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URBAN HEAT ISLANDS MITIGATION BY GREEN OPEN SPACE (GOS) CANOPY IMPROVEMENT: A CASE OF YOGYAKARTA URBAN AREA (YUA), INDONESIA

Widodo Brontowiyono[1,2*], Ribut Lupiyanto[2], Donan Wijaya[2], Joe Hamidin[2]

[1]*Department of Environmental Engineering, FTSP, Islamic University of Indonesia (UII), Yogyakarta*
[2]*Center for Environmental Study (PSL) UII, Yogyakarta*

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ABSTRACT
The growth of the Yogyakarta Urban Area (YUA) has led to an increasing of the microclimate, characterized by elevated temperatures. One of the efforts to decrease temperature is by establishing the development of Green Open Space (GOS). According to Law Number 26/2007 about Spatial Planning, a minimum of 30% of the total area must be designated as green open space. IKONOS satellite images taken in 2009 showed that GOS represented 43.36% of the total area for YUA. However, there are still areas which are characterized by high temperatures (more than 36.5^{o}C). By applying Geographical Information System (GIS) analysis with an overlay technique among three factors such as canopy, building and population density, the priority zone for GOS development was identified. Based on the analysis, 38.82% of the area was designated as low priority for GOS development, 32.38% as middle priority, and 28.80% as very high priority to be developed as GOS. The land conversion is bigger and has high potency on private sector. GOS development needs to be established in the public sector, such as the creation of urban parks. Community empowerment strategies, application of incentive - disincentive mechanisms, and efforts towards GOS productivity improvement can encourage implementation.

Keywords: Canopy; Green open space; Urban heat island; Yogyakarta

1. INTRODUCTION
The complex dynamics of an urban area presents challenges for sustainable development. The urban physical area is continually crowded with buildings, blocked surfaces either on the roofs of buildings or the yards, which then cause crowded impressions; on the other hand, green open space (GOS) keeps narrowed or, even worse, almost none. The urban surroundings tend to be economically developed, but the corresponding ecological environments have not been developed. One of the impacts is an increase of the surrounding air temperature leading to the emergence of urban heat islands, although in a small scale (Li et al., 2005).
Kartasapoetra (1986) and Fandeli (2003) stated that factors influencing temperature on the earth's surface are:

- Influence of land and sea,
- Influence of elevation,
- Influence of wind,
- Influence of rising angle of the sun, and
- Amount of radiation gained per year, per day, per season
- Influence of land coverage,
- Influence of soil type,
- Influence of latent heat,

* Corresponding author's email: widodo.bronto@gmail.com, Tel./Fax: +62-274-898444 Ext 2503

The height of artificial land caused by development activities in an urban area, increases the environmental temperature by 0.5-1.5^{o}C. In order to create more comfortable conditions in urban areas, establishment of vegetation sets in the form of forests or other models is necessary.

The most effective strategy for the mitigation of urban heat islands and even for a global warming threat is to improve the local environmental condition (Widodo et al., 2009; Lupiyanto, 2009). Aynsley et al. (2009) and Dinas Kimpraswil DIY (2006) stated that there are two main principles for preventing the urban heat islands: shading solid surface in public places and preventing blockage of wind flow. Law Number 26/2007 about Spatial Planning, requires that a minimum of 30% of a total urban area must be designated as green open space, consisting of 20% Public GOS and 10% Private GOS. This research explores the existing GOS and explaining the need of GOS development in YUA.

2. RESEARCH METHOD

Data collecting was conducted through observation, field measurement, and interpretation of other data. The main data collected were data of vegetation volume and temperatures at noon. Secondary data was taken from IKONOS images, topographic maps, and statistical data. Locations for samples taken were determined using purposive random sampling which referred to the complexity of the population activity; in this case, crossroads, offices and shopping areas were chosen as sampling sites.

Analyses of canopy and microclimate were conducted using primary measurements through sampling parameters. Canopy measuring was performed directly to find the width of the crown and its height so that the canopy volume of each vegetation could be identified. Measuring of microclimate was conducted using the parameter of midday-temperature at strategic places. Analyses of vegetation and canopy were performed to calculate canopy volume needed to modify the microclimate and intercept rainwater. This simulation was based on the calculation of vegetation canopy volume obtained by identifying and calculating the existing canopy volume at YUA and connecting the volume with the microclimate and hydrology. Analysis was conducted using remote sensing and a Geographic Information System (GIS).

