Note:

Understanding Regional Building Characteristics in Yangon Based on Digital Building Model

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It is indispensable for a government to assess urban vulnerability to natural disasters such as earthquakes or flood in order to take appropriate disaster measures. However, it is sometimes difficult to obtain necessary dataset for cities or regions, especially for developing countries. The authors have been involved in a SATREPS project named "Development of a Comprehensive Disaster Resilience System and Collaboration Platform in Myanmar," which aims to make urban vulnerability maps for Yangon City based on several datasets including building inventory of each ward. However, Yangon City has not catalogued enough data for the assessment so far. In this context, in order to understand and to arrange regional building characteristics of the city, this paper explores the possibility of using digital building model (DBM) data obtained from remote sensing imageries for the urban vulnerability assessment.

Firstly, a field survey was conducted in Sanchaung Township, and building characteristics such as structural types and the number of stories were analyzed. Therefore, DBM data was prepared for the following comparative analysis. Thirdly, additional field surveys were conducted in Latha and Pabedan Townships, located in the central business districts in the city. Finally, DBM data and the actual building data obtained by the surveys were compared to examine the applicability of DBM for building collapse risk assessment. As a result, it was found that DBM data of 3 m- 7 m represent low-rise buildings, and DBM data of more than 18 m reflect high-rise buildings.

Keywords: urban vulnerability, Myanmar, building collapse risk, remote sensing, DBM

1. Introduction

1.1. Background and Purpose

It is indispensable for a government to assess urban vulnerability to natural disasters such as earthquakes or floods in order to take appropriate disaster measures. However, it is sometimes difficult to obtain necessary dataset for cities or regions, especially for developing countries. Myanmar is such a country, facing recent rapid urbanization; it is therefore necessary to appropriately manage future disaster risks for the cities in the country.

Possible disasters in Myanmar are earthquakes, cyclone, and floods. Especially "earthquake" is an alarming disaster because Naypyidaw, the capital, and Yangon are located in the Sagaing Fault. Earthquakes of more than M7 has been recorded more than 16 times in the history of Myanmar, including six earthquakes that occurred along the fault. Proper disaster management is critical for Myanmar to reduce future damage caused by earthquakes.

The authors have been involved in a SATREPS project named "Development of a Comprehensive Disaster Resilience System and Collaboration Platform in Myanmar," aiming to make urban vulnerability maps for Yangon City based on several datasets including building inventory of each ward (Murao et al., 2015 [1]).

The urban seismic vulnerability evaluation of Yangon City, namely building collapse risk assessment, in this SATREPS project follows the community earthquake risk assessment conducted by the Tokyo Metropolitan Government (TMG) (2013) [2] that has, in its forty-year history, defined building collapse risk follows:

> *Building collapse risk is a measure of the danger of buildings collapsing or tilting due to shaking from an earthquake. This risk is measured according to the type of buildings in the community and ground soil classification.*

In order to apply this earthquake risk assessment to Yangon, information on soil conditions, building inventory, and building vulnerability functions are necessary (Murao et al., 2016 [3]). However, Yangon City has not catalogued enough data for such an assessment thus far. Japan International Cooperation Agency (JICA) prepared GIS dataset, explained in section 3.2, with the number of buildings. This means that we can obtain building data necessary for the building collapse risk evaluation:

namely, the number of buildings in terms of structural types (RC and wooden building at least) and the ratio of building structural types in each township or ward.

In this context, this research aims to propose a method to obtain building inventory available to be used for building collapse risk evaluation, for regions or countries that do not maintain those dataset as Yangon City. This research explores the possibility of using digital building model (hereafter DBM) data, obtained from remote sensing imageries, to understand and arrange regional building characteristics based on the building type ratio of the city.

1.2. Existing Related Research

Recently, the improvement and rapid spread of remote sensing technologies have influenced research on urban disaster reduction with respect to garnering detailed information regarding the physical environment such as buildings or urban fabric. These technologies cover a wide range from damage estimation just after a disastrous event to post-disaster recovery, or urban vulnerability assessment.

Some research groups have considered the use of satellite images for emergency response. For example, Koarai et al. (2008) [4] analyzed large-scale geological hazards in the case of the Northern Pakistan Earthquake, the Middle Java Earthquake, and the Leyte Landslide by using optical high-resolution satellite imagery such as QuickBird, IKONOS, ALOS and SPOT5, and found that 1 m resolution stereo images are necessary for recognizing building damages in urban areas. Matsuzaki et al. (2010) [5] conducted visual damage interpretation of buildings damaged due to the 2007 Peru Earthquake and compared the field survey data with QuickBird satellite images and reported that the accuracy of the damage grade depends on factors such as the influence of building shadows, differences in the time of data acquisitions, and local building/environmental conditions. Gokon et al. (2017) [6] developed a method to estimate building damage in tsunami-affected areas using L-band SAR (ALOS/PALSAR) data, focusing on Sendai City and Watari Town affected by the 2011 Great East Japan Earthquake and Tsunami.

Satellite imagery have been used for the research field of post-disaster recovery to understand urban recovery processes from great disasters. Nakaoka and Nakao (1998) [7] attempted to grasp recovery conditions from the 1995 Great Kobe earthquake using hue information of satellite images. Murao et al. (2004) [8] reported the post-earthquake urban recovery of Chi-Chi Township affected by the 1999 Taiwan Earthquake using a base map made from IKONOS image. Following the urban recovery research in Chi-Chi, Murao et al. (2013) [9] and Hoshi et al. (2014) [10] conducted field surveys in Pisco, damaged due to the 2007 Peru Earthquake, and examined how QuickBird and WorldView-2 were useful in understanding the five-year recovery process of Pisco.

Remote Sensing Technology has also been applied to obtain building information for research on urban vulnerability. For example, Miura and Midorikawa (2006) [11] created building inventory data in Metro Manila in the Philippines using building shadows appearing in IKONOS satellite images. Shaker et al. (2011) [12] assessed building heights in Cairo, Egypt, from IKONOS satellite stereo-pair images. Matsuoka et al. (2013) [13] extracted the spatial distribution of building age from time-series Landsat satellite images and building heights from ALOS/PRISM stereovision images for earthquake damage estimation for Lima, Peru, comparing aerial photographs and field survey.

As seen above, various remote sensing technologies have been used to obtain building inventory in several cities. However, none of them have been applied to the characteristics in Yangon except for some cases. For example, Sritarapipat and Takeuchi (2015) [14] proposed a methodology to estimate land value and disaster risk areas in Yangon using satellite images of GeoEye-1 and Landsat 1-7 from 1970 to 2010. This paper attempts to extract regional building characteristics of Yangon City for earthquake damage assessment based on DBM.

