and evaporation, remains practically intact in the areas of the city where there is no vegetation at all. The values measured were found to be exceptionally high (60,000 Kcal/per year/per m^2). During the daytime the centers of the cities can have a temperature up to 10 deg. C higher than the temperature of the surrounding countryside, and the average figures for a whole year show over-temperatures of 0.5 to 1.5 deg. C in the cities. This corresponds to lowering the altitude of the city with respect to sea level by 100 to 300 meters and means a change from normal climate to a more unhealthy climate. At the same time atmospheric humidity is reduced, resulting in an increase of diseases affecting the respiratory organs.

In a short article like this one all these changes with their negative effects resulting from the masses of buildings, traffic, industry, and exhaust gases can only be outlined. The facts have to be taken as such. The figures given here will increase in proportion to growing density, growing traffic and the resulting larger amounts of combustion gases. To be sure, air pollution could be reduced to a certain extent by adequate measures taken at the source, for example by after-burning of exhaust gases, filtering of industrial combustion gases, electric heating in the houses, etc. However, no technical means are available to reduce other deleterious effects such as increased temperature, reduction of atmospheric humidity, slowing down of air currents, traffic dust, unless one would go so far as to build highly complicated weathering installations as, on a smaller scale, are used frequently in the mining industry now.

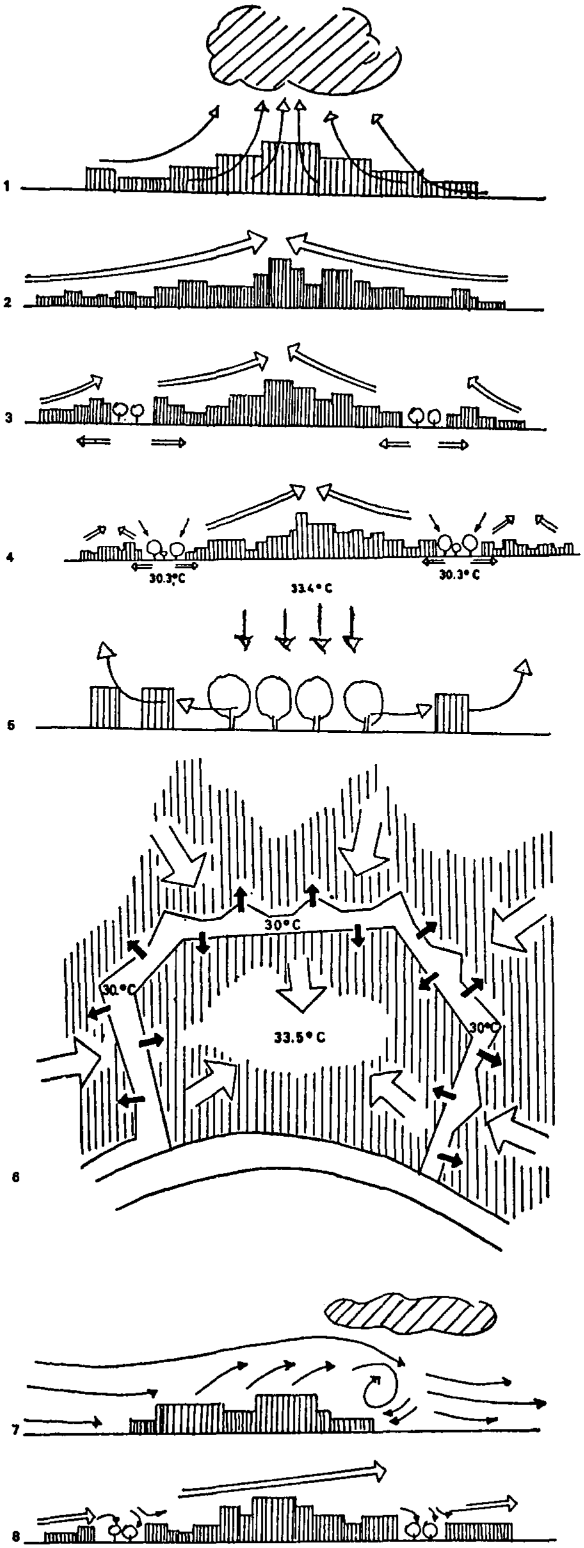
In fact, green spaces are the natural and only effective way of making the unnatural climate of the cities somewhat more natural. By measurements that he took himself at Frankfurt, Germany, the author has been able to prove that green belts — even though they were not larger in width than 50 to 100 meters, have the effect of reducing the temperature in summer by not less than 3.5 deg. C, compared with the center of the city. This corresponds to raising the altitude of the town area by 700 meters (counting one centrigrade of decrease in temperature for every 200 meters of increase in level). These effects of the green spaces — which are, of course, all the greater the higher the temperatures and the larger the surfaces — are highly significant, all the more as continually cool air from the green spaces was flowing to the built-up centers while the measurements were taken. The relative atmospheric humidity showed an increase of 5% in comparison to the town center.

