Urban Remote Sensing and Energy Planning
Doctoral Consortium Contribution

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1 RESEARCH PROBLEM

Although provision, transport and consumption of energy are strongly spatial related topics, for a long period of time energy planning was hardly part of urban planning strategies or development plans. City-wide energy-planning requires understanding of the complex system interdependencies at urban level with regards to demand and supply of energy resources, including their spatial distribution. (Agugiaro, 2015)

In developing and emerging countries the acquisition of data or information is challenging due to the lack of resources, organizational, financial, legal or social factors (Schneider et al., 2007). In addition to limited capacities urban planners have to face fast urban growth, informal settlements, informal economic activities as well as colliding interests that are carried out spatially. Contemporaneously energy planning calls more and more attention to public authorities in terms of Smart City and Smart Growth.

Moreover in European cities the provision of geo-spatial infrastructure is normally carried out by the city administration, comprising digital information on urban structure, housing, and infrastructure. In addition there is information available on energy related issues, thus allowing for spatially related analysis on energy demand and consumption as well as on potentials of improvement. This is not valid for developing and emerging countries, representing a serious lack of information when urban planning or energy planning strategies are to be developed.

In this context, remote sensing appears to have the potential to bridge at least part of the above described information gap.

This leads to the research question, if there is a correlation between remote sensing derived urban structural parameters and energy related issues and which remote sensing products can bridge information gaps, can emphasize spatial trends and can enable city planners to implement energy planning in a spatial context.

2 OUTLINE OF OBJECTIVES

Since no standardized remote sensing products for energy planning exist, the overall objective is to identify correlations between the consumption of energy and the urban structure, to ascertain correlations between urban inventory and inhabitants as well as their economic activity. Further needs comprise the development of methodologies and the design of corresponding geo-information products derived from urban remote sensing.

Remote sensing systems shall be examined regarding their aptitude for urban planning and energy planning. The wealth of scientific experience and scientific research shall be consolidated and linked to practical experience and demands of urban planning authorities and energy planning experts.

The objective is to enhance the quality of life for residents of urban areas and to ease the work of urban planners. Urban remote sensing shall facilitate the implementation of energy planning in a spatial context and bring together two entities that actually have never been separated.

3 STATE OF THE ART

3.1 Application of Remote Sensing

The application area for remote sensing has continuously grown during the last years. Both in disaster management as well as in forestry and agriculture remote sensing is a constant factor. Moreover, in urban areas it is partially used, here mainly from industrialized countries. In latter urban remote sensing is a contribution to monitoring and surveillance. In Austria e. g. remote sensing is used as a device for a tree protective law or to control building regulations manually by visual interpretation of aerial

Lehner, A. and Steinnocher, K.
Urban Remote Sensing and Energy Planning - Doctoral Consortium Contribution.
In *Doctoral Consortium (DCGISTAM 2016)*, pages 8-11

photos or satellite images. Internationally remote sensing is used e. g. by the United Nations to observe and to track the development of refugee camps. The resulting data is used to estimate how many people approximately reside in one camp. (Bjorgo, 2000)

3.2 Urban Remote Sensing and Energy Planning

Energy planning-related remote sensing activity takes place e. g. in the creation of solar potential maps or cadasters. These cadasters provide information about the energetic potential for solar collectors or photovoltaic modules (Agugiaro et al., 2012). High-resolution LIDAR data or high-resolution Radar data are used for site selection of wind generators (Arcidiacono, 2012; Klärle and Ludwig, 2005). Furthermore, multiresolution remote sensing data is used for the assessment of small hydropower potential (Dudhani et al., 2006).

Both, urban planning and energy planning always include statements about the future. Presently it is very challenging to make statements about the future when it comes to urban areas and population change. Moreover, models and scenarios that were developed by means of urban remote sensing are often strongly adapted to the study areas where models or scenarios were performed initially and thus transferability remains complex and demanding. (Hofmann et al., 2011, 2008)

Within the context of transferability the World Urban Database and Portal Tool (WUDAPT) has been conceived as an international collaborative project for the academic work with climate relevant data on the physical geographies of cities worldwide (Mills et al., 2015) Data about form and function of cities, e. g. surface cover, the consumption of energy, water etc. is acquired and local climate zones (LCZ) can be mapped globally by local experts after one publicly available method. (Mills et al., 2015)

One effect of densely built-up areas with lack of open spaces and green spaces are urban heat islands or generally differences in temperature between different regions within the urban area. These differences can easily be monitored and visualized, e. g. between parks and densely built-up area (Nichol, 2005). Based on the resulting knowledge, planning actions can be applied that have influence on the urban energy consumption whether for cooling or heating.

Through data about impervious surface and its change through population growth, scenarios can be developed and remote sensing data about land use can support efficient planning of infrastructure and can therefore contribute to a more efficient use of energy and less consumption of energy (Bhatta, 2010) This can happen through the adaption or improvement of the journeys to particular public facilities, e. g. hospitals, doctors etc. (Barona and Blaschke, 2015).