2. Method

With a focus on Yangon, this research aims to extract regional building characteristics in terms of building height using DBM data.

To this end, the following procedure is conducted.

First, a field survey is carried out in Sanchaung Township, a typical residential and commercial district in Yangon, to collect building inventory in order to analyze building characteristics. A dataset provided by JICA is used to support the survey.

Second, the possibility of using DBM data to understand regional characteristics is considered. The DBM data was arranged by Sritarapipat and Takeuchi (2017) [15].

Following the DBM consideration, other field surveys are conducted in Latha, and Pabedan Townships in the central business district (hereafter CBD) to collect more building information for the next stage.

Finally, the data on the number of stories of buildings obtained by the surveys is compared with DBM data to examine how we can use DBM to extract regional building characteristics.

3. Field Survey and Building Characteristics in Sanchaung

3.1. Outline of the Survey

First, the authors conducted a field survey to comprehensively understand building characteristics and their tendency in Yangon for the following steps. The survey was taken in May 2016 in Wailuwn Ward (North) in Sanchaung Township (**Fig. 1**), which is a typical residential area in the country, with houses, apartments, temples, a residential block for public employees, and local markets for the communities.

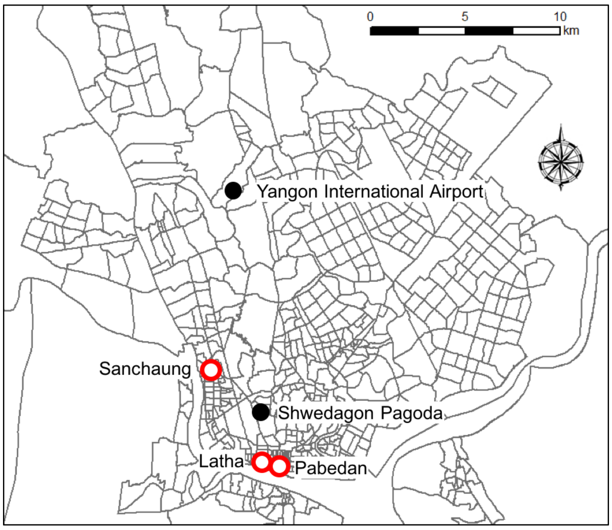


Fig. 1. Location of field surveys in Yangon.

Fig. 2. Wailuwn Ward (North) in Sanchaung Township with JICA point data.

(a) Wooden

(b) Brick nogging in a wood frame

(c) RC (including brick nogging)

Fig. 3. Structural types of the buildings.

3.2. Date Used

JICA and Yangon City Development Committee (YCDC) released "A Strategic Urban Development Plan of Greater Yangon" in April 2013 [16], as a result of comprehensive urban investigation. JICA provided the GIS datasets used and arranged for the investigation to us such that we could use one dataset showing each building location point for the survey. However, it did not contain the building inventories, necessary for the research, i.e., the number of stories, and structural types. We therefore investigated these building properties by visual observation on-site based on JICA point data as shown in **Fig. 2**.

3.3. Visual Observation On-site

According to the JICA data, the total number of the objective building points in the site was 350. Walking around the district, we observed building characteristics and collected building inventory in terms of the number of stories and structural types. The structural types were basically classified into three categories, as shown in **Fig. 3**: (a) wooden, (b) brick nogging in a wood frame, (c) RC (including brick nogging). Because we found some simple storage space and light steel huts not used for living space, among the JICA point data, these structures were categorized into "Others." Furthermore, we recognized that some building conditions had been changed from the investigation conducted by JICA in 2010-2012 [16]: Some of them became vacant lots, and the other lots were under construction. These lots were recognized as "Not Applicable (NA)" data.

3.4. Building Characteristics Tendency

Figure 4 shows the structural type ratio to the total number of buildings in the objective district. The ratio of wooden buildings is the highest by 56.3%, followed by RC (19.4%) and brick nogging in a wood frame (11.7%). The lots of 11.1% had been changed.

Figure 5 demonstrates the number of buildings classified in terms of the number of stories and structural types. The largest number of stories is two-story buildings by 193, followed by one-story buildings. Most of these low-rise buildings (1 F–2 F) are wooden and brick nogging in a wood frame by 97.5%, different from the other story buildings (3 F–8 F) constructed by RC.

The fact that most of the low-rise buildings consist of wooden and brick nogging in a wood frame, and that

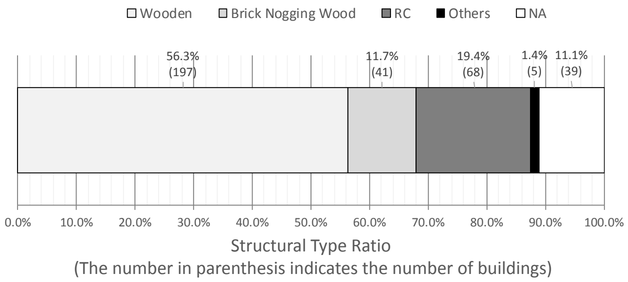


Fig. 4. Structural type ratio in Wailuwn Ward (North), Sanchaung Township.

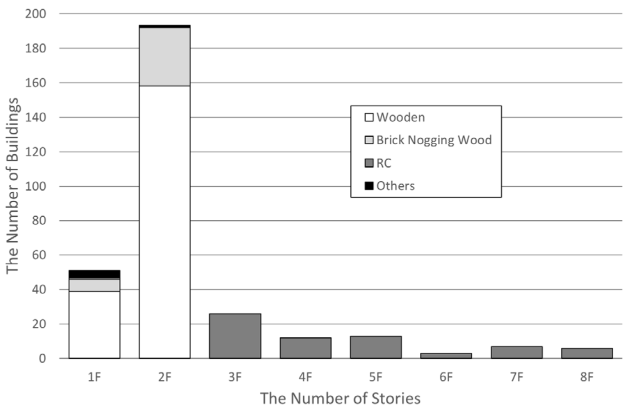
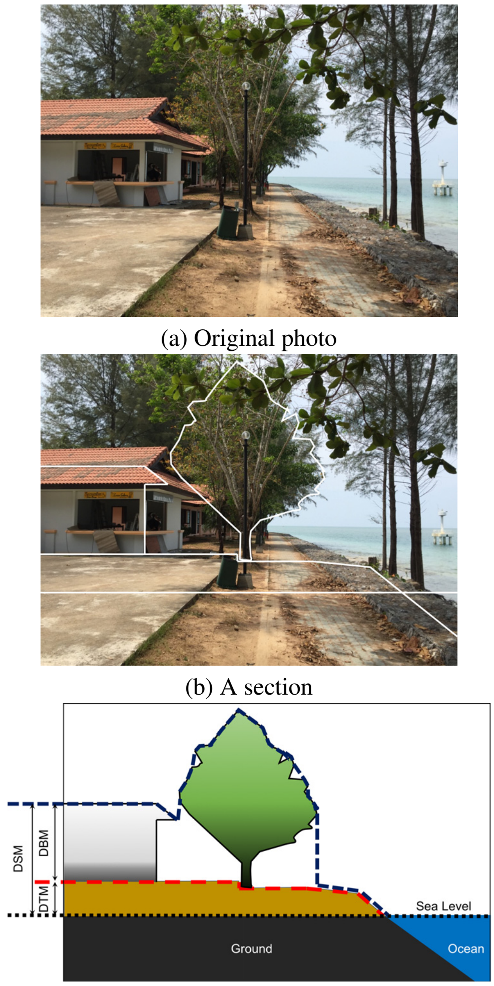


