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Article

Integrating Urban Heat Assessment in Urban Plans

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Abstract: The world is increasingly concerned with sustainability issues. Climate change is not the least of these concerns. The complexity of these issues is such that data and information management form an important means of making the right decisions. Nowadays, however, the sheer quantity of data is overwhelming; large quantities of data demand means of representation that are comprehensible and effective. The above dilemma poses questions as to how one incorporates unknown climatologic parameters, such as urban heat, in future urban planning processes, and how one ensures the proposals are specific enough to actually adapt cities to climate change and flexible enough to ensure the proposed measures are combinable and compatible with other urban planning priorities. Conventional urban planning processes and mapping strategies are not adapted to this new environmental, technological and social context. In order come up with more appropriate urban planning strategies, in its first section this paper analyzes the role of the urban planner, reviews the wide variety of parameters that are starting to be integrated into the urban planners practice, and considers the parameters (mainly land surface temperature, albedo, vegetation, and imperviousness) and tools needed for the assessment of the UHI (satellite imagery and GIS). The second part of the study analyzes the potential of four catalyzing mapping categories to integrate urban heat into spatial planning processes: drift, layering, game-board, and rhizome.

Keywords: mapping; urban planning; urban design; climate adaptation; urban heat; urban heat island

1. Introduction

There seems to be a clear mismatch between existing urban planning tools and the actual urbanization processes [1]. Corner refers to urbanists such as Banham, Soja, Harvey, Koolhaas, or Tschumi, to highlight the need to study a broader range of parameters (territorial, political, psychological, social, *etc*.) and interactions beyond the purely formal ones, to ensure alignment between the urban planning discipline and the on-going urbanization processes. Traditional urban planning focused on the production of rigid proposals, organizing objects and functions, and seeking to reinstate in a certain way a lost stability, instead of evolving and adapting to the instability of today´s spaces and structures [2].

One of the parameters that growingly affect cities' comfort is urban heat accumulation. The temperature difference between the urban environment and its immediate rural surroundings is defined as the Urban Heat Island (UHI). Several studies analyze the UHI in cities such as London [3], Paris [4,5], or Pune [6]. There is an increasing awareness of the impact of urban heat on health and comfort of the population [7]. In the framework of the Dutch research program Climate Proof Cities, the authors were assigned with the task to develop urban design guidelines to improve the adaptation of cities and regions to urban heat accumulation.

The research questions for this particular study were:

- How can we incorporate climatologic parameters, such as urban heat, in future urban planning processes?
- How can we ensure that the mitigation proposals are accurate enough to prevent heat accumulation and open enough to ensure they are compatible with other urban planning priorities?

In order to come up with renewed urban planning mapping strategies and tools, the first part of this study reflects on the mapping processes connected to the original nature of urban planners' activity—which somehow falls in between the artistic creation and the scientific assessment—then illustrates the diversity of the parameters affecting contemporary practice—which are mainly environmental and digital—and, finally, identifies relevant indicators and mapping instruments to represent urban heat accumulation during heat waves. The second part of the study suggests catalyzing mapping strategies—drift, layering, game-board, and rhizome [1]—for the integration of urban heat into future urban planning processes.

2. Methodology: Overview of the Role Mapping as a Design Tool

2.1. The Nature of the Urban Planners' Work

Many instruments have been developed, throughout history, in order to help increase the accuracy with which we represent the physical world that surrounds us. These instruments can probably be classified into two groups: the instruments that help represent the world we perceive, and the instruments that allow visualizing the world that the bare human eye cannot grasp. Regarding the representation of the world we perceive, Nuti [8] reminds us that Vermeer and Saenredam consulted geodesists or surveyors to construct their paintings, while a couple of centuries later other artists used transparent glasses. In the 19th century the use of panorama also became rather extended. Artists were mostly concerned with the accuracy of the representation of the perceived world. In turn, it seemed that scientists were rather more concerned with the representation of the world that the human eye cannot see. Cosgrove associates this concern to modern scientific curiosity, and mentions the telescope and microscope as the most extreme examples [2]. Both artists and scientists used instruments to increase the accuracy of their representations; however the representations by artists contained, comparatively, a higher degree of subjectivity than those by scientists. The observation of cities by urban planners seems to fall somewhere between these two worlds. On the one hand cities and landscapes are physically perceived by the human eye and, on the other, cities are more than ever influenced by "invisible" parameters that need to be taken into consideration. The urban planner is, therefore, supposed to reconcile both the tangible world that shapes the cities, and the intangible parameters that influence it. Urban planners can be seen as both artists and scientists or, as Weller states [9], planners need to address both planning (which typically refers to mechanical systems and land-use designation) and design. Many urban planners urge for the development of new urban planning tools to update our discipline to the current times. Girot [10] precisely refers to the need to achieve a balance between scientific and empirical data through the development of new instruments when intervening in our cities.