Another important feature is the dust-reducing effect of the greens. To begin with, they produce no dust themselves. Then, if there is no wind, dust elements in the air will settle on the plants in the parks. Measurements taken near the Frankfurt main station and in the town center showed a concentration of 18,000 pollution particles per air unit, whereas measurements taken at the same time at the Rothschild Park (surface 4 hectars) showed a concentration of not more than 1,000 to 3,000 particles per unit. As concerns dust particles the figures read 3,000 in streets planted with trees, compared to 10,000 to 12,000 particles in streets without trees in the same quarter of the town.

The influence of the green spaces on the climate within the city limits varies considerably. Much depends on whether there is wind or no wind, and on the force or intensity of the wind. The braking action exercised by the buildings has also to be taken into account, as well as the above mentioned air cushion which also reduces the effects of the draught near ground level. On windy days the difference of temperature between the city and the surroundings is not so manifest, whereas, on the other hand, the dust-filtering action of the green belts lying in the path of the wind is all the more intense — an important point as the air, while flowing through the city, is being charged more and more with kernels, dust particles, and other foreign substances, so that those parts of the city that are not touched by the breeze will show the greatest density of air pollution.

If there is no wind, i.e. during the hottest months of the summer and under anticyclone weather conditions, when temperatures reach their local maxima, additional air currents are being formed. The air which is being warmed up will rise — especially at places where the density of the buildings and their masses are greatest — whereas from the outskirts of the town currents of cooler air will flow from all directions to the center. These currents are charged more and more with pollution as they flow along, so that the greatest density of pollution results in the centers of the cities. In this case green belts laid out concentrically around the city centers are at their best, their filtering and temperature regulating action working with the greatest possible efficiency. Other parks, spread irregularly over the town area, are certainly not useless in respect of climatical conditions in the city, but they can never show the same good results as green belts that were systematically planned according to prevailing winds and with a view to exercising the most healthy influence on the city climate. The wider and the more numerous these green belts encompassing the city are, the stronger and the more effective are the air currents resulting between the greens and the built-up areas, which will then constantly supply the dense city with fresh, cool and salubrious air. Meadows and fields lying within the town limits are certainly not without any effect on the climate of the city, but they will not produce the same good results as parks with trees and the rich foliage provided by systematical plantings.

