Generation of DEM for Urban Transformation of Hanoi, Vietnam

Go Yonezawa

Kyoto Working Papers on Area Studies No.62
(G-COE Series 60)

March 2009

The papers in the G-COE Working Paper Series are also available on the G-COE website:
(Japanese webpage)
http://www.humanosphere.cseas.kyoto-u.ac.jp/staticpages/index.php/working_papers
(English webpage)
http://www.humanosphere.cseas.kyoto-u.ac.jp/en/staticpages/index.php/working_papers_en

Center for Southeast Asian Studies
Kyoto University
46 Shimoadachi-cho,
Yoshida, Sakyo-ku,
Kyoto 606-8501, JAPAN

ISBN978-4-901668-55-2

The publication of this working paper is supported by the JSPS Global COE Program (E-04): In Search of Sustainable Humanosphere in Asia and Africa.

Generation of DEM for Urban Transformation of Hanoi, Vietnam

Go Yonezawa

Kyoto Working Papers on Area Studies No.62
JSPS Global COE Program Series 60
In Search of Sustainable Humanosphere in Asia and Africa

March 2009

Generation of DEM for Urban Transformation of Hanoi, Vietnam*

Go Yonezawa**

Abstract

Generating a Digital Elevation Model (DEM) which contains information about the latitude, longitude and the elevation plays an important role towards an explanation of urban transformation. DEM is a digital representation of ground surface topography and the most important element of topographic analysis for urban transformation (i.e. evidence of existence such as old rivers, lakes, fills and land subsidence) and sustainability (i.e. improvement of urban infrastructure and disaster prevention). In this study, the DEM of Hanoi City in Vietnam was generated by the elevation survey data. Based on the surface estimation method using Cubic B-Spline Function, it is generated at 2 m resolution and the contour interval is 0.5 m. The very subtle elevation gaps which can not be distinguished on the satellite images are significantly recognizable on this DEM. Meanwhile, the topographic map as a paper map was generated by French government in 1950 which belongs to French library. The DEM at 2 m resolution is generated based on the STRIPE method.

1. Introduction

Hanoi City, the capital of Vietnam, is one of the fastest-growing cities in Southeast Asia. However, there were many lakes and ponds which were relict lakes of Red River in Hanoi City before the 19th century. According to Haruyama (2004), the construction of dike in Hanoi City was the influential event. Hanoi City is located over a flood plain of the Red River, the average elevation being less than 10 m. Many floods have struck Hanoi City continuously from the ancient times. Therefore, the construction of dike was necessary to protect all over the capital city. When the mainstream of Red River is cut by the construction of dike, some of meander channels are left as the crescent lake and the pre-improved channel in a flood plain. Tay Lake and Hoan Kiem Lake in central Hanoi City are the typical example of them. Although the dike was broken several times by severe floods, each time it was rebuilt and raised the dike height. Then the infrastructure construction of flood-control can be found much earlier in Hanoi City.

---

* The original version of this paper is submitted to Southeast Asian Studies (SEAS). This paper is an expanded version of the original paper.
** Special Researcher, Institute of Sustainability Science, Kyoto University, Kyoto Japan. Email: go-yone@cseas.kyoto-u.ac.jp

In the early 20th century, many lakes and ponds had disappeared almost completely on the map. The outline of this urban transition is explained by Sakurai et al. (2007). It was shown by the historical materials (i.e. old maps and literatures.) that the remarkable urban transformation of Hanoi City caused during the Nguyen Dynasty period (1802-1945). This change would be related to French government planning. Because Vietnam was under French rule from 1887 to 1954, French army headquarters were strategically placed in the Thang Long Citadel (in central Hanoi City). At first, many military facilities of France were built in the citadel. The urban development around the citadel continued until the 1930s. It was developed by continuous land-filling of many lakes and ponds. This is verified by Yonezawa et al. (2007), suggesting different viewpoint from history or Area Studies with a method of information technology and informatics such as GIS and RS. However, it is difficult to figure out in two-dimensionally how the lake and pond disappeared and how the construction of dike has influenced the urban environment of Hanoi City (Shibayama et al., 2008). It is necessary to analyze a topographic change three-dimensionally to solve it (Yonezawa et al., 2008). Consequently, it can be effective to analyze using a DEM for the urban transformation.