The potential of mapping is somehow undervalued because many urban planners and designers still believe in the undisputed neutrality of maps, which makes them perceive mapping as a systematic action, consisting merely of the automatic translation of data into drawings, thus missing the opportunity to explore its unique potential. Accepting this inherent "opacity" and subjectivity should not detract the value of maps; on the contrary, it just unfolds the endless possibilities of the tool. As Cosgrove states "mapping *a priori* features are scale, framing, selection and coding" [2]. Regardless of the degree of intentionality with which these actions are undertaken, the four of them are inherent to the mapping activity. They all imply decisions that alter our way of representing and interpreting a given reality, unfolding connections between dissociated elements and revealing the emergence of hidden structures [1].

2.2. New Parameters to Be Integrated in Contemporary Practice

Traditionally, urbanism studied shapes and land uses, which change little over time. In the 1970s, exogenous parameters started to be integrated into design and, already by then, Science magazine praised the landscape architecture department of the University of Pennsylvania, founded by McHarg [11] because of its multidisciplinary team, which integrated physicists, biologists, sociologists, architects, landscape designers, urban planners, and territory planners. McHarg's Design with Nature [12] was actually the seed of the integration of new parameters in the design of landscapes (we shall note that back then the polarity between the urban and the rural delimitated, very clearly, the field of action of urban planners and the one of landscape architects), overlapping wildlife habitats with geological landmarks, water-table constraints, or scenic value into the design guidelines. In the 1990s, Corner took over McHarg's legacy with a less guided approach towards the integration of disciplines, generating a set of inspiring and revealing maps during his aerial trip with MacLean, which actually culminated in the production of the book "Taking measures Across the American Landscape" [13]. In parallel, Deleuze and Guattari [14] reflected on the dynamism of the processes influencing the lives in cities.

In the present days new instruments need to be explored in order to be able to assess the two main changing realities that characterize the post-industrial world, which according to Shane are the technological and the ecological ones [15]. Grimm *et al.* stress the need to incorporate geological, ecological, climatic, social, and political data to describe and understand urban functioning [16]. Girot refers to the invisible "natural substrate of the sites" and, more specifically, mentions the natural water flows (covered or diverted), the erased topographies, or the fragmentation of forests [10]. Cities have started to be considered as dynamic, living organisms. Ridd and Hipple refer to cities as ecosystems and, as such, they identify the energy and moisture fluxes as the main drivers of their activity [17]. They use remote sensing to investigate parameters such as anthropogenic energy or the percentage of imperviousness of surfaces, parameters that affect these two balances. Aligned with this dynamic concept of cities, Acebillo refers to the urban metabolism and studies parameters such as energy consumption, waste emissions, or mobility matrixes [18]. Chao *et al.* [19] have produced a review of the evolution of the urban climatic maps which propose urban planning guidelines based on parameters that range from thermal imagery to topographic maps, land use maps, urban air paths, emission maps, *etc.* By means of energy potential mapping, or heat mapping, Broersma tracks city's heat characteristics; these can be represented by layered maps or three-dimensional images [20]. Their heat map of Rotterdam maps the heat demand and yield potential. Van der Hoeven and Wandl mapped air and land surface temperatures, the components of the surface energy balance, as well as social and physical factors that contribute to the vulnerability of the urban population for urban heat [21]. Other urban planners have started to study a wide range of statistics concentrating in the behavior of citizens, crime rates, surveillance, traffic, light-switch activity [22] (Figure 1), or even cell phone activity [23] (Figure 2).

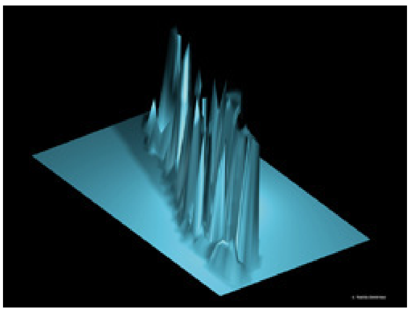

Figure 1. Densityscape, New York City, a three-dimensional map depicting the super-dense residential population landscape of Manhattan Island [22]. The exposed city: mapping the urban invisibles. London: Routledge.

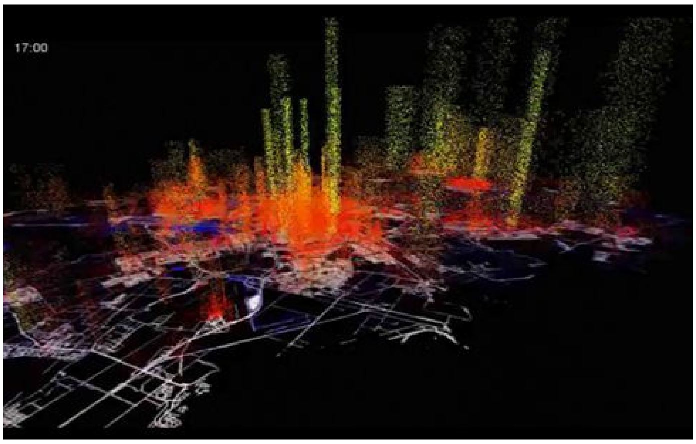

Figure 2. SMS activity at midnight, New Year's Eve in Amsterdam [23].

The incorporation of new disciplines in urban planning processes, imply not only the need to study, analyze, and interpret new parameters, but also the need to understand the way these evolve in space and time. The most didactic metaphor we can find to describe this phenomenon is Weller's "fluid field" of data, ideas, and form when referring to cities and landscapes [9].