Fig. 5. The number of buildings in terms of the number of stories and structural types in Wailuwn Ward (North), Sanchaung Township.



(a) Original photo

(b) A section

(c) DSM, DTM, and DBM differences

Fig. 6. Meaning of DSM, DTM, and DBM.

most of the other middle- and high-rise buildings are constructed by RC, is useful information to consider DBM application for understanding the regional building characteristics in the following stages.

4. Use of Digital Building Model Data

4.1. Digital Building Model

DBM, which is indispensable data for this research, is explained using a digital surface model (DSM) and digital terrain model (DTM) in this section. Pictures shown in **Fig. 6** demonstrate significance of DSM, DTM, and DBM. **Fig. 6(b)** indicates one section of the coastal space shown in **Figs. 6(a)**, and **6(c)** illustrates the section diagram with the lines showing DSM, DTM, and sea level. DSM represents the earth's surface and all objects on it, including trees and buildings. On the other hand, DTM is a model of the earth surface itself in terms of the height from sea level. Thus DBM is produced by the difference between DSM and DTM at the same point, showing heights of objects such as buildings or trees.

4.2. DBM Data Used

Sritarapipat and Takeuchi (2017), members of the Myanmar SATREPS Project, proposed a methodology to classify and extract types of buildings by using Stereo GeoEye images, multi-spectral Landsat image, and night-time light (NTL) images from Visible Infrared Imaging Raiometer Suite (VIIRS) [15].

Table 1. Details of the remotely sensed dataset (Sritarapipat and Takeuchi [15]).

Satellite	Resolution	Bands	Acquisition date
GeoEye-1	0.5 m	3	2013/11/08, 2013/11/16
Landsat-8	30 m	11	2015/02/26
NPP-VIIRS (DNB)	460 m	1	2012/04/18-2012/04/26, 2012/10/11-2012/10/23

The study location of their research was focused on the center areas of Yangon city. Remotely sensed dataset was acquired from three sources with GeoEye, Landsat 8, and National Polar-orbiting Partnership (NPP) – VIIRS. The stereo GeoEye images with a high spatial resolution were employed to provide the heights of buildings. The multispectral Landsat image with a high spectral resolution was classified to obtain land cover areas. The NTL image from NPP-VIIRS, which has the capability to obtain day/night band composite data (DNB), was exploited to observe NTL consuming activities. The radiance of DNB is a number with the magnitude of 10^{-9} and the unit of W/(cm^2-sr). The details of the satellite dataset are displayed in **Table 1**. For the first classification process, the

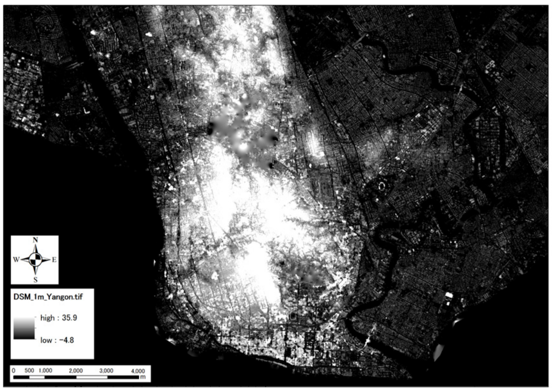


Fig. 7. DSM of Yangon City.

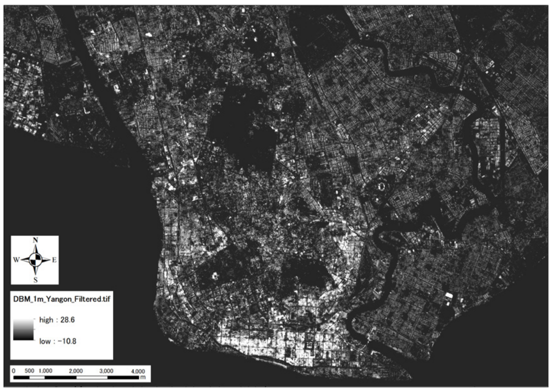


Fig. 8. DBM of Yangon City from which vegetation areas removed.

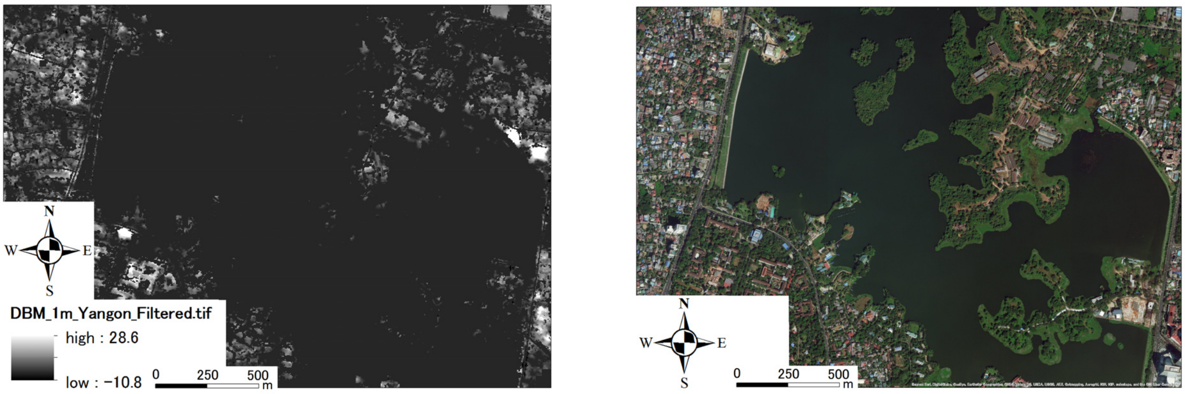


Fig. 9. Comparison of DBM (left) and aerial photo (right) of Inya Lake.