In this paper, it is described how to receive and generate the requisite DEM through the study of the urban transformation of Hanoi City. The complete DEM must be meaningful not only for the study of urban transformation but also for the study of the urban sustainability such as the fields of civil engineering, construction and environmental preservation and so on.

2. Regional and global DEM

In general, DEM is a surface given in a form of grid. It is generated by overlaying the grid on a topographic map and recording the height of the grid node in a matrix form. It is suited as a DEM of Raster type and can be described with a simple file structure. Recently, there are many kinds of DEM, and they are the regional and global DEM datasets such as "Digital Map 50m Grid (Elevation)" published by Geographical Survey Institute in Japan, "GTOPO30[1]" (the grid spacing 30-arc seconds, approximately 1 km) available from the USGS (U.S. Geological Survey) and "SRTM[2] (Shuttle Radar Topography Mission)" is an international project produced by the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA). The SRTM data has two patterns of resolution, the resolution of SRTM-3 is about 90 m and SRTM-30 is about 900m.

1 GTOPO30 Data; ftp://edcftp.cr.usgs.gov/pub/data/gtopo30/global/
2 SRTM; http://www2.jpl.nasa.gov/srtm/
SRTM Data; ftp://e0srp01u.ecs.nasa.gov/srtm/

(a) (b)

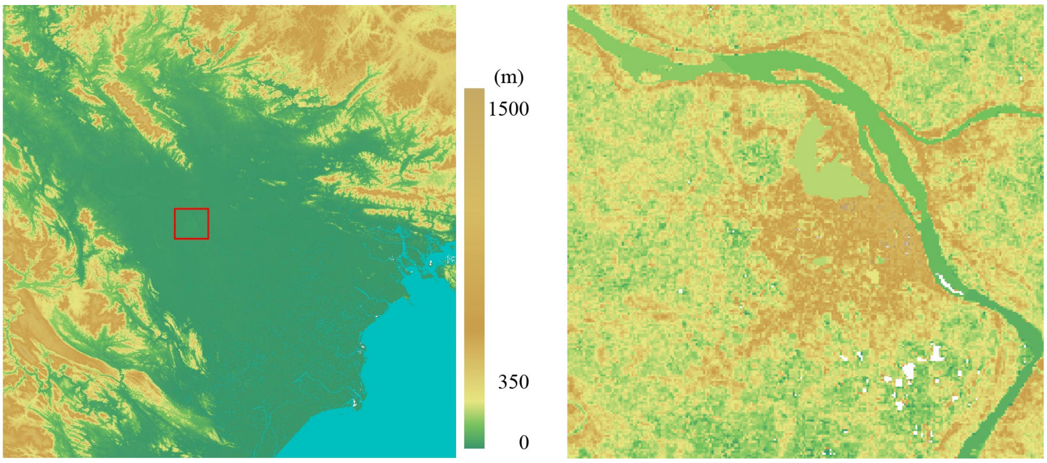

Figure 1: Visualization of SRTM-3 data.
(a) Elevation data of areas surrounding Hanoi City from SRTM-3 data. (b) Visualization of SRTM-3 data in central Hanoi City using an image analysis.

There are not high resolution DEM in Vietnam like “Digital Map 50m Grid (Elevation)”. Therefore, we need to generate the high resolution DEM based on a various data sources. In this paper, it is generated the DEM of Hanoi City from SRTM, the survey data and topographic map.

3. Generation of DEM

3. 1 Utilization of SRTM

SRTM-3 that contains Hanoi City is shown in Figure 1 (a). It is a mosaic image connected four data (N20E105.hgt, N20E106.hgt, N21E105.hgt, N21E106.hgt) using the GIS software (GRASS GIS[3]). These data can be downloaded from NASA web page. The bottom-left corner of the downloaded file “N20E105.hgt” means latitude 20° N and longitude 105° E of WGS 84 as a geographic coordinate system. Figure 1 (b) is the central area of Hanoi city. However, we can not see the detail changes in such a flat terrain. Because it is a low resolution for analyzing the urban transformation of Hanoi City, it needs to generate much higher resolution DEM.