Another area of research represents the gathering of building parameters by means of active sensors or stereo photogrammetry. Building height, area, volume, style of roof or other building parameters are acquired to calculate the heating demand and the cooling demand of a particular building (Agugiaro, 2015).

Many of the aforementioned approaches focus on research questions that correspond less to the holistic principles of energy planning rather than on the solution of particular challenges. The solar potential cadaster e. g. can visualize the energetic potential of existing roofs of buildings. However, the influence of remote sensing data on land use plans, building plans or other planning instruments remains low. The most usable building orientation for photovoltaic modules could be recommended or negative influence of additional buildings in a wind corridor could be calculated and additional constraints for the construction of new buildings within this wind corridor could be given.

It can be summarized that research in the field of urban remote sensing, urban planning and energy planning has led to diverse new approaches and researches worldwide face the complexity of urban growth, growth of population and increasing demand of energy.

4 METHODOLOGY

The methodological development will focus on the derivation of urban parameters from urban remote sensing data. It is expected that the parameters required will rather be of a complex nature combining object information such as buildings or infrastructure and attribute information such as object functions and energy related information.

Depending on spatial, spectral and radiometric resolution of remotely sensed data, the acquisition of object information varies in accuracy and usability. Moreover, spatial information in imagery includes aspects such as image texture, contextual information, pixel proximity, and geometric attributes of features (Blaschke, 2010).

The multiple approaches of increasing the outcome of image data has led to different methods, e.

g. sub-pixel techniques, pixel-by-pixel techniques, the regionalization of pixels into groups of pixels and the aggregation of pixels to objects. In urban areas especially, it appears that object-based approaches have several advantages when mapping land cover change, monitoring a city for building code compliance, quantification of sealed surface (Blaschke and Strobl, 2001) or other energy planning relevant approaches. However, most of the current applications rely on simple per-pixel classification of the imagery (Bhatta, 2010).

The election of a proper method depends on the requirements and on the level of detail, whereby only the integration of urban remote sensing derived objects and ancillary information derived from statistics will certainly enhance the information content significantly and thus allows us to get closer to the overall objective of an all-embracing energy planning. In order to achieve best results with object-based image classification (OBIA) the use of (very-) high resolution images is obligatory.

The goal of the methodological development will be to evolve functional and structural classes from the classification of the urban area using a diverse set of socioeconomic and statistical data as additional input. Test sites will be defined, which will be located in developing and emerging countries. Data acquisition will be based on requirements and availability. However, since urban remote sensing has the potential to bridge information gaps, methods and workflows will be developed that enable the substitution of missing data from the ground by remote sensing, e. g. the estimation of inhabitants within a particular area. (Aminipouri et al., 2009; Galeon, 2008)

5 EXPECTED OUTCOME

The expected outcome will depend on the application of the methodologies on the data of test sites that will ultimately result in reference geo-information products.

A breakdown of existing remote sensing systems will be given which will provide support for urban planners within planning tasks. Geo-information products will be evaluated after their thematic resolution. Thematic resolution means an assessment of the suitability of specific geo-information products; e. g. for the compilation of precise building outlines high resolution image data is essential whereas data with a coarser resolution is more suitable for the computation of climate models because of the resulting large amount of data and its global availability.

Depending on data availability and on other factors, geo-information products can be suggested that can be used for green zone plans or other planning instruments. For strategic plans like green zone plans the land surface temperature within a specific urban area can be developed from remote sensing data (Figure 1). In particular, hot or cool areas can be identified. This information can be used to visualize the cooling effect of the expanse of water, parks or other open spaces that may be relevant for the urban climate. Hotspots can easily be identified; changes and impacts through time can be monitored through time series analysis of remote sensing data.

Further scenarios about urban growth can be generated. By means of an object-based approach the future energy consumption or the future land consumption resulting from urban growth can be related to particular units or referred to individual buildings.