2.3. Urban Heat Assessment

2.3.1. Urban Heat Indicators

There are two main categories of urban heat islands: the air temperature urban heat island (UHI), which concentrates in the air temperature difference, and the surface urban heat islands (SUHI), which measures the surface temperature difference. They have different behaviors and patterns. The SUHI hits its peak during daytime, when the sun is still shining, reaching up to 15 °C difference [24], whereas UHI reaches its peak after sunset, when warm urban surfaces start radiating the heat absorbed during the day towards the atmosphere, registering air temperature differences of up to 12 °C. There are several studies that correlate the urban heat to the size of the cities. A linear correlation was established in 1973 by Oke between maximum urban heat island intensity and the logarithm of the population of cities in Europe and North America [25]. In Japan and South Korea, similar studies have been carried out [26,27]. It was only after the heat wave of 2003, which caused over 70,000 deaths across Europe [28], that urban heat started to be perceived as a concern [29].

Air temperature seems a more relevant indicator of human comfort than the surface urban heat island. However, retrieving consistent air temperature data in the urban environment is a challenge. In the particular case of the Netherlands, the KNMI meteorological stations are all located in the rural environment, precisely to erase the influence of urban heat in the temperature retrieval. With the emergence of the Internet of Things and the involvement of citizens in the gathering of scientific data new possibilities emerge. Netatmo, producer of personal weather stations, gathers live data of all of its connected weather stations to visualize it online on a scalable weather map, while allowing the data to be harvested by means of a public application [30].

Consistent surface temperature data can also be mapped using satellite imagery. Even though the spatial pattern of UHI and SUHI differs [31], many climatologists use land surface temperature to assess the urban heat accumulation behavior [31–39]. Moreover, remote sensing also allows mapping parameters that influence the urban thermal behavior, such as albedo, vegetation index, imperviousness, storage heat flux, latent heat flux, and sensible heat flux.

The vegetation index can be considered as a relevant indicator for urban heat studies. Several studies show that minimum air temperatures and vegetation indexes (more specifically the Normalized Difference Vegetation Index—NDVI) are correlated: there is a linear relationship between the difference of urban and rural NDVI and the difference of the urban and rural minimum air temperatures [40]. In rural environments, heat fluxes can be expressed as a function of the vegetation index [41,42].

Albedo is an index that represents surface reflectance. It is strongly related to urban heat. Increasing the albedo of roofs and pavement reduces their surface temperatures. When a surface has an albedo of 0, it means that it does not reflect any radiation, whereas an albedo of 1 means that all of the incoming radiation is reflected by the surface to the atmosphere. In European cities the average albedo is around 0.20 [43]. Increasing the surface albedo from 0.25 to 0.40 could lower the air temperature as much as 4 °C [44].

Imperviousness makes a strong contribution to urban heat. Imperviousness seals the surface, it prevents water from evaporating, and hinders the growth of vegetation. In this way it prevents solar radiation from being converted into latent energy. Impervious surfaces have in addition, the capacity to store heat during the daytime. The heat that is stored in this process is then released at night.

The influence of other factors such as sky view factor (SVF) does not seem to be clear. Some studies find a clear correlation between SVF and nocturnal UHI [45,46], while in other cases the correlation is not so clear [47]. In any case the three-dimensional analysis of the areas is often critical to ensure that the effect of the building radiation is also taken into consideration.

2.3.2. Instruments and Technology Used to Produce Urban Heat Maps: Remote Sensing

For urban planners the principal limitation of remote sensing lies in the fact that even though an aerial view provides a very comprehensive overview of cityscapes and landscapes, these must be complemented by the analysis of other tangible (street level views, pedestrian flows, *etc.*) and intangible parameters (economic activity, social cohesion, *etc.*). Weller [9] also warns about the risks of granting excessive attention to aerial photography. However, the most important challenge for urban planners is to be able to turn these accurate and precise images into maps. Satellite imagery, *per se*, cannot be taken as a true record of reality. First, the selection of scale and frame are critical, and then the way in which the information is filtered and represented also plays an important role. Mastering the use of software to treat satellite imagery becomes critical for urban planners to be able to integrate these into design.

ENVI is a geospatial software designed by Exelisvis [48] to process and analyze any kind of satellite imagery. The combination of ENVI and GIS allows for the greatest integration between the available raster and vector information. There is a third type of software consistently needed to work with satellite information. These are the programs that atmospherically and geometrically correct the raw satellite imagery. The geometrical correction is needed in order to be able to transpose the information retrieved from the curved surface of the earth into a two-dimensional image. The atmospheric correction is needed because the satellites retrieve the radiation emitted by the surface of the Earth through the atmosphere. The radiance retrieved is somehow distorted due to the composition of the atmosphere (humidity, chemical content). Atmospheric correction software "erase" the effect of the atmosphere from the retrieved radiance through the use of certain atmosphere composition models which vary, depending on the latitude and longitude, on the season, and on whether the image captures a rural or an urban environment.