[3] GRASS (Geographic Resources Analysis Support System) is a software for performing spatial analysis. It consists of more than 350 modules for processing vector (2D/3D), raster and voxel data. Many interfaces to other programs in related domains like geostatistics, databases, mapserver and even other GIS software exist. It can serve as a Desktop GIS and as the backbone of a complete GIS infrastructure.
URL; http://wgrass.media.osaka-cu.ac.jp/grassh/

3. 2 Utilization of survey data

Figure 2 (a) is shown in the one of the result map (paper map) for elevation survey by the ministry of resources and environment in 2005. Scale is 1:2,000. 21 maps were collected through Hanoi University of Mining and Geology. The example of survey data is listed in Figure 2 (b). The numbers of encircled points are elevation data (meter). Figure 2 (c) is all area of elevation survey and it is joined 21 maps. Survey area is 5km x 5km. The survey points are 8,015 points (Figure 2 (d)). First, it is generated in area of old quarter (Pho Co district). The DEM can be generated as follows:

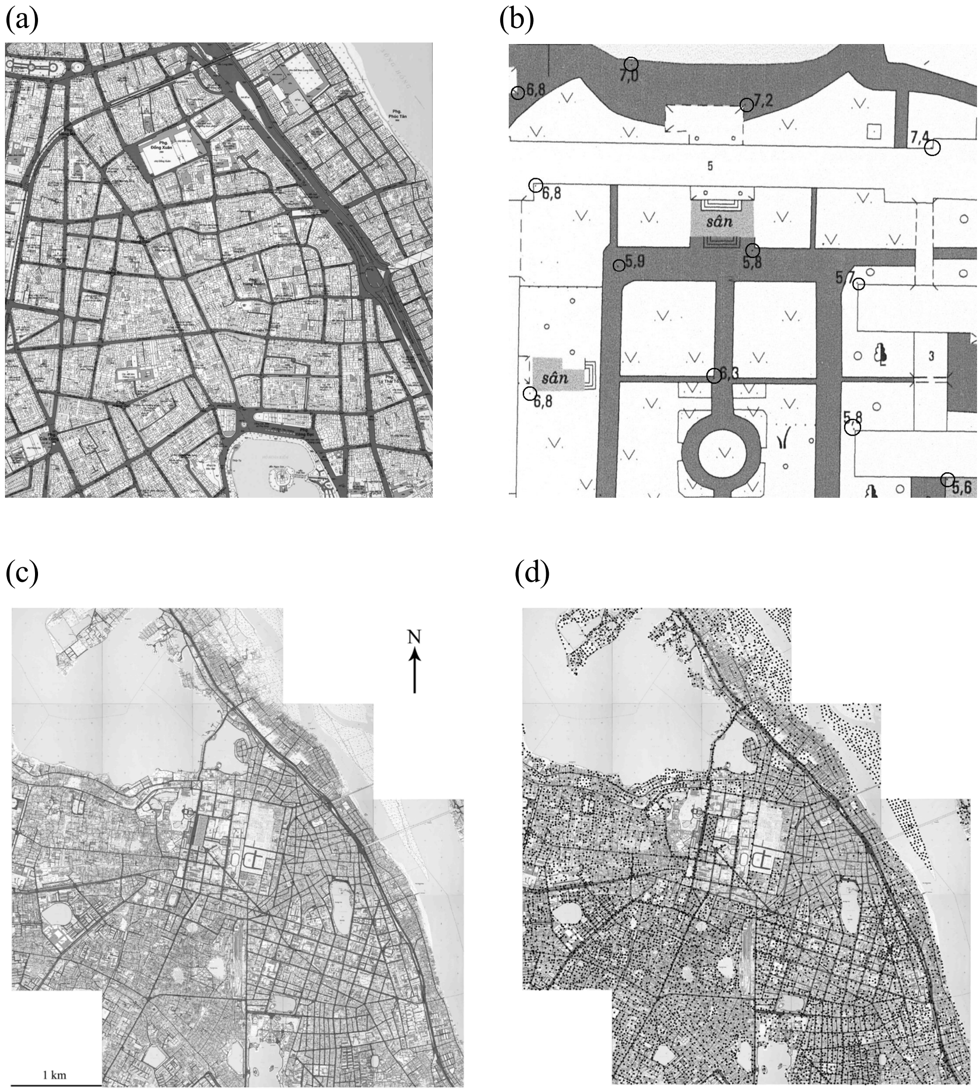

Figure 2: Elevation survey data of Hanoi City.
(a) Result map of elevation survey (Scale is 1:2,000.). (b) Example of elevation data. Encircled number is elevation (meter). (c) Area of elevation survey (Joined map of the 21 maps.). (d) Visualization of survey points (8,015 points).

