MODELING URBAN EXPANSION WITH REGARD TO DISASTER VULNERABILITY IN YANGON, MYANMAR

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ABSTRACT: Disaster is the fundamental problem that highly damages to humanity. Especially, when a disaster occurs in an urban area; which has the characteristics of high population density and a number of human activities, it makes a colossal loss in direct and indirect ways to the people. To protect or reduce the impact of the disaster in a long term, the situations of the disaster with the disaster-prone area and the urban area in the future are necessary to consider. Yangon is the former capital of Myanmar with more than five million people. It has faced a series of floods and it suffered the damage of the earthquake. This research proposed a methodology to model urban expansion that can predict the urban area in the future and represented the situations of the flood and earthquake in Yangon, Myanmar. Firstly, the urban expansion model was created by using Remote Sensing data such as GeoEye, Landsat, SRTM and Geographic Information Systems data such as roads and railways. In this research, the relevant factors to indicate the urban expansion are (1) the distance from the multi-centers of the urban areas, (2) the distance from the urban areas in the past, (3) the distance from roads, (4) the distance from railways, (5) the class translation, (6) land elevation, (7) the separated lands by the rivers. In the estimation of urban expansion, the maximum likelihood estimator was applied to our model. In the prediction of urban growth in the future, the polynomial regression was used to estimate the unknown parameters in the future. The experimental results show that our model estimated urban expansion with the accuracy of 88.63% and predicted urban expansion with the accuracy of 81.14%. Secondly, the urban expansion was related to disaster vulnerabilities of flood and earthquake. The past to future situations of flood and earthquake are shown in term of the average of flood and earthquake vulnerability indexes in the urban areas from the past to the future.

1. INTRODUCTION

With respect to population growing and economics expanding also climate changing, the human has encountered the several disasters that cause the loss of life and property. Seriously, when a disaster occurs in an urban area; which has the characteristics of the highest population density and various human-built features compared to its surrounding areas, the disaster impacts directly and indirectly on the people and their properties. In order to prepare and mitigate the effect of disaster in the future, the prospect situations of the disaster in term of spatial information with the disaster-prone areas and the urban areas in the future are required to be assessed.

Urban growth is rather a complicated process. Since urban expansion causes from many factors such as human behaviors, population rates, the economic states, the policies of the government and so on. Remote sensing (RS) technology can directly observe the urban areas from the past to the present and provides the physical information such as the building height. Geographic information system (GIS) gives the important information with the location such as transportation information. Hence, RS and GIS can be used to lead us to understand the mechanism of urban expansion and predict the urban areas in the future.

Many urban expansion models have been widely developed in order to understand the system of urban expansion and predict the urban areas in the future. Urban land-use model based on spatial interaction model was developed by Lowry (, 1964). The statistical model was used for introducing urban expansion model (Sklar, 1991). An Urban growth model based on automata cellular was proposed by Batty (, 1997). Moreover, by using multi-agent-based model, the residential distribution estimation was developed (Benenson, 1998).

Yangon, Myanmar, known as the former capital, is the major economics of the country with more than five million population (Morley, 2013). Yangon has faced a series of floods such as in 2011, 2013 and 2015. Yangon had also experienced with the impact of the earthquake in 1930 (Swe, 2015).

This work introduced a methodology to model urban expansion based on the dynamic statistical model using RS and GIS and relate to flood and earthquake vulnerabilities in Yangon, Myanmar.

2. METHODOLOGY

2.1 Introducing urban expansion model with regard to disaster vulnerability

Generally, urban expansion considers on three aspects of (1) the facilities such as department store, office, school etc., (2) the transportation such as roads, railways, (3) the environments such as river and mountain (Zhang, 2001). In this research, we defined the factors to indicate urban expansion as follows; (1) the distance from the multi-centers of the urban areas, (2) the distance from the urban areas in the past, (3) the distance from roads, (4) the distance from railways, (5) the class translation, (6) land elevation, (7) the separated lands by the rivers. Then, we prepared the urban expansion data and the defined factors data from RS and GIS data. Next, we monitored the urban expansion by relating to the defined factors to understand the mechanism of urban expansion. We also obtained all parameters for modeling urban expansion. In the estimation step, the maximum likelihood estimator (Cho, 2006) was used with the observed parameters to estimate urban expansion. In the prediction step, the unknown parameters in the future were estimated from observed parameters. Using the estimator with the estimated parameters, the urban areas in the future was predicted. After that, we compared the urban expansion to flood and earthquake vulnerability maps (Sritarapipat, 2015). Finally, the averaged values of flood and earthquake vulnerability indexes in the urban areas were calculated and shown as the situations of the disaster from the past to the future. The flowchart of modeling urban expansion with regard to flood and earthquake vulnerability is displayed in figure 1.