The satellite images themselves, can be downloaded through the US Geological Survey Global EarthExplorer [49], such as Landsat or MODIS. Landsat 8 has a resolution of 100 m and MODIS of 1 km. Land surface temperature, heat fluxes, and albedo can be mapped using Landsat imagery (100 m resolution) and processing it in ATCOR [50], which allows not only completing the geometric and atmospheric correction of the images but also calculates the before-mentioned parameters. Satellite imagery product MODIS 11A1 (1 km resolution) contains a layer where land surface temperature (day and night averages) and albedo are already processed and calculated. In this study we have only focused on the use of open source satellite imagery which have enough resolution to assess the SUHI at a city and regional scale. There are high-resolution satellite imagery which provide a more accurate analysis; however, these are not open source.

The normalized difference vegetation index is typically used to calculate vegetation index. It can be mapped after calculating NDVI = (NIR − VIS)/(NIR + VIS). Where VIS is the surface reflectance in the red region (650 nm) and NIR is the surface reflectance in the near infrared region (850 nm). If we want to use Landsat, both NIR and VIS are bands of the satellite imagery. If we use MODIS, NDVI is included as one of the satellite products.

The production of land surface temperature maps, vegetation index maps, and albedo maps is, therefore, not straightforward. Urban planners have started to integrate new tools and parameters into their plans and maps, to ensure their designs address the concerns of a world in constant change. The great disparity of newly assessed features and map typologies reveals the struggle of urban planners to find means to represent and integrate new disciplines into their plans. New planning processes require updated mapping typologies that efficiently address climatic and social contemporary issues, while providing an overall spatial vision and direction.

3. Results: Catalyzing Mapping Strategies to Suggest Urban Heat Adaptation Guidelines

Drift, layering, game board, and rhizome are four creative mapping strategies that have been studied as urban planning catalytic strategies first by James Corner [1], and further by Aarie Graafland [51]. Even though we can find some overlaps and similarities between the before-mentioned mapping principles (and the practical examples used to illustrate them) each of these techniques is meant to provide different visions of existing and future urban environments and landscapes. Each of them is meant to be created by different author categories (urban planners, decision makers, *etc.*), addresses different audiences (citizens, politicians, *etc.*) and are meant to trigger different actions and processes (revolution, interrelate different parameters, identify main processes taking place in cities, *etc.*). We have used these four categories to come up with innovative ways of suggesting urban design measures to adapt existing and future urban areas to the UHI, and we have actually associated each of them with a different phase of the urban planning process.

3.1. Game-Board: Preliminary Strategic Analysis

Game-board is a mapping process which aims at identifying hidden driving forces which "strongly affect physical states and behavior" and which are actually manifestations of global influences on local environments [52]. Unplanned urbanism or slums probably represent the most extreme example of the variety of factors (beyond the urban plans, regulations and policies) intervening and affecting the urbanization process. In Bunschoten's book "Urban Flotsam" [53], he describes different phases to identify the "field of forces"; the first chapter—"proto-urban conditions"—analyze their way of functioning; the second chapter—"taschenwelt"—in English, "pocket world", investigates ways of intervening in those on going processes; and chapters three and four—"taxonomy and unfolding". The whole process's aim is to develop scenarios to promote and inspire negotiations between the different driving forces. Game-board is not just one more mapping procedure; it should actually be the first phase of any urban planning process. Many extraordinary spatial plans and visions never actually see the light of day because they fail to involve all "actants" (partners, agents, and actor). Game-board is a strategic analysis, which is even more crucial, in the case of the implementation of design guidelines to adapt cities to urban heat. Urban heat is one of the most worrying consequences of climate change in cities; however, the measures to reduce it should always be combinable and compatible with the rest of the social, economic, and environmental priorities defined in the spatial visions of the different municipalities. In a thermal study of Midden-Delfland parks [54], the preservation and promotion of the cooling capacity of this provincial park located between Rotterdam and The Hague, could be considered as one proto-urban condition to be incorporated into the Spatial Vision of the region of South Holland [55] which, on the one hand, aims at developing the necessary infrastructure to connect the two cities and, on the other hand, intends to protect and preserve the park. Echevarria *et al.* carried out a detailed land use assessment to come up with different design scenarios (Figure 3) to increase the Midden-Delfland park's natural cooling capacity, suggesting landscape interventions which are flexible and combinable with the rest of the spatial planning priorities. Several urban hotspots were identified in the park's surroundings and different design measures are proposed to increase the cooling capacity of the park areas adjacent to the hotspots. The study analyzes how the average night and day time surface temperature varies depending on the nature of the park land use (forests, cropland, grassland, water surfaces, built areas, and greenhouse areas) size and shape of the patches, and the design solutions proposed to increase the cooling capacity of specific park areas are based on these conclusions.

Figure 3. Diagnosis and adaptation design for hotspots with an LST > 42 °C [54].