Table 1: Example of data file.

id	x	y	z
1	6407	1172	6.5
2	6420	1341	7.1
3	6441	1632	6.9
4	5851	1210	6.5
…….			
0	9e9	9e9	9e9

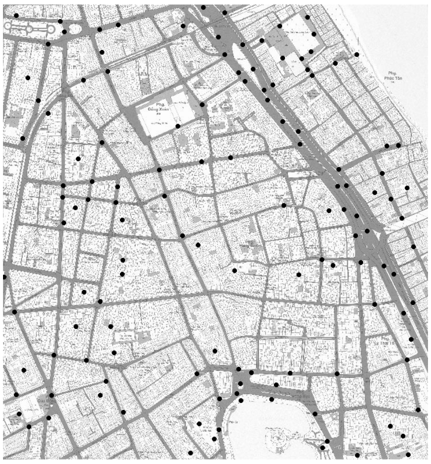

Figure 3: Survey points of old quarter (Pho Co district).

(1) Input the point data (x, y, z)

First of all, the paper map included the survey data is converted to digital data (TIF format file) by the scanning. Figure 3 is the survey data on the map. It can be read the coordinates (x, y, z) of the point using the painting software such as Corel Paint Shop Pro. Table 1 is the result data of the coordinates (x, y, z). (x, y) is a pixel position and z is a elevation (meter). If you can find a geographic coordinate system of the map, it can be converted the latitude and longitude by the affine coordinate transformation.

(2) Estimate the topographic surface using the developed program

The topographic surface is estimated from (x, y, z) based on the surface estimation method (we called it BS-Horizon.) using Cubic B-Spline Function (Nonogaki et al., 2008). BS-Horizon is one of the surface estimation programs for geologic boundary surfaces and topographic surfaces. This algorithm is coded in a FORTRAN program. BS-Horizon has a capability not only to generate a DEM but also to define a surface in a form of bi-cubic B-spline function, which gives a continuous surface up to the partial derivatives of second order. Therefore, we can calculate directly the topographic characteristics without any approximation. The data of Step (1) is inputted in this program.

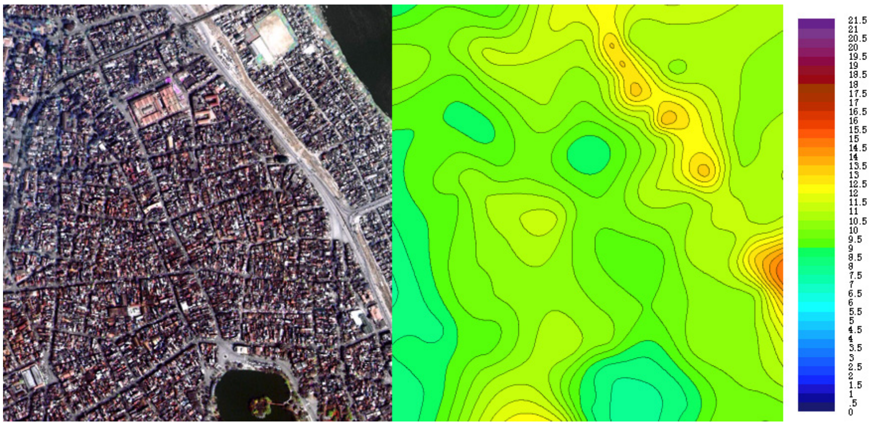

Figure 4: Visualization of satellite image and generated DEM.
Contour interval is 0.5 m.

(3) Output the topographic surface (DEM)

The satellite image (IKONOS) and the generated DEM in old quarter of Hanoi City are shown in Figure 4. The resolution of generated DEM is 2 m and the contour interval is 0.5 m. Hoan Kiem Lake and the great dike are visible in generated DEM.