The purpose of GIS Analysis was to collect data regarding existing GOS extent, conduct the isothermal estimation, and determine the potential materials existing and also the priority of GOS development. GIS analysis in this research utilized Arcview GIS software to analyze data in the form vector such as data associated with buildings, suprastructures and infrastructures, and also data regarding the heat dust stream obtained from the results of image interpretation.

3. RESULTS

Yogyakarta Urban Area (YUA) is a rapid growth area which covers all administrative places in Yogyakarta, some parts of the Sleman District and some parts of the Bantul District. Geographically, YUA's position is in the middle of the Special Territory of Yogyakarta Province. YUA covers 2 districts and 1 city with 23 sub-districts, with the total extent measuring 18,819 ha.

Area of developed land use is dominant (57%), and the rest is undeveloped land. Developed land is dominated by housing areas which keep growing as the population increases in this area. In addition, existing new access ways have been asphalted, and the emergence of hotels and campuses alongside Yogyakarta suburbs have increased the need for housing and reduced the use of rice fields. Growth of housing areas, according to the Report of Regional Plan of YUA 2007, has reached 47% per year.

In the meantime, the use of undeveloped land is dominated by rice fields, but the extent of undeveloped land keeps decreasing year by year. Rice fields represented 43% of the total Yogyakarta Urban Area, which covers 2,828 ha of land at the same year. Yogyakarta (city), the center of YUA growth, had the smallest amount of land devoted to rice fields in 2007, covering 98 ha or 3.15% of the city area. In 2004, land used is as rice fields. In Yogyakarta, it was 145,403 ha, so that the extent of land used for rice fields in YUA decreased by 8.15% per year from 2004 to 2007.

In general, the extent of GOS has met legal minimum requirements of 30%. Only Public GOS needs to be improved. However, the existing GOS has not been functioning optimally yet, specifically in hydrological function and decrease in microclimate. Thus, direction for another development is based on the fulfillment of GOS function/quality; in this case, it is based on the volume of GOS canopy. A certain extent of GOS is not always in line with the function; it depends on the canopy. Purpose of the analysis is to give directional development as a basis of plan arrangement which has correlation to microclimate.

Microclimate generally consists of humidity and air temperature. The air humidity is influenced by air temperature. The higher the temperature, the lower the average humidity (which currently ranges between 41% and 95% in YUA). Air temperature is influenced by strength of the sun's rays time length of sun illumination, existence of clouds and rain, and the use of land around the area. The greater the sun's heat and the longer the illumination without clouds and rain, and supported by the use of non-vegetation land, the higher the air temperature. YUA air temperature currently ranges from 24-38.5^{o}C. This average temperature is gained from monthly temperature averages over the last 5 years (Bapeda Kota Yogyakarta, 2008). Air distribution in the area actually fluctuates hourly, depending on sun illumination. At night, it reaches the lowest temperature and the highest temperature is recorded at noon. Temperature conditions and its spread throughout YUA at noon can be seen on Figure 1.