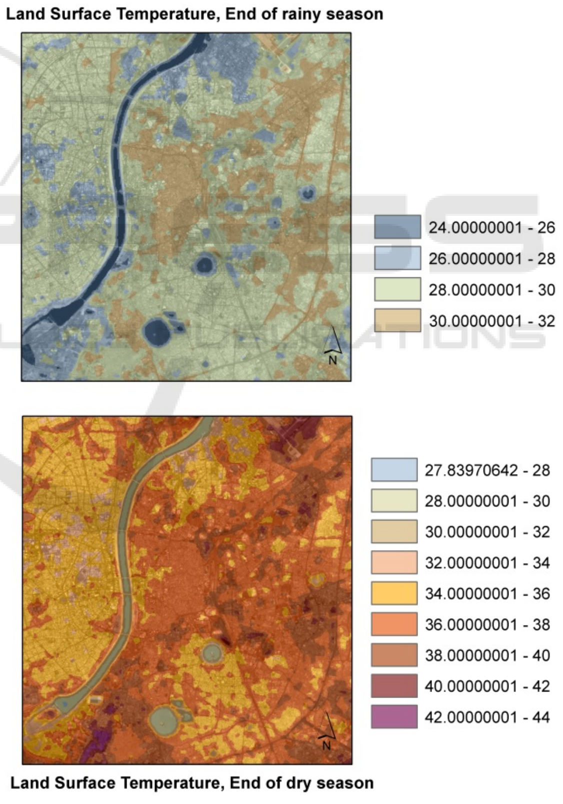

Figure 1: Comparison of land surface temperatures (LST) in degrees centigrade of a study area in Ahmedabad, Gujarat, India.

Finally these geo-information products will be evaluated against the user requirements and the feasibility of the entire process, they will be critically analyzed and the potential of improvements will be defined. The final result will describe the design of the reference geo-information product and contain guidelines of how to use the information product for supporting energy planning.

6 STAGE OF THE RESEARCH

One of the first stages of research is the literature review that has almost been completed; the sheer amount of particular methodologies and approaches within the field of energy planning and urban planning makes a concentrated approach quite challenging though. Presently urban remote sensing products are analyzed and are assigned to a particular thematic order.

So far, a verification method for demographic forecast with the use of remote sensing data could be evolved (previously unreleased). Within this case study it could be proven that with a minimum of freely available data planning authorities can be supported.

The development of a continuous exchange with experts from the field of urban remote sensing and energy planning as well as the transfer of knowledge, complement the base for further research.

REFERENCES

Agugiaro, G., 2015. *Energy planning tools and CityGML-based 3D virtual city models: experiences from Trento (Italy)*. Appl. Geomat. 1–16.

Agugiaro, G., Nex, F., Remondino, F., Filippi, R., Droghetti, S., Furlanello, C., 2012. *Solar radiation estimation on building roofs and web-based solar cadaster*. ISPRS Ann Photogramm. Remote Sens Spat Inf Sci 1, 177–182.

Aminipouri, M., Sliuzas, R., Kuffer, M., 2009. *Object-oriented analysis of very high resolution orthophotos for estimating the population of slum areas, case of Dar-Es-Salaam, Tanzania*, in: Proc. ISPRS XXXVIII Conf. pp. 1–6.

Arcidiacono, S.A., 2012. *GIS-based Site Potential Analysis for Small-scale Wind Power Plants*. Department of Geography and Anthropology, Louisiana State University, Baton Rouge.

Barona, P.C., Blaschke, T., 2015. *Healthcare Accessibility and Socio-economic Deprivation: A Case Study in Quito, Ecuador*. GI_Forum 2015, 484–492.

Bhatta, B., 2010. *Analysis of urban growth and sprawl from remote sensing data*. Springer Science & Business Media.

Bjorgo, E., 2000. *Refugee camp mapping using very high spatial resolution satellite sensor images*. Geocarto Int. 15, 79–88.

Blaschke, T., 2010. *Object based image analysis for remote sensing*. ISPRS J. Photogramm. Remote Sens. 65, 2–16.

Blaschke, T., Strobl, J., 2001. *What's wrong with pixels? Some recent developments interfacing remote sensing and GIS*. GeoBIT/GIS 6, 12–17.

Dudhani, S., Sinha, A.K., Inamdar, S.S., 2006. A*ssessment of small hydropower potential using remote sensing data for sustainable development in India*. Energy Policy 34, 3195–3205.

Galeon, F., 2008. E*stimation of Population in informal settlement communities using high resolution satellite image*, in: XXI ISPRS Congress, Commission IV. Beijing. Citeseer, pp. 1377–1381.

Hofmann, P., Blaschke, T., Strobl, J., 2011. *Quantifying the robustness of fuzzy rule sets in object-based image analysis*. Int. J. Remote Sens. 32, 7359–7381.

Hofmann, P., Strobl, J., Blaschke, T., 2008. *A method for adapting global image segmentation methods to images of different resolutions*. Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. 38.

Klärle, M., Ludwig, D., 2005. *Einsatz von Flugzeugscanner-Daten für die Standortoptimierung erneuerbaren Energien*. na.

Mills, G., Ching, J., See, L., Bechtel, B., Foley, M., 2015. *An Introduction to the WUDAPT project,* in: 9th International Conference on Urban Climate, Toulouse.

Nichol, J., 2005. *Remote sensing of urban heat islands by day and night*. Photogramm. Eng. Remote Sens. 71, 613–621.

Schneider, T., Goedecke, M., Lakes, T., 2007. Berlin (Germany) U*rban and Environmental Information System: Application of Remote Sensing for Planning and Governance—Potentials and Problems*, in: Applied Remote Sensing for Urban Planning, Governance and Sustainability. Springer, pp. 199–219.