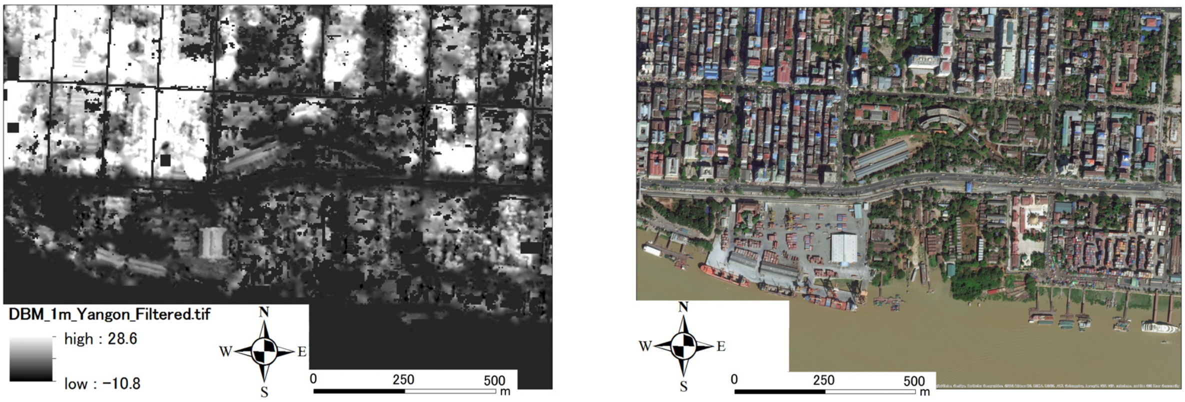


Fig. 10. Comparison of DBM (left) and aerial photo (right) of the ferry terminal.

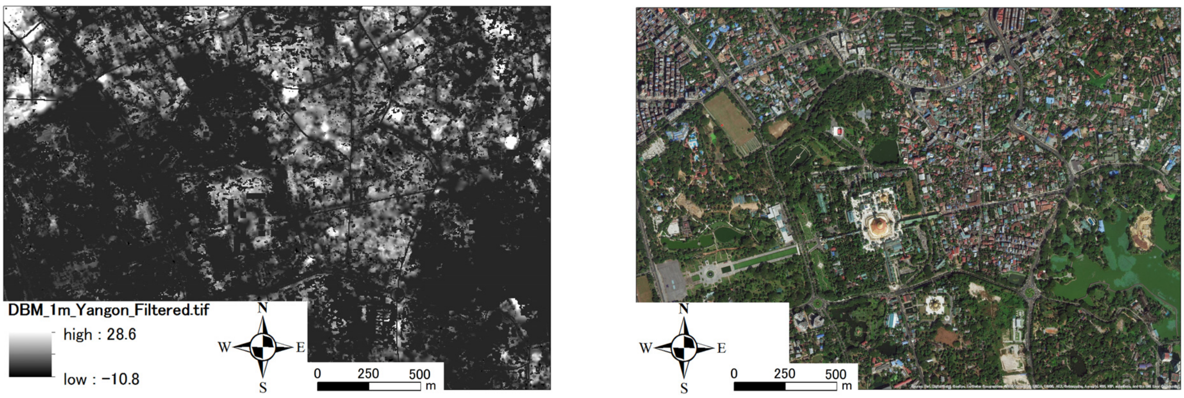


Fig. 11. Comparison of DBM (left) and aerial photo (right) of Shwedagon Pagoda.

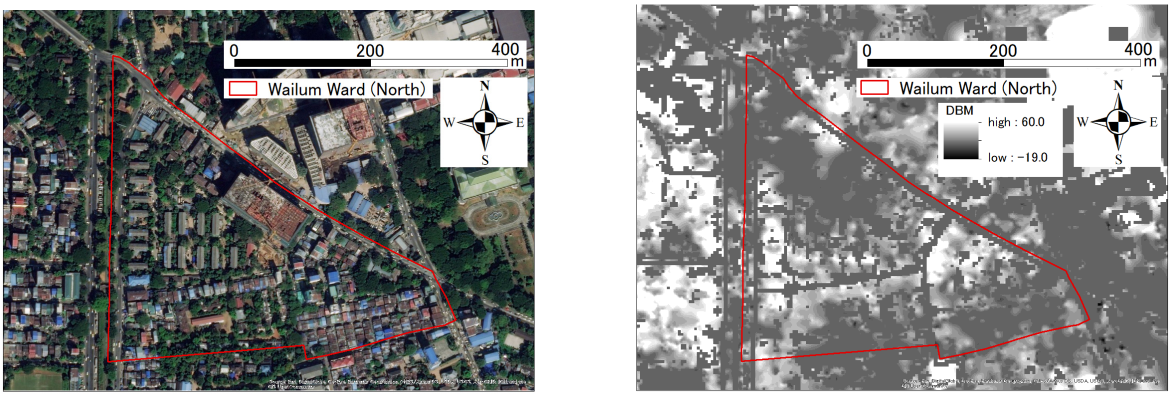


Fig. 12. Aerial photo (left) and DBM (right) of Wailuwn Ward (North), Sanchaung Township.

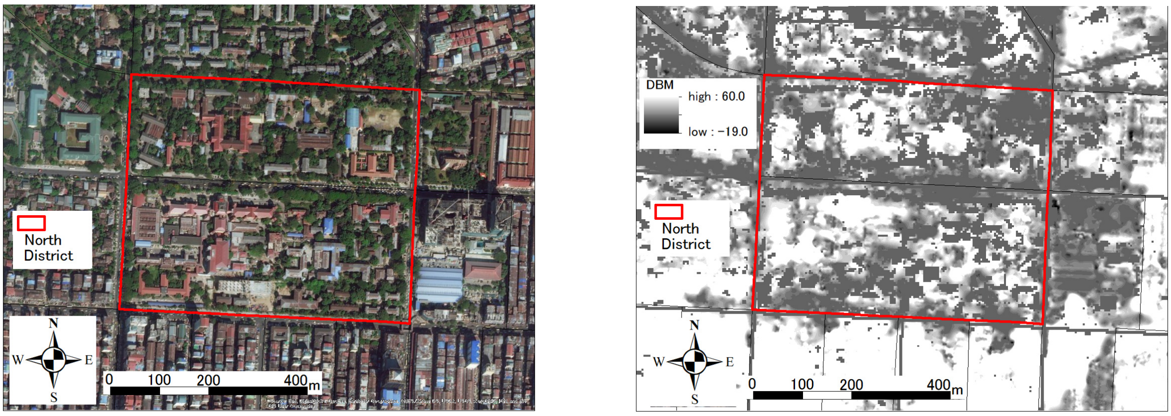


Fig. 13. Aerial photo (left) and DBM (right) of the North District of Latha Township.

stereo GeoEye images were used by PCI Geomatica 2015 software to provide the DSM, which was, thereafter, filtered with a morphological filter to get DTM. By subtracting the DSM from the DTM, the DBM was provided as shown in **Fig. 7**. They were checked to confirm that the DBM was reliable to be used and found that the root mean square error (RMSE) between the estimated DTM and the surveying elevation data was 1.62m.