3.2. Rhizome: Integration Schemes

The "plane of consistency" [14] is highlighted by Corner as the core of the rhizomatic mapping, and summarized as an inclusive (of existing elements) and structuring (of new connections) plane [1]. We suggest this representation practice, as a second phase of the planning process, which would take place after the game-board phase. If we understand game-board as the strategic thinking, rhizome would consist in mapping the "actants'" influences, relating one with the other and suggesting open and combinable actions. In this context rhizome mapping would contain and represent not only the physical environment, but also abstract considerations, political or administrative neighborhood boundaries, accessibility, social tendencies, *etc.*, identified during the game-board phase. The implementation of urban heat adaptation measures in existing cities will often require the intervention in existing urban contexts, as the sole thermal argument is, most of the time, by itself insufficient to justify integral neighborhood interventions. In their study called "Surface thermal analysis of North Brabant cities and neighborhoods during heat waves" [56] Echevarría *et al.* relate conventional neighborhood classifications (high-density city center, city center, pre-war neighborhood, post-war compact neighborhood, *etc.*)—developed (among others) for housing policy implementation and created based on density, accessibility, function mix, and building quality criteria—with surface thermal clusters (Figures 4 and 5). Each thermal cluster comprises surfaces with specific combinations of albedo, NDVI, and imperviousness and, thus, specific interventions are associated to each of them for their surface temperature reduction (the Cluster 1 signature corresponds to areas with large asphalt patches. Intervention proposals to reduce surface temperature of asphalt patches would include introducing a high reflective coating, reducing the imperviousness of the surface in specific areas or introducing shades to prevent exposure to radiation). Relating the surface thermal analysis, to an existing neighborhood classification is a way of integrating the climatologic study into the existing political, operational, and administrative framework.

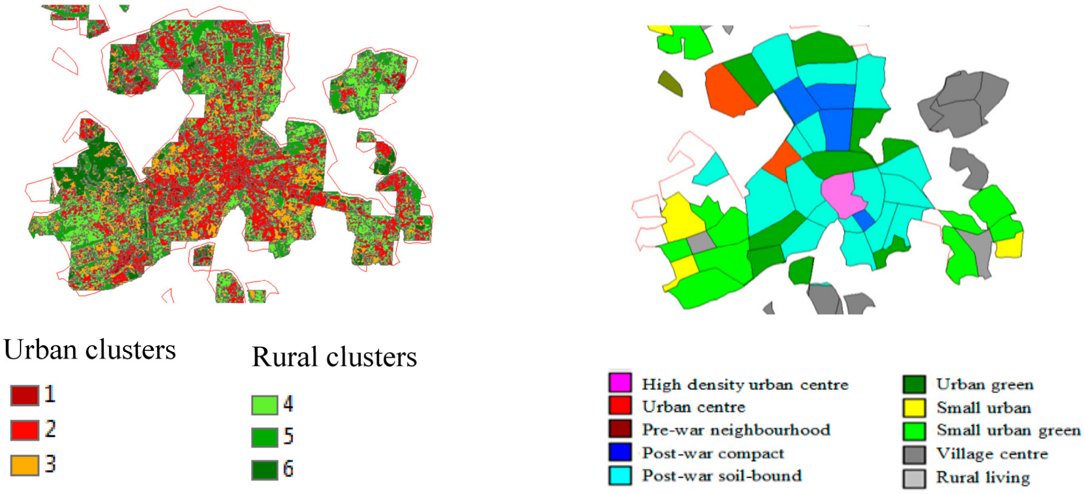

Figure 4. Compilation of LST-related maps for the Eindhoven metropolitan area: surface cover clustering and "urban living environment" categories [56].