In this connection the question whether the amount of CO_2 produced in the towns can be absorbed by the green spaces and whether the necessary amount of oxygen can be produced at the same time is of special interest. Exact figures are not at our disposal and are not likely to become available in the near future. The question must be considered as a whole and the two factors be brought into relationship to each other. Goldmerstein and Stondiek carried out research work in this respect and found, by calculation, a production of 10 million kg of CO_2 within the city of Berlin, whereas the great Park of Berlin, the "Tiergarten," which measures 250 hectars, could absorb 144,000 kg. Calculations of more recent date carried out by the author showed an absorption of 900 kg of CO_2 per hectar in 12 hours (that is the CO_2 content of 6 millio m^3 of air) and the production of 600 kg of oxygen during the same time, the test grounds consisting of lawn and trees and bushes of different sizes whose foliage, according to physiological research, made up a total surface of at least five times the surface of the ground. To obtain exact figures of CO_2 and oxygen values each tree on public and



1. On calm hot days a depression is formed above the city which is filled from the sides.
2. Continual increase of air pollution as well as of temperature in direction of the center of the city.
3. The increase of air pollution is interrupted by the greens, and the air is filtered.
4. Interruption of the temperature rise, cooling down of the air by the greens, providing the built-up areas with cool, salubrious air.
5. Diagram showing the balancing of temperatures between the greens and the built-up areas. Filtering of the falling air by trees. Cooler and cleaner air flows to the built-up centers.
6. Effects of concentrically laid-out greens on temperature.
7. On windy days. Diagram showing the direction of the main air currents and pollution of the town.
8. Filtering action of the greens.

private ground and every spot of lawn would have to be taken into account.

The warmed up air rising from the ground certainly contributes to the aeration of the city, but, as we have seen, the air which is drawn into the city center, where there are no greens, is of poor quality. Therefore, this "ventilation" is of small importance. More efficacious are the little currents resulting from differences of temperature and flowing from the parks through the lanes of the densely built-up quarters. Cooler and cleaner air thus shifts underneath the warmer and polluted air and produces an exchange in horizontal direction which reaches the smaller and larger spaces. On hot and calm summer days quite an efficacious reconditioning can take place in this way. In the evening, however, the air pollution will come down from the dust-dome above the city as the air is getting cooler, and that is when the filtering action of the foliage of the trees will set in.

What green spaces can perform in the interest of the climate of a city is best illustrated by the work done by a single tree. Let us take a free standing beech, 80 to 100 years old. With its crown of 15 meters in width and its height of 25 meters it covers a spot of 160 m^2. The total surface of all its leaves adds up to 1600 m^2. But this is the outer surface; the inner surface of the leaves, i.e. the total of the cell walls which are active in assimilation, makes up a hundred times as much — according to plant physiologists (Walter) — that is 160,000 m^2. The dry weight of all the wood of this tree is about 240 cwt (15 m^3 x 800 kg). Half of this is carbon. As one m^3 of air contains 0.15 g of carbon on an average, the 120 cwt of this tree result from 30 million m^3 of air. Consequently, in its 80 years of life this single tree has taken up and transformed the total carbon content of 40 million m^3 of air (that is of 80,000 one-family houses, or the volume of 3 houses per day). At the age of 80 this tree transforms 2,352 g of CO_2 and 960 g of water (making a total of 3,312 g) per hour into 1,600 g of glucose, using up 6.075 Cal. of sunlight, and giving 1,712 g of oxygen to the air (totalling again 3,312 g). As a man uses up the oxygen production of 150 m^2 of leaf-surface per year himself, theoretically, 30 to 40 m^2 of green space are required per inhabitant from this point of view.

Improvement of the climate of a city is of special importance as far as the center is concerned. That is where the green spaces are small — if there are any — and have a tendency of getting still smaller. It must be pointed out that green spaces are not interchangeable if they are to have any influence on the climate of the city. Or, in other words, a tree cut down in the center of the town cannot be replaced by a tree planted somewhere at the edge of the town, where its influence of the climate is irrelevent.