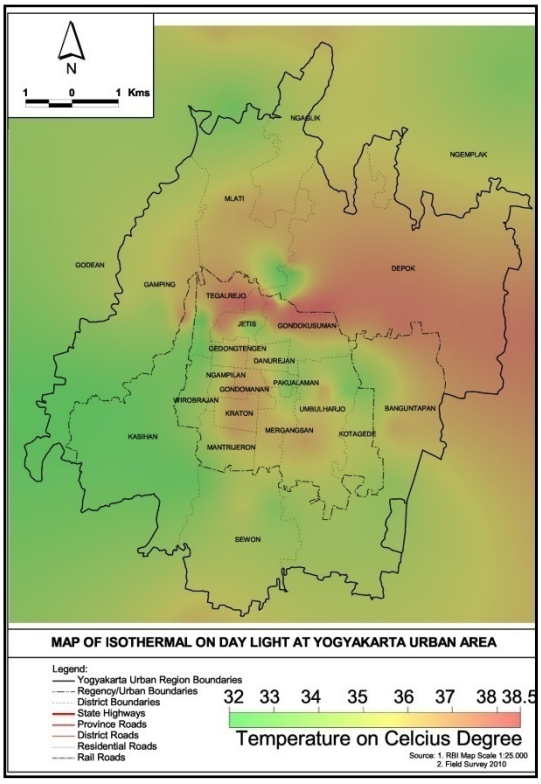

Figure 1 Map of day temperature in YUA

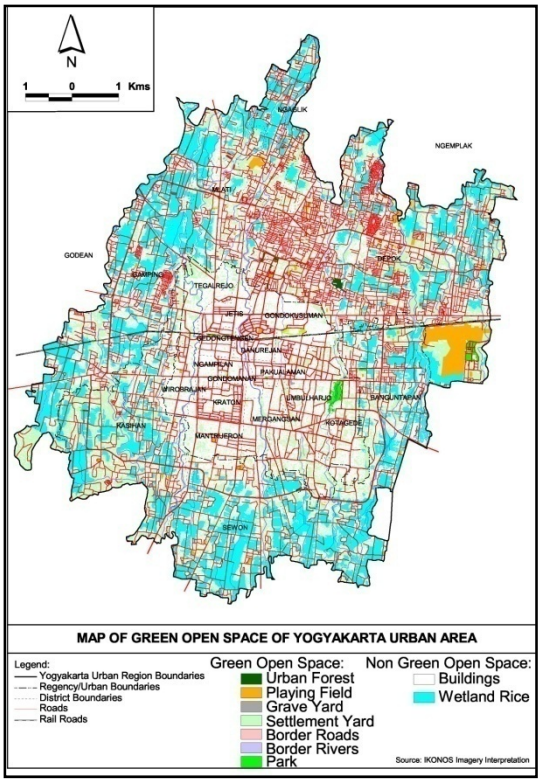

Figure 2 Map of existing GOS in YUA

3.1. The existing GOS

The majority of GOS in YUA is the green zone type, characterized by green space and parks surrounding office areas (Figure 2). Therefore, the use of GOS tends to create aesthetic and ecological values. Based on the status of ownership and management, the majority of GOS is private GOS with total extent reaching 628.96 ha and the rest representing public GOS. The data can be seen on Table 1.

Public GOS has its own management authority. Based on the Peraturan Menteri Dalam Negeri (Law of Domestic Minister) No 1, 2007 "On Space Mapping of Green Open Space", public GOS is to be provided and maintained under the local regency/city. Private GOS is comes under a private party/institution, or personal and public community which controls the permitting of land use through regency/city government.

Based on the data above, YUA is not considered as ideal yet in the matter of the need fulfillment on green open space, specifically Public GOS. Factors influencing such conditions are the increasing mobilization of the urban population as indicated by the rise in vehicle numbers and street volume, and the increase in social-economic activities that contribute to traffic density.

Table 1 Extent of GOS in YUA based on the ownership status

Subdistrict/Village	Area extent	Status		
		Public GOS	Private GOS	Total GOS
Yogyakarta City				
Total (Ha)	3,250.01	399.83	628.96	1,028.79
(%)	100.00	12.30	19.35	31.65
Sleman Regency				
Total (Ha)	7,609.00	1,012.51	3,149.46	4,161.97
(%)	100.00	13.31	41.39	54.70
Bantul Regency				
Total (Ha)	5,236.80	387.45	2,044.13	2,431.58
(%)	100.00	7.40	39.03	46.43

3.2. Need of GOS development

LAW Num.26/2007 about Spatial Planning states that the proportion of green open space in an urban area must be minimum 30% of total area. The extent of YUA is 16,096 ha; therefore, based on the standard of this law, GOS area should cover minimum 4,829 ha. GOS should contain 3,219 ha covering Public GOS and 1,609 ha of Private GOS. In general, the extent of GOS in YUA is in accordance with the law, covering 7,622 ha or 43.36% of the total extent. However, Public GOS still only covers 11.18 making the distribution uneven.

3.3. Potential GOS development

The biggest challenge related to GOS development in YUA is its high potential of land conversion. Thus, it needs to designate 20% of Public GOS as the main priority and demonstrate efforts to maintain the private GOS or at least to control its immediate change (Table 2). The Public Work Ministry explains that a rice field is not included as GOS as long as there are not any laws which clearly define its function as GOS.

In fact, rice fields have the most potential or probability to be developed as GOS, either from a physical or an economical aspect. Rice fields can be identified as perpetual rice fields or for development as other types of GOS. Based on that, potential of land to be GOS will show a wider alternative.