DEM of whole Hanoi City (5km x 5km) is shown in Figure 5 (a) and there are 8,015 points of survey data in this area. The all point data are shown in Figure 2 (d). Figure 5 (b) is a contour map and contour interval is 0.5 m. The very subtle elevation gaps which can not be distinguished on SRTM data or the satellite image are significantly recognizable on it.

(a) (b)

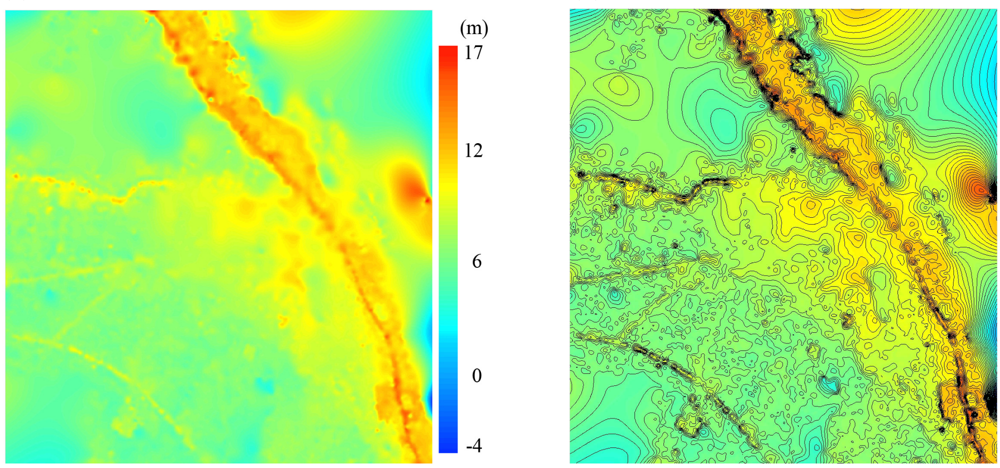

Figure 5: DEM of Hanoi City.
(a) Visualization of generated DEM. (b) Visualization of generated DEM with contour. Contour interval is 0.5 m.

(a) (b)

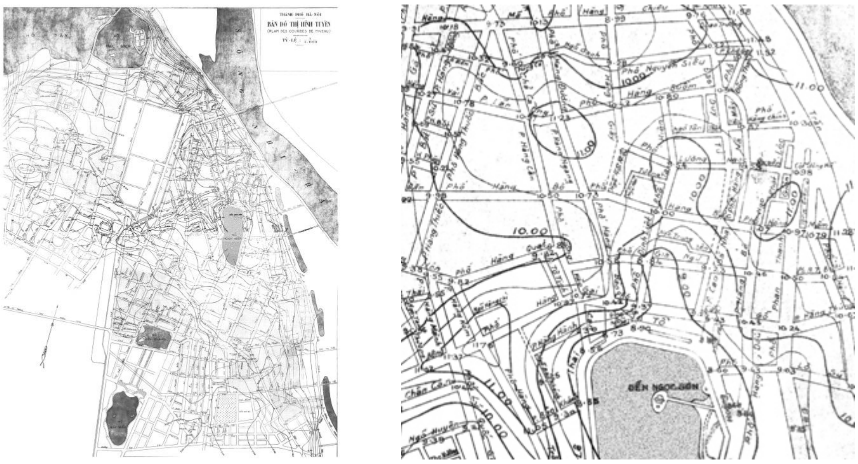

Figure 6: Topographic map in 1950.
(a) Topographic map from French government (Scale is 1:4,000).
(b) Example of Contour. Contour interval is 0.5 m.

3. 3 Utilization of Topographic Map

Topographic map is generated by French government in 1950 comes from French library as paper map (Figure 6 (a)). Scale is 1:4,000. Figure 6 (b) is the example of contour, contour interval is 0.5 m. The DEM at 2 m resolution is generated based on the STRIPE method (Noumi et al., 2003). The STRIPE method is an efficient generation of DEM from a topographic map. An elevation $f(x_p, y_p)$ at a point (x_p, y_p) in a space between two successive contour lines h and H must be

$$h < (x_p, y_p) < H \, .$$

Based on this idea, we can generate quickly a DEM by assigning the inequality constraints to each point in a space between contour lines after scanning a topographic map. This result is shown in Figure 7 (a). Contour interval is 0.5 m. Figure 7 (b) is the accuracy of the STRIPE method, it is rarely different from the original contour.