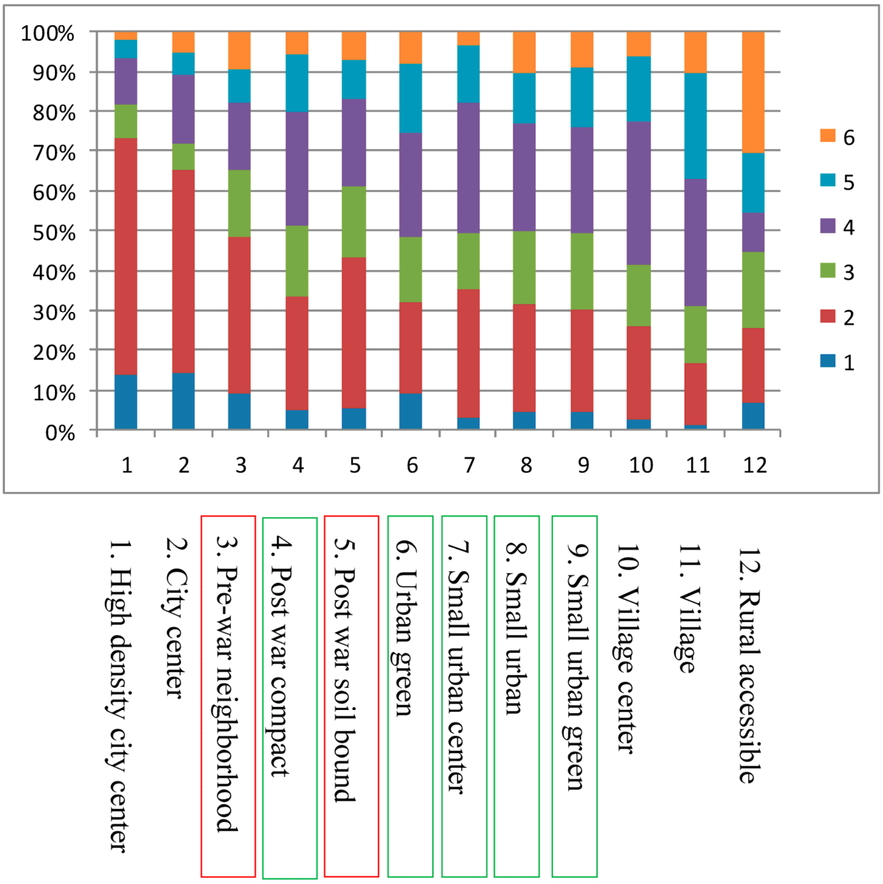

Figure 5. Surface cover cluster proportions for each of the "urban living environment" categories in the analyzed medium-size cities of the North Brabant region [56]. Neighborhoods 3 and 5 present similar cluster proportions, and thus could be grouped. Neighborhoods 4, 6, 7, 8, and 9 present similar cluster proportions and, thus, could be grouped.

3.3. Layering: Physical Overlap

Following the rhizome mapping, which we understand as the integrative representation of existing and proposed urban planning conditioning and determining factors, we would suggest introducing the layering phase. Layering consists of the physical overlap of different structures over a common territory. In the context of this study, we understand that layering corresponds to a more concrete activity than rhizome, we suggest that the main difference between these two mapping principles is that layering integrates mainly physical parameters. Layering is an appropriate mechanism to represent different heat reduction options for one particular urban area since there are several mechanisms to reduce urban heat and the selection of these depends on many other factors. Echevarria *et al.* [57] (Figure 6) map different temperature-related parameters for several Dutch cities. Figure 6 presents the results obtained for the city of The Hague. The storage heat flux mapping (Figure 6a) is used to identify hotspot areas, these are areas that tend to accumulate heat throughout the day, and that are likely to release it at night. Thus, these are areas to concentrate design adaptation efforts. Figure 6d represents day land surface temperature; higher LST mainly correspond to industrial areas, which warehouses could benefit from flat roof cooling measures, consisting primarily of the introduction of high reflection coatings. Figure 6c shows vegetation maps, and identifies, in white, the areas with a total lack of green. Greenery can always be implemented at street and roof levels, however, it requires a deeper assessment, as both implementation and maintenance are critical for the survival of the introduced species. Figure 6e maps albedo and allows identifying areas with low surface reflection, while Figure 6g,h represent the quantification of specific material surfaces which allow estimating the heat mitigation effect of the replacement of low albedo materials by higher albedo materials. The coolspot maps (Figure 6j), which maps the storage heat flux in rural environments), together with the height map (Figure 6i) and the sky view factor map (Figure 6l), allow identifying potential cool wind corridors (Figure 6k) that would promote the natural fresh air circulation from coolspots to hotspots. Finally the "life quality map" (Figure 6f) [58] introduces a layer of combined physical and social parameters which is used by the Dutch Ministry of the Interior and Kingdom Relations to assess the municipalities' quality of life.

This set of heat related layers can be overlapped, combined, and filtered by urban planners with other discipline's layers in order to produce integrating urban plans.