Table 2 Analysis of GOS Needed in YUA

Regency / City	Area extent	Existing GOS			Need of GOS			Lack of GOS		
		Public GOS	Private GOS	Total	Public GOS	Private GOS	Total	Public GOS	Private GOS	Total
Yogyakarta City										
(Ha)	3,250.01	399.83	628.96	1,028.79	650.00	325.00	975.00	-250.17	303.96	53.79
(%)	100.00	12.30	19.35	31.65	20.00	10.00	30.00			
Sleman Regency										
(Ha)	7,609	1,012.51	3,149.46	4,161.97	1,521.80	760.90	2,282.70	-509.29	2,388.56	1,879.27
(%)	100.00	13.31	41.39	54.70	20.00	10.00	30.00	-	-	
Bantul Regency										
(Ha)	5,236.80	387.45	2,044.13	2,431.58	1,047.36	523.68	1,571.04	-659.91	1,520.45	860.54
(%)	100.00	7.40	39.03	46.43	20.00	10.00	30.00	-	-	-

4. DISCUSSION

Microclimate in Yogyakarta Urban Area can be modified for enjoyment and comfort of urban dwellers by managing GOS type and distribution; managing height and width of buildings; and managing building types, materials, and decor, including paint color, and use of glass and wood building materials.

In this GOS planning activity, the modification of microclimate focuses on the planning and management of GOS. Besides the management of land which may have potential to be planted in order to modify microclimate, there is also potential to plant on the walls of high buildings or on their roofs (roof gardens) so that there will be a cooler microclimate, especially during the day.

The temperature condition can be influenced by building conditions and human activities as well as the canopy. From each aspect we can determine the development priority for GOS (Figures 4 and 5). The analysis of each aspect uses three levels: low, middle, and high. Next, the priority of areas for GOS development can be determined by observing the overlay among the condensed canopy, building density, and population density. The map of GOS development priority zones in YUA is shown in Figure 6.

Based on the priority map, combining with maps of potency and need, we can plan the development preparation. The target of GOS development is to be able to decrease the microclimate so that ideal conditions will be around 34-36^{o}C. On Figure 6, the “priority-zone” will be determined as the main target. On the other hand, the other zones under it will be the first priority. The consequences potentially emerge are the need to conduct the expansion of land and an increase of canopy volume quality. The next analysis is to determine where to add GOS locations. Figure 7 shows a landscape design which can be developed, as an example, to fulfil the development of GOS.