Our research is based on the DBM obtained in the research above. However, it was difficult to recognize one place observed by aerial photo as the same place by the DBM image. We assumed this was caused by greenery, and decided to remove vegetation areas for the following analysis. Because GeoEye images do not have NIR band to use NDVI, the vegetation areas were removed from DBM by using ExcessGreen (ExG) GeoEye image in 2013. Through those processes, the final DSM data for the following analysis was obtained as shown in **Fig. 8**.

In order to confirm the reliability of using the DBM obtained by the above process, the DBM of the following three characteristic districts were compared with the aerial photos: Inya Lake (**Fig. 9**), the ferry terminal in CBD (**Fig. 10**), and Shwedagon Pagoda (**Fig. 11**). Although detailed information such as individual buildings are not clear, large scale structures and urban fabric are more understandable than using the original DBM.

The original DBM value of each pixel is a floating number. We rounded off the value to the nearest integer for the following analysis.

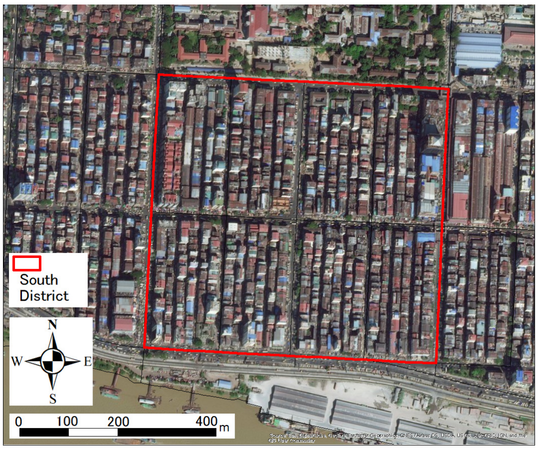
Fig. 14. Yangon General Hospital in the North District of Latha Township.

5. Field Surveys in Latha and Pabedan

5.1. Outline and Aim of the Surveys

In order to explore the possibilities of using DBM, a comparative study of DBM and actual building conditions was needed. Although the actual building inventories of Wailuwn Ward (North) in Sanchaung Township had already been obtained, as mentioned in section 3, it was not enough because the analysis required more congested, higher districts. We therefore conducted more field surveys in three districts in Latha and Pabedan Townships, as shown in **Fig. 1**, considering the balance of districts' densities, building heights, and other characteristics.

The purpose of the surveys was to collect the number of



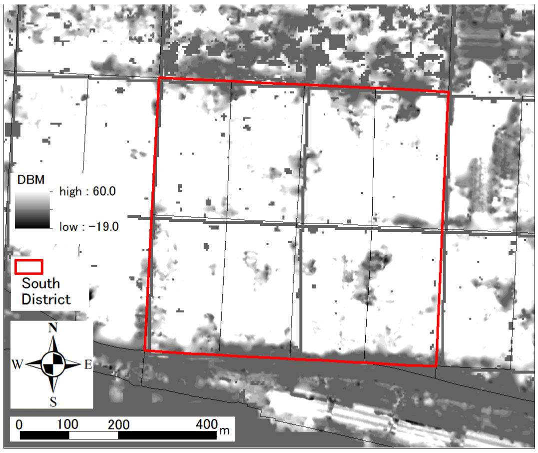


Fig. 15. Aerial photo (left) and DBM (right) of South District in Latha Township.

stories of all the buildings in the object districts. According to a result of the analysis in section 3, we classified the number of stories into three groups: 1 F–2 F (low-rise buildings), 3 F–6 F (middle-rise buildings), and more than 6 F (high-rise buildings). We investigated all the buildings in the object districts in December 2016, and collected building story information by visual observation based on this classification.

5.2. Object Districts

The accuracy of the obtained DBM data, which shows regional characteristics in terms of object height, depends on building density or building height because of off-nadir angle of the original satellites used for creating the DBM. It is difficult for satellites to acquire reflection of lower buildings surrounded by higher buildings in high density areas. Therefore, we chose two types of districts for a comparative analysis in the next step: lower districts and higher districts. The aerial photos and DBM of the districts, including Wailuwn Ward (North), used for the surveys, are shown below.

In addition to Wailuwn Ward (North) (**Fig. 12**), where we had already conducted the survey, the North District of Latha Township (**Fig. 13**) was chosen as another lower district. Latha Township is located in the CBD, developed in the late 19th century. The northern part of Latha is a low-building density district with Yangon General Hospital (**Fig. 14**), the University of Public Health, and high-schools.

However, the southern part of Latha was chosen as a higher district for the surveys (**Fig. 15**). The South District is orderly crowded with middle- and high-rise buildings (**Fig. 16**) for residences, shops, and manufactories, including a part of China Town.

Another higher district was chosen from Pabedan Township, the east of Latha (**Fig. 17**). Pabedan Township is also a part of the Yangon CBD, which boasts the famous Bogyoke Aung San Market, hotels, and shopping malls. The southern part of the township, facing the Sule Pagoda, was chosen for the survey. It has similar characteristics to the southern district of Latha, with narrow

Fig. 16. South District of Latha Township, surrounded by middle- and high-rise buildings.

streets and crowded buildings (**Fig. 18**); however, it is closer to the center of the CBD with the heritage buildings of Yangon, such as the Former Ministry of Hotels and Tourism, and Myanmar Oil and Gas Enterprise.

6. Comparjson of DBM and Actual Building Height

6.1. Comparison of Point Level Between DBM and the Number of Building Stories

This section compares DBM data with actual building height, in terms of the number of building stories, obtained in the field surveys. Firstly, focusing on Wailuwn Ward (North), point levels indicating each building location on the JICA's GIS map and the number of stories are compared.