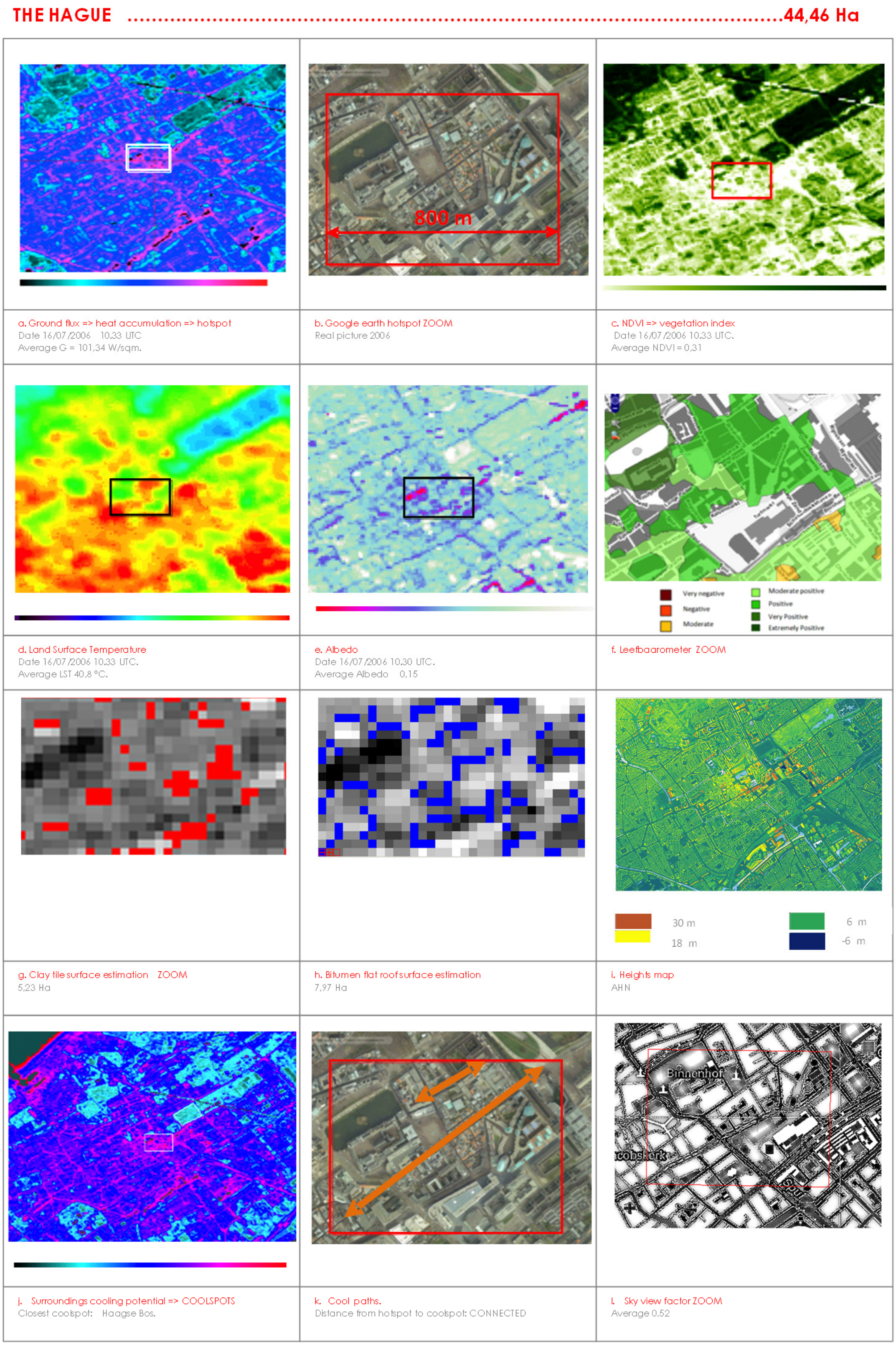

Figure 6. Modified from [57]. Layers for the urban heat assessment of the city of The Hague.

3.4. Drift

The concept of drift was originally introduced by the situationists and the main driver of this mapping category was a political one, which aimed at actually empowering the working class to promote a revolution. Corner uses the work of the situationists and of Richard Long [59–62], to illustrate the drift concept, which emphasizes the importance of how the user experiences the city. Data collection was done through the city walks, and the actual data collected consisted of the urban scenes perceived and experienced during those pedestrians' itineraries. However, the authors of these journey guides were not random citizens, but instead some sort of super head [51]—not necessarily urban planners—aiming at restoring a lost social justice, bringing back the public space to citizens. The scale of this assessment was done at street and neighborhood levels. Even though the nature of these maps was actually political, the essence of this mapping category is to guide citizens through the city public spaces. A certain parallelism can be found between this mapping category and the existing mobile phone applications containing GPS and guiding unequivocally 21st century pedestrians through cities in their search for public transportation directions and schedules, identification of specific commercial information, *etc.* However a deeper analysis reveals that these mobile applications can precisely be very limiting depending on how we use them. The most extreme case would be to use them as a subway map, allowing an efficient circulation through its corridors without any reference or connection to the surrounding environment, which precisely represents the opposite of the drift's aim. Thus, mobile applications can be useful tools if we use them to guide us through cities, but also if they encourage us to discover and experience unexpected situations throughout the city, thus if they promote the interaction between citizens and with surrounding environment. Drift mapping could for example provide street level temperatures to guide pedestrians to fresher public areas during hot summer days. The parameter actually mapped would be storage heat flux using satellite imagery retrieved during previous heat waves, and it would be overlapped in GIS with squares, parks, and streets to create routes to guide pedestrians to cooler open space areas. Echevarría *et al.* 2016 [57] carried out the hotspots, coolspots, and wind corridor analysis for the Dutch cities of The Hague, Delft, Leiden, Utrecht, Den Bosch, and Gouda. Where several high level arrows suggest the direction to follow in order to reach cooler areas during heat waves (Figure 7).