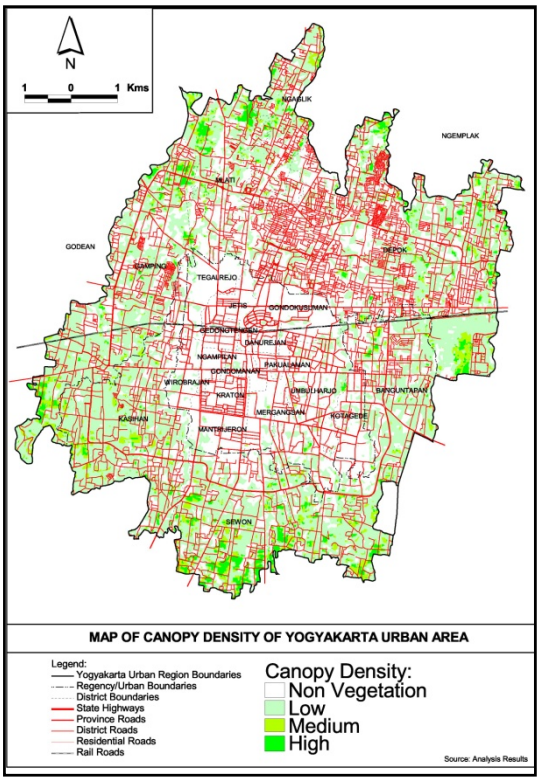

Figure 3 Map of canopy density in YUA

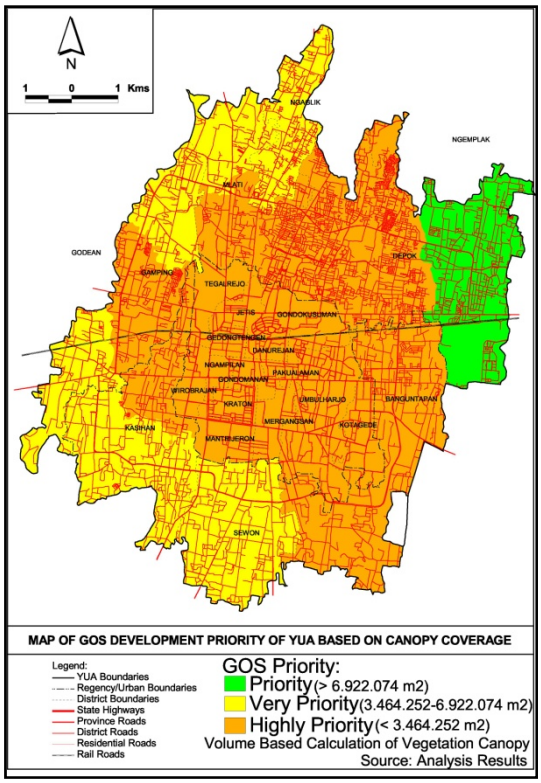

Figure 4 Map of GOS development priority based on canopy

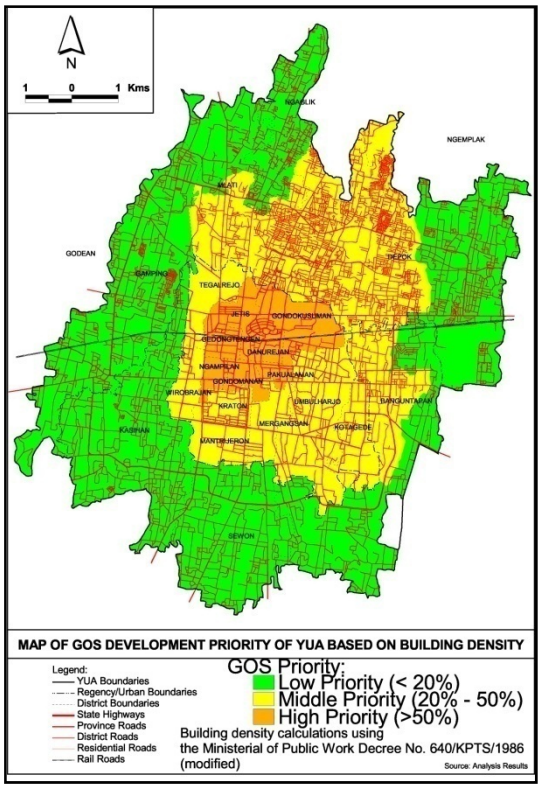

Figure 5 Map of GOS development priority based on building and population density