As we see, green spaces are much more than ornaments to enhance the beauty of our cities, although, in planning, they are often valued on that account only. This is by no means their only merit. If in the year 2000 we have cities which are built still more densely, with still higher houses, more cars and greater quantities of exhaust gases, then it will be evident that the city climate — already now conspicuous by negative values — is still worse, and it follows that all the measures that can be taken in the interest of keeping the air in tolerable condition should be carried out now. A tree requires about 35 years to grow. Improvement of the city climate can only be achieved by green spaces that are carefully planned. Theirs will be the greatest contribution to establishing tolerable conditions. All other measures that might help should not be neglected — but they should come in the second place. As the situation is different in each case, no hard and fast rules about planning and layout of the green can be given, but those who are in authority and the city planners should at any rate be acquainted with the scientific aspects. As regards climatical conditions in a city green spaces will always accomplish an important task. This makes them so valuable, even if they should not be used as recreation grounds as it is sometimes (quite wrongly) claimed. Whether their lay-out — with "picturesque" variations of trees, bushes, shrubs, and lawns — is always to best advantage in the interest of climate improvement is a different matter.

Practical application of what we know about their influences on climate depends on the question whether greater density in city building or, on the contrary, greater dispersion is to be recommended. If such an alternative is to be taken into consideration at all, then we should first be clear about what greater density actually means. In examining this question we find that the negative effects (impairment of air exchange, heat accumulation, higher temperatures, less sunshine in winter, etc.) will increase in proportion to the larger masses of the buildings and their height. Even if we leave the heavier traffic apart which will necessarily be the consequence of compact building, we find evidence to show that every additional m^3 of building masses has its definite deleterious effect on climate within the city which can only be made good by intense planting of the free spaces between the buildings. Placing large tubs with plants will not meet the case; the only answer is trees of quite some size, and consequently the subterranean garages and other rooms should be covered with a layer of soil thick enough to allow for the trees to grow to substantial heights. Why should not the centers of the future cities (of the Tertiary Economy, according to Fourastier), which are accessible only to pedestrians and consisting of large spaces surrounded by office towers — late descendents of the classical columns around the forum of the ancient world — become healthy places, thanks to intense plantings warranting a healthier climate. If they look attractive at the same time so much the better.

The other extreme, innumerable houses with gardens of a size of 1,000 m^2 and more, thus spreading the living quarters over a very large area — must be ruled out, too, as the land reserves are getting scarcer every year. Towers with flats to meet the problems of dwindling land reserves is certainly not an ideal solution either and, hence, adopting the middle course is the only possible alternative. It means limitation of man's private sphere, in opposition to the public sphere, to a certain extent, so that, indeed, such dwellings would form a modern counterpart to the classical Roman Atrium. The space should measure at least 200 to 250 m^2, else the "green chamber" would be too small, but it should not exceed 250 m^2 either. If segregation of motorized and pedestrian traffic is planned in such a way as to provide paths for pedestrians between the private greens, then these greens can form part of a general conception which includes measures for the improvement of the climate. The space requirements of these private greens are then by no means prohibitive. In Western Germany, for example, the census of 1961 shows that 4,010,000 dwellings are inhabited by one person, 5,156,000 by two persons, and 10,994,000 by more than two persons.

Out of the latter 10 million families about 5 million may already have a garden, which means that, roughly, 5 million more families might wish to have one. If such a garden should measure 300 m^2, then the total area would be 1,500 km^2 — which is equal to 0.6 percent of the total surface of the Federal Republic. This is certainly not unreasonable, especially when compared to the general use made of the available area in towns with more than 10,000 inhabitants. Taking again Germany as an example, we find the following figures:

Surface covered by building	19.9%
Streets and squares for traffic	9.0%
Green spaces	2.0%
Agricultural grounds	43.0%
Forestry grounds	18.0%
Ponds, rivers, etc.	3.1%
Other spaces	3.7%

Although in this article special emphasis is given to the influence of the greens on climatical conditions in the cities, the author is by no means of the opinion that other considerations are of minor importance. Towns, after all, are not just places where to dwell, to work, to earn and to spend money. They should be more than places where we find culture. They should be places where one can live, in the full sense of this word. The greens can highly contribute to making life in a town more worthy of a human being. But they must be planned ahead. They take time to develop. The trees for the year 2,000 must be planted now.

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