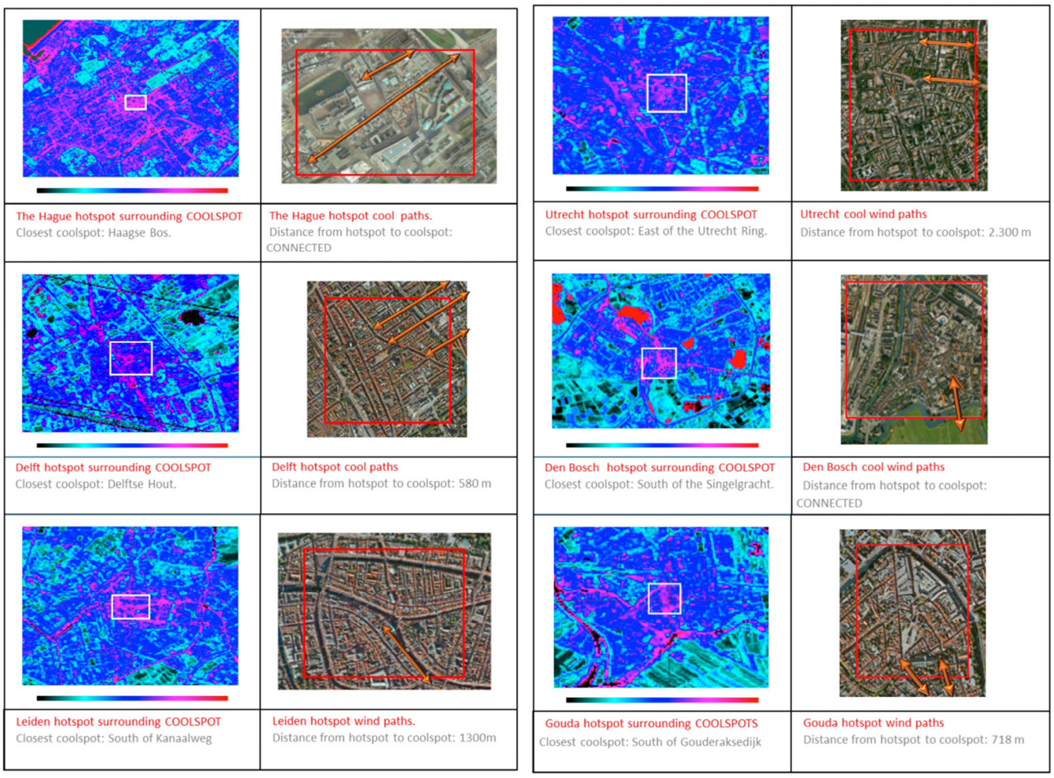

Figure 7. Comparative hotspot, coolspot, and wind corridor analysis for the Dutch cities of The Hague, Delft, Leiden, Utrecht, Den Bosch, and Gouda [57].

4. Discussion

In order to be able to incorporate critical climatologic parameters, (such as urban heat) in future urban planning processes, it is important first to identify relevant indicators affecting the studied phenomena, then to understand the instruments needed to map the indicators, and finally to choose the scale, frame, and representation code to visualize best the information and to ensure that the output can be integrated into catalyzing mapping categories drift, layering, game-board, and rhizome.

For the integration of the urban heat assessment in the urban planning processes, the heat fluxes, the land surface temperature, the albedo, the NDVI, and imperviousness have been proved to be relevant. The instruments used to map these parameters are satellite images, treated with specific geospatial software (such as ENVI), vector analysis software (Geographic Information Systems—GIS), and atmospheric and geographic correction software (such as Modtran or Atcor). Urban planners need to reinterpret the use of these powerful tools in order to ensure they do not lead to static prescriptions but, instead, they need to reveal inspiring connections and information, which trigger interactions between actants, parameters, and systems.

The incorporation of these parameters and tools into open and integrative urban plans can be done through the use of the before-mentioned catalyzing mapping categories, which we suggest to use in a particular order during the urban planning process. Since urban heat is often not the only priority to be addressed during the planning process, the need to find integrative and catalyzing mapping strategies becomes even more crucial. Game-board is the strategic analysis to be carried out in order to understand which are the "driving forces" affecting the process; rhizome is used to define the representation of all aspects (including abstract considerations) that condition the process; layering describes the mapping phase which displays the overlap the different strategies that could be used to reduce urban heat; and, finally, drift is used as a tool to guide citizens to fresher areas during heat waves.

5. Conclusions

Even though urban planners should aim at producing integrating plans, the urban planner cannot be an expert in all disciplines of mobility, sociology, economy, climatology, *etc.* The urban planner needs to be able to retrieve input from different experts, and build up integrating proposals from there. In principle, the urban planner should not necessarily have a specific command of the tools used by climatologists, sociologists, transportation engineers, *etc.* However, some of the instruments used for the assessment of those specific disciplines have proven to have wider applications, which can be used for a more general assessment by urban planners. It is the case of remote sensing, which is often used by climatologists, to study in depth the Urban Heat Island (for example) phenomenon, but which can also be used by urban planners for a more superficial assessment of the phenomenon, more oriented towards the development of design adaptation guidelines, rather than focusing in the accuracy of the retrieved measurements. Remote sensing, combined with GIS, not only provides information on the distribution of heat, it can also calculate gradients, provide urban classification maps based on thermal behavior and vegetation density assessment, calculate the influence of the size of an urban core in its overall surface temperature, identify locations with albedo (reflectance) below a certain threshold, identify coolspots, and their land uses, *etc.* The applications are manifold. The maps of urban planners need to give answers to specific questions that can often be answered using satellite imagery. The depth and accuracy of the climatological assessment produced by urban planners is inevitably not comparable to the ones issued by climatological experts. In that sense it is important to remind the different purposes of these two disciplines. Climatologists aim at having the most accurate insight of the phenomena themselves, while the focus of urban planners is in developing design guidelines to reduce the effect of the phenomena and that are flexible and compatible with other urban planning priorities. The use that those two disciplines make of certain tools is, therefore, not the same.

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