JICA data locate each building position in each building foot print as a point data. The points in **Fig. 19** indicate building locations created for JICA's investigation [16]. The numbers in blue represent DBM data of the points respectively, and the numbers in yellow show IDs we used in the survey. The relationship between DBM value and the number of building stories belonging to the points are examined.

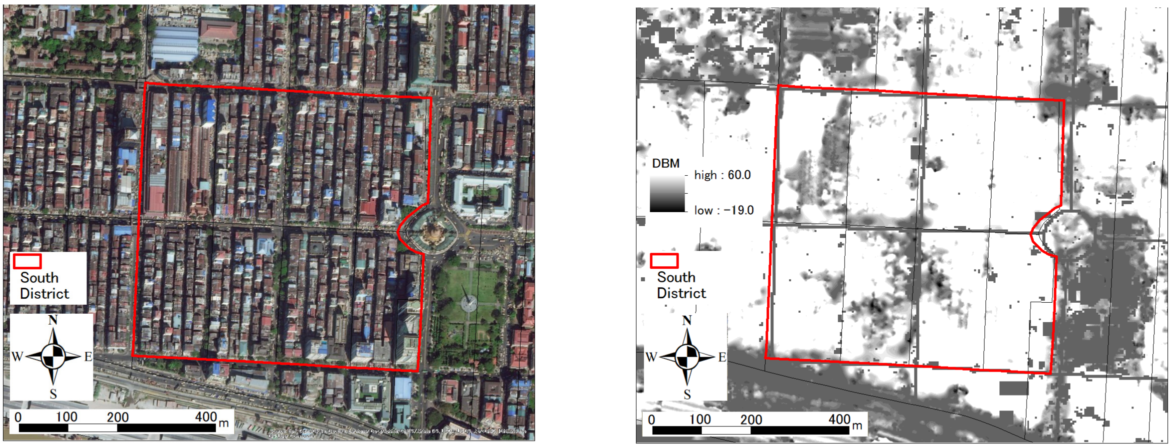


Fig. 17. Aerial photo (left) and DBM (right) of South District in Pabedan Township.

Fig. 18. South District of Pabedan Township, surrounded by middle- and high-rise buildings.

Fig. 19. Points indicating building locations in Wailuwn Ward (North), Sanchaung: Numbers in blue showing DBM, and in yellow showing ID in the field survey.

Figure 20 demonstrates a scatter diagram of the relationship. As shown, the correlation between DBM value and the number of building stories is very low. It can be inferred that a point having a DBM value produced as a result of remote sensing satellite reflection of objects, does not always correspond to an actual point because of the off-nadir angle. This is especially so for high-rise buildings. The actual surface height of areas hidden by neighbor higher buildings is difficult to obtain by satellite. This resulted in big gaps shown in the figure. Furthermore, DBM is a dataset produced by the complicated process of using DSM and DTM, so it has some uncertainty. Therefore, another idea is needed for the analysis.

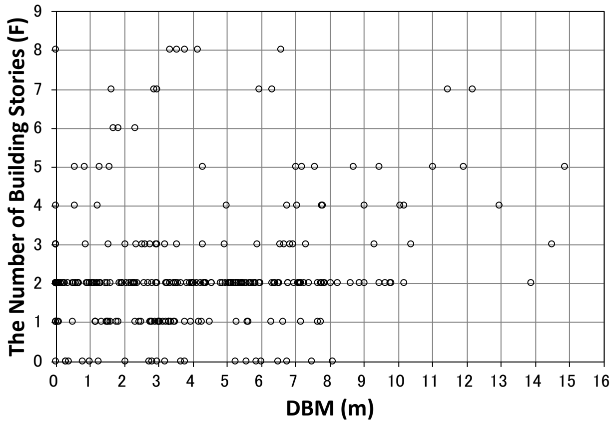


Fig. 20. Scatter diagram of the relationship between DBM value and the number of building stories for Wailuwn Ward (North).

6.2. Concept of Comparison Based on DBM Area Ratio

For the next step, this section proposes an area ratio-based comparison, instead of the point level-based comparison. As earlier mentioned in section 1, the vulnerability assessment we are aiming at is based on the earthquake risk assessment conducted by TMG [2]. This method is to evaluate the number of buildings in a spatial unit, such as neighborhood, that would be damaged by a strong earthquake. Hence, necessary information on the building vulnerability assessment in this project is the number of buildings in terms of building characteristics. Because the JICA GIS data already contains the total number of buildings for each ward, a spatial unit for communities in Yangon, what we need is the ratio of the number of buildings to the total number of buildings in an area in terms of height, namely the number of building stories. The concept of this comparative study is illustrated in **Fig. 21**.

The top right figure shows an actual building location image of an area. In order to calculate the ratio of higher

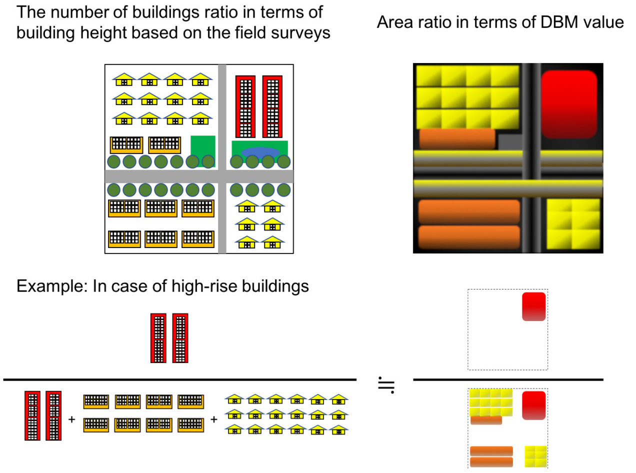


Fig. 21. Concept of the comparison based on DBM Area Ratio.

buildings, red ones, to the whole buildings, the answer, 0.071 in this case, is easily drawn by the number of each type of building, shown in the bottom right figure. However, to count the number of buildings in terms of building characteristics of Yangon, which number up to millions, is very difficult.

We therefore assume that the number of buildings ratio can be obtained by area ratio in terms of DBM value. The top left figure illustrates a DBM image for the right area. The red area represents the place of the higher buildings: The yellow areas for the lower-rise houses, and the orange areas for the middle-rise building. The areas for streets, greenery, and water place are in black because the values of the DBM for the elements should be close to 0. Although the heights of trees are not same in the real world, they are taken as the same along the street in the right figure, albeit less than the height of the yellow houses. Then the areas for the trees are colored with yellow-black in the right figure. The DBM area ratio for the higher buildings can be calculated as shown in the bottom left figure. It is the ratio of red areas to the total areas of red, orange, and yellow, representing building location zones after eliminating the lower-value DBM area from the whole area.