4. Discussion

Unfortunately, the topographic map was not available excepting the survey data in 2005 and French topographic map in 1950. Therefore, by the comparing of both DEM, it can be expected to show the urban transformation in Hanoi City from the topographic perspective.

The difference is calculated by the comparing between 2005's DEM and 1950's DEM shown in Figure 8 (a). The red end of the spectrum is higher than 1950's elevation. It can

(a) (b)

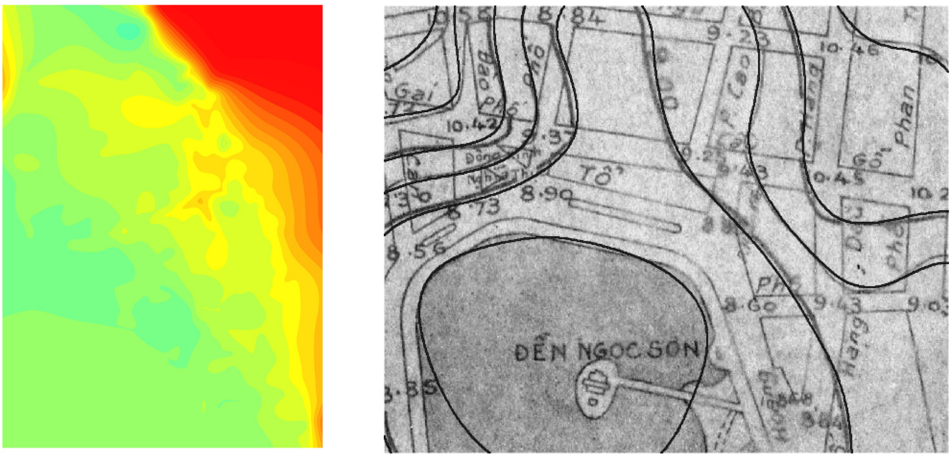

Figure 7: Generated DEM from topographic map.
(a) Visualization of generated DEM. (b) Accuracy of STRIPE method.

(a) (b)

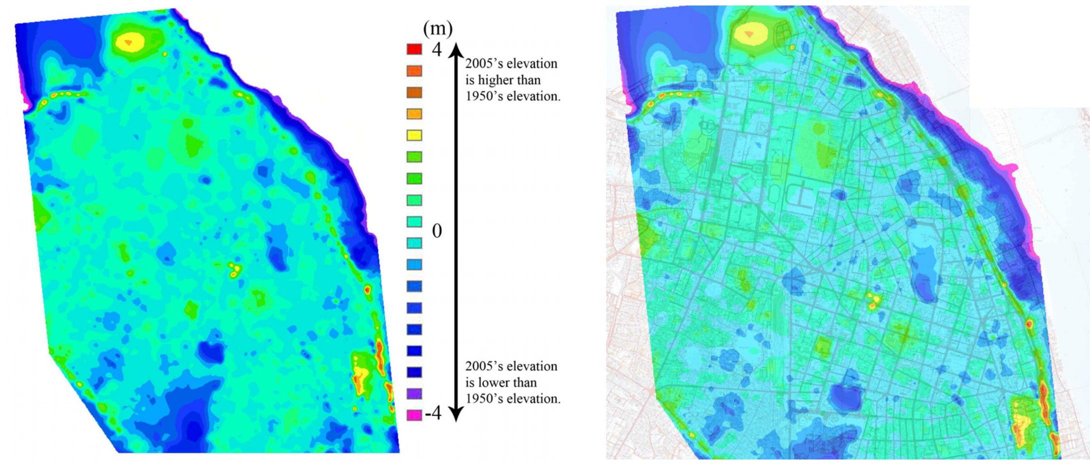

Figure 8: Difference of DEM (2005 and 1950).
(a) Result map of difference between 2005's DEM and 1950's DEM. The red end of the spectrum is higher than 1950's elevation.
(b) Map (1:2,000) overlay with difference of DEM.

be found two remarkable points from Figure 8 (a). One is the elevation of big dike. It is about 2 m higher than the 1950's elevation. The average height of dike in 2005 is about 12 m, on the other hand in 1950 it was about 10 m. This difference shows that the dike is additionally constructed from 1950. Haruyama (2004) showed the height of dike in 1809 was 3.5 m from several historical materials. Therefore, the height of dike seems to be increased year by year.

The other is a land subsidence in Pho Co district. Figure 8 (b) is the overlaid map with the 2005's map over the image of Figure 8 (a). The blue end of the spectrum is lower than 1950's elevation. The average elevation of Pho Co district is about 9 m in 2005. This is 0.5 m lower than the elevation in 1950. Therefore, it can be defined the land subsidence has happened.

5. Conclusions

In this study, the DEM of Hanoi City in Vietnam was generated by the elevation survey data and the topographic map. The very subtle elevation gaps which can not be distinguished on the satellite images are significantly recognizable on their DEM. They are high resolution not only for analyzing the urban transformation of Hanoi City, but also for the urban sustainability of Hanoi City such as an improvement of urban infrastructure and disaster prevention.

The generated DEM give us not only the detail information of terrain of Hanoi City, but also the information of landform changes for approximately 50 years. There are two remarkable changes; (1) the additional construction of dike, (2) the change of terrain around Pho Co district. Future work, the relation between the flood and the construction of dike would be the most important element to study in this area. Hanoi City is going to have its 1,000th anniversary in 2010. This city has been protected by this dike from the flood of Red River for a long time. It is necessary to concern about the effects of dike of Red River on the urbanization and the life of residents. Additionally, it is necessary to search the traces of an ancient rivers and the landfills area from the generated DEM. These signs can be more practical indicator when we consider the relation between the urban transformation and the topographic changes.

Acknowledgement

This research is based on "Development of system for spatiotemporal mapping with emphasis on urban area in Southeast Asia" in Grant-in-Aid for Young Scientists (B) (Issue No. 19710208), "Originating of Area Informatics-with a Focus on Southeast Asia" in Grants-in-Aid for Scientific Research, Scientific Research (S) (Issue No. 17101008) and "Impacts of Development Programs on Sustainable Use of Ecological Resources of Southeast Asia" in Integrated Research (Institute of Sustainability Science, Kyoto University).

References

Haruyama, S. 2004. Natural Environmental Study Applied for Agriculture in the Northern Vietnam: Natural Hazard and their Diffence Policy against Disaster, the Red River Delta. KOKON SHOIN, 131p.

Nonogaki, S., Masumoto, S. and Shiono, K. 2008. Optimal Determination of Geologic Boundary Surface Using Cubic B-Spline. *Geoinformatics*, 19, 2, pp. 61-77.

Noumi, Y. 2003. Generation of DEM Using Inter-Contour Height Information on Topographic Map. *Journal of Geosciences*, *Osaka City University*, 46, 14, pp. 217-230.

Sakurai, Y. and Shibayama, M. 2007. GIS4D Analysis of the Distribution of Thang Long-Hanoi Relics and Inscriptions. *Symposium "Area Studies and Informatics: Opening a New Horizon" Lecture Series*, Center for Southeast Asian Studies, Kyoto University, pp. 37-53.

Shibayama, M., Yonezawa, G. and Luan, T. 2008. Hanoi Urban Transformation in the 19th, 20th, and 21st Centuries on Area Informatics Approach - Disappearance of the Lakes and Ponds, and Transition of Villages -. *Proceedings of International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences 2008*, pp. 397-402.

Yonezawa, G. and Shibayama, M. 2007. Clarification of historical changes and urban transfiguration in Hanoi, Vietnam using GIS. *IPSJ Symposium Series 2007*, 15, pp. 139-146.

Yonezawa, G., Shibayama, M., Nonogaki, S., Masumoto, S., Raghavan, V. and Luan, T. 2008. Hanoi Urban transformation in the 19-21 Centuries - Topographic Changes and 3-d Modeling -. *Proceedings of International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences 2008*, pp. 409-414.