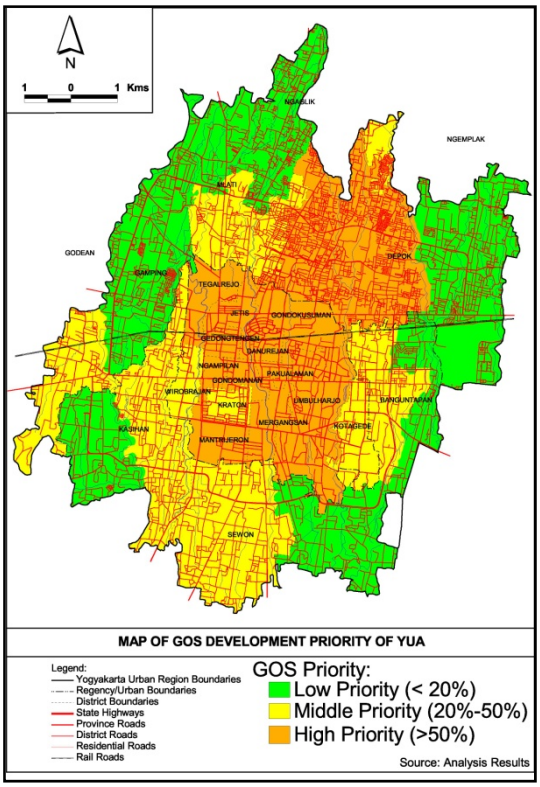

Figure 6 Map of GOS comprehensive development priority

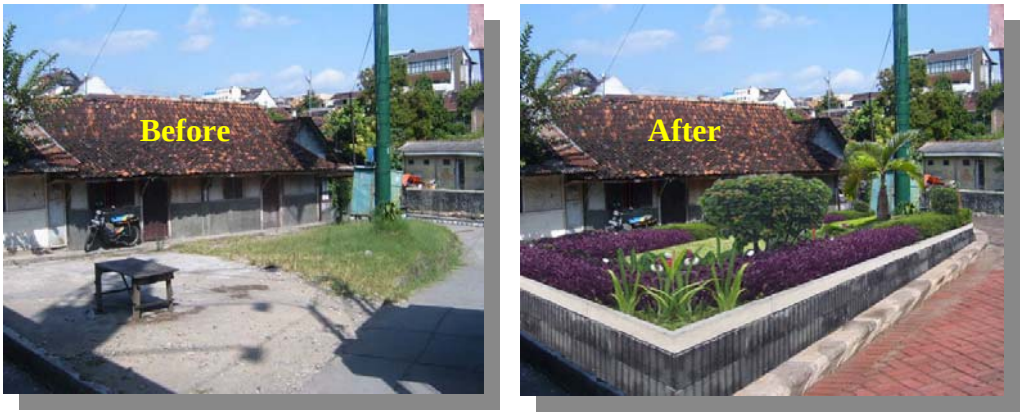

Figure 7 Design of park in housing area

5. CONCLUSIONS

Several alternative solutions to establish 20% public GOS and to increase canopy volume are:

1. The determining of some rice fields for the conversion to GOS based on regulations of perpetual rice fields or as land which the government can buy to use as GOS,
2. The management of private space (house yards, office and housing complexes) so that it will be possible to establish minimally 30% of the total extent to be as GOS that has sufficient canopy condensed,
3. Optimization of land and government buildings to be GOS samples,
4. Private GOS engineering on dense buildings zones, such as the creation of roof gardens, pots, pergola, or others,
5. Efforts to establish the new GOS can be encouraged through community empowerment strategies, incentive-disincentive mechanisms, and increased productivity of current GOS.

6. ACKNOWLEDGEMENT

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7. REFERENCES

Aynsley, R., Gulson L, 2009. Microclimate and Urban Planning in Humid Tropics, Planning in Hothouse. *27th National Congress of the Royal Australian Planning Institute*, Darwin.

Bapeda Kota Yogyakarta (Development Planning Board of Yogyakarta City), 2008. Laporan Akhir Master Plan Ruang Hijau Kota Yogyakarta (Final Report – *Master Plan for Green Space of Yogyakarta City*) , Government of Yogyakarta City, Yogyakarta. Unpublished (in Bahasa)

Dinas Kimpraswil DIY (Public Work - Settlement and Energy-Mineral Resources Agency (PUP-ESDM) of Yogyakarta Special Province), 2006. Penyusunan RDTR Kawasan Purdowo Kabupaten Sleman (*Detailed Spatial Plan of Purdowo Sleman Regency*). Final Report, Dinas Kimpraswil DIY. Unpublished (in Bahasa)

Fandeli, C., Kaharuddin, Mukhlison, 2003. Perhutanan Kota (*Urban Forestry*). Faculty of Forestry, University of Gadjah Mada, Yogyakarta. Unpublished (in Bahasa)

Kartasapoetra, A.G., 2006. Klimatologi: Pengaruh Iklim Terhadap Tanah dan Tanaman (*Climatology: Climate Influence to Land and Vegetation*), Bumi Aksara, Jakarta. Unpublished (in Bahasa)

Li, F., Wang, R., Liu, X., Zhang, X., 2005. Urban Forest in China: Development Patterns, Influencing Factors and Research. *International Journal of Sustainable Development and World Ecology*; Academic Research Library. Jun 2005; 12, 2; pp. 197.

Lupiyanto, Ribut, 2009. Merancang Kampung Hijau di Tepian Sungai Kota: Kasus Tegalpanggung, Yogyakarta (*Green Kampong at Urban River: A case of Tegalpanggung Yogyakarta*), Bulletin TATA RUANG - Edition of July-August 2009, Badan Koordinasi Tata Ruang Nasional (Board of Spatial Planning Coordination). Unpublished (in Bahasa)

Widodo, B, R., Lupiyanto, Donan W., 2009. Urban Kampong Improvement on Global Warming Mitigation Basis (A Case Study of Code River Bank Settlement Area, Yogyakarta). *Proceedings of The First International Seminar on Science and Technology*, Islamic University of Indonesia (UII) – Universiti Kebangsaan Malaysia - Universiti Malaysia Trengganu, January 24-25, 2009, Yogyakarta.