6.3. Comparison Based on DBM Area Ratio for the Object Districts

6.3.1. Regional Building Characteristics in the Object Districts

The number of buildings and the ratioo in terms of building stories in the object districts obtained by the field surveys are shown in **Table 2** and **Fig. 22**. The dominant is low-rise buildings in Wailuwn Ward (North) and Latha North District and the number of high-rise buildings are very few in these districts. On the other hand, the largest number is that of middle-rise buildings, followed by high-rise buildings in Latha South District and Pabedan South District. Low-rise buildings are in the minority in the districts. This result clarifies the characteristics of the districts.

Table 2. The number of buildings in terms of building stories in the object districts.

ID	1	2	3	4
Township	Sanchaung	Latha	Latha	Pabedan
Object District	**Wailuwn Ward (North)**	**Latha North District**	**Latha South District**	**Pabedan South District**
1-2F (low-rise)	244	75	111	62
3-6F (middle-rise)	54	52	492	701
7F- (high-rise)	13	0	271	303
Total	311	127	874	1066

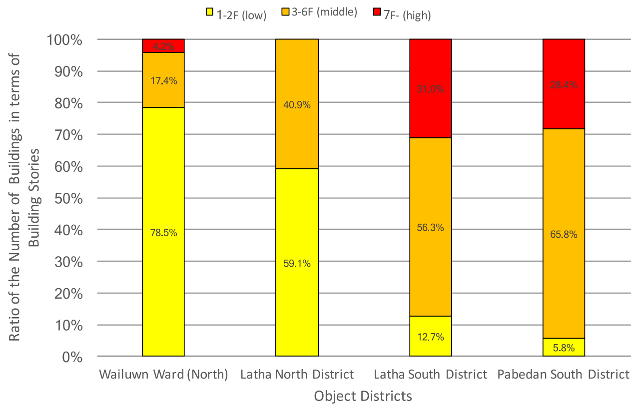


Fig. 22. Ratio of the number of buildings in terms of building stories on the object districts.

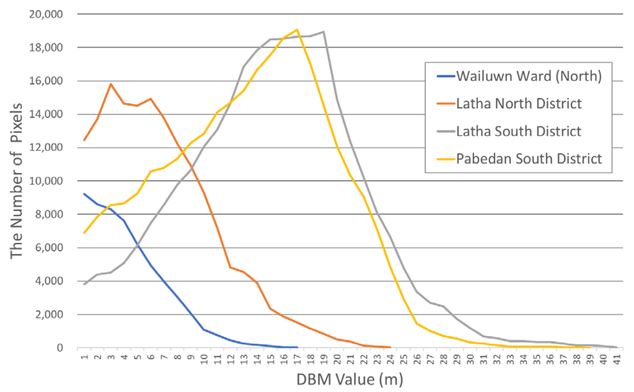


Fig. 23. Distribution of DBM value by the number of pixels in the object districts.

Each pixel in DBM image, shown in **Fig. 8** for example, has its own DBM value (1 m unit). **Fig. 23** shows the distribution of DBM values by the number of pixels in the object districts (**Figs. 12–15**). These curves also demonstrate the regional characteristics described above: Wailuwn Ward (North) and Latha North District as lower districts, and Latha South District and Pabedan South District as higher districts.

6.3.2. Procedure

Hereafter, the number of buildings ratios is compared with the DBM area ratio. After the vegetation areas being removed from the original DBM, the DBM (**Fig. 8**) data basically contains streets, water places, empty places,

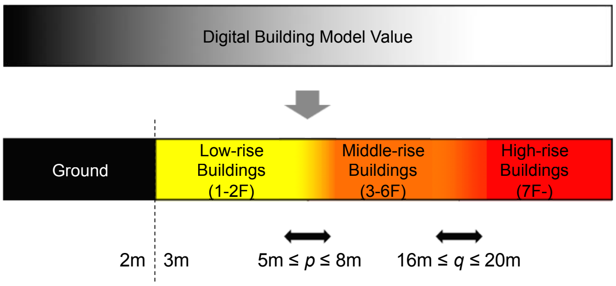


Fig. 24. Adaptation Trial of actual building stories to DBM value.

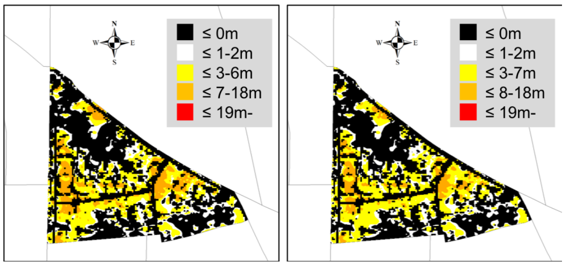


Fig. 25. DBM Map of Wailuwn Ward (North) for boundary value consideration.

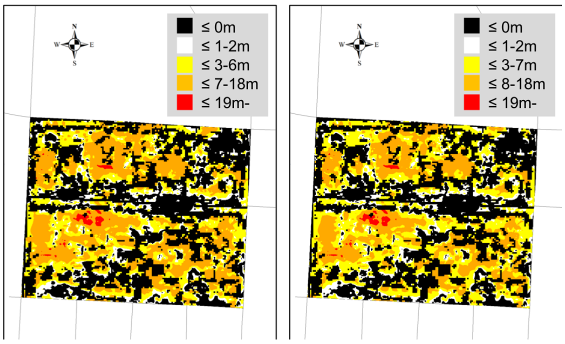


Fig. 26. DBM Map of Latha North District for boundary value consideration.

huts, structures, and buildings. Now, assuming that the value representing buildings on the DBM map is more than 2 m, the pixels having less than 3 m, representing streets, empty places, or small structures, are eliminated from the original DBM (**Figs. 12–15**) at first. On this assumption, the rest of pixels are for higher objects representing buildings in the districts, consisting of low-, middle-, and high-rise buildings. This classification of three categories in terms of building height should correspond to DBM value.

Figure 24 explains the adaptation trial of actual building stories to DBM value for the analysis. As a result of the above elimination, the data of 3 m and over is the range of the DBM value. The determination of the value for the boundaries between low-rise buildings (1 F–2 F), middle-rise buildings (3 F–6 F), and high-rise buildings (7 F -) is the research question. Here let the former boundary be p and the latter be q. Usually the height of one story is recognized as 3 m. However, most lower-rise buildings in the districts are not RC buildings with flat roof but

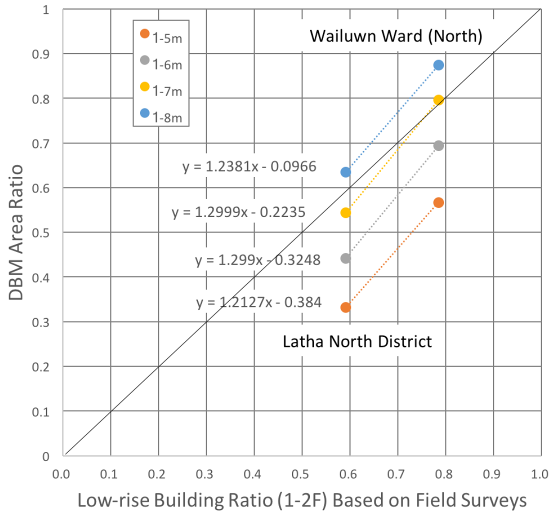


Fig. 27. Comparison of low-rise building ratio and DBM area ratio in the Lower Districts.

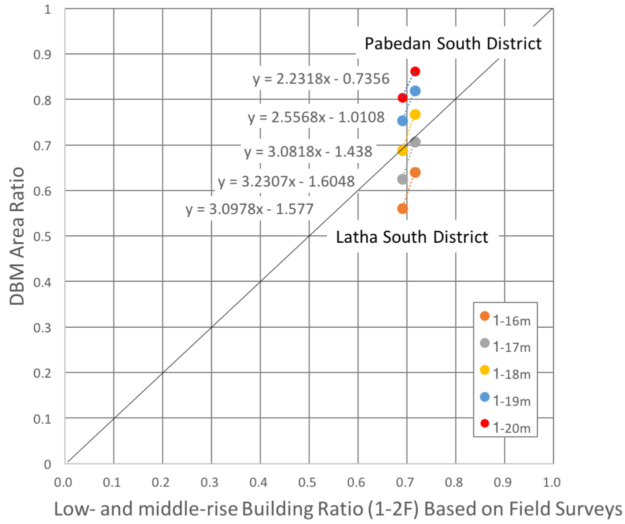


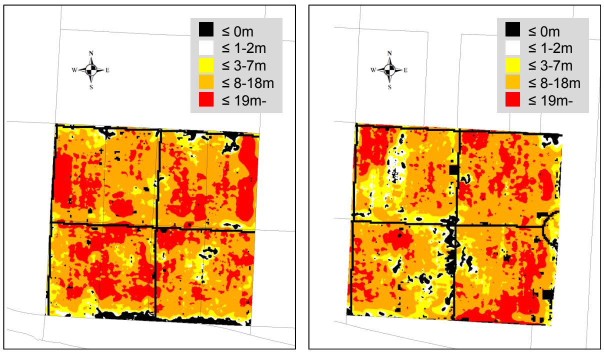
Fig. 28. Comparison of low- and middle- rise building ratio and DBM area ratio in the Higher Districts.

wooden or brick nogging in a wood frame with triangle roof. We thus regard the p value as between 5 m and 8 m, and the q value as between 16 m and 20 m.

According to the difference of regional characteristics, the p value is considered by the study of Wailuwn Ward (North) and Latha North District, and the q value is considered by the study of Latha South District and Pabedan South District.

6.3.3. Comparative Analysis

Based on the procedure, the building ratio and DBM area ratio is compared. For the lower building districts, Wailuwn Ward (North) and Latha North District, the p value is changed from 5 m to 8 m. **Figs. 25** and **26** show the case of 6 m and 7 m for low-rise buildings as examples in the both districts respectively. The result of the comparison using scatter diagram is shown in **Fig. 27** with x-axis



(a) Latha South District (b) Pabedan South District

Fig. 29. DBM map for the Higher Districts as a result of analysis.

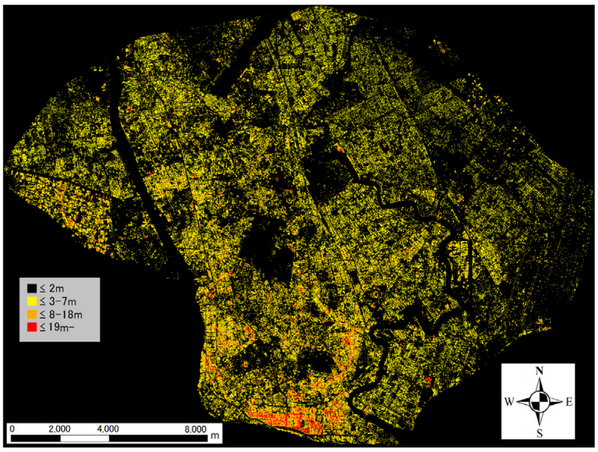


Fig. 30. DBM map for Yangon demonstrating regional building characteristics.

indicating low-rise building ratio (1 F–2 F) based on field surveys and y-axis indicating DBM area ratio. The diagonal means ideal correspondence of two factors. The highest relationship is in the case of 1 m–7 m.

The comparison for the higher districts was conducted in the same manner as shown in **Fig. 28**. The higher relationships were seen in the case of 1 m– 17 m and 1 m –18 m. However, the sum total of errors was less in the case of 1 m–18 m. Thus, 18 m is adopted as the q value, the boundary between low- and middle-rise buildings (1 F–6 F) and high rise buildings (7 F-). DBM maps for the two higher districts are shown in **Fig. 29**.

Finally, the DBM map (**Fig. 30**) was produced based on the above classification of buildings as the result of the research. This map demonstrates regional building characteristics, which are necessary information for urban vulnerability assessment of Yangon City.

7. Conclusions

This research was conducted in order to explore the possibility of DBM data, obtained from remote sensing imageries, to understand and to arrange regional building characteristics of Yangon city.

To this end, firstly, a field survey was conducted in Sanchaung Township and building characteristics such as structural types and the number of stories were analyzed. The DBM data was then prepared for a comparative analysis. Thirdly, additional field surveys were conducted in Latha and Pabedan Townships, located in the CBD in the city. Finally, the DBM data and actual building data obtained by the surveys were compared to examine an applicability of DBM for building collapse risk assessment. As a result, it was found that DBM data of 3 m–7 m represent low-rise buildings (1 F–2 F), and DBM data of more than 18 m reflect high-rise buildings (7F-). Along with the JICA data containing the total number of buildings in each ward in Yangon, this finding can be used to calculate the number of buildings in terms of building height, representing building vulnerability.

Because there are lots of developing countries without sufficient datasets for urban vulnerability assessment, such usage of remote sensing data based on the proposed method in this research will be helpful for these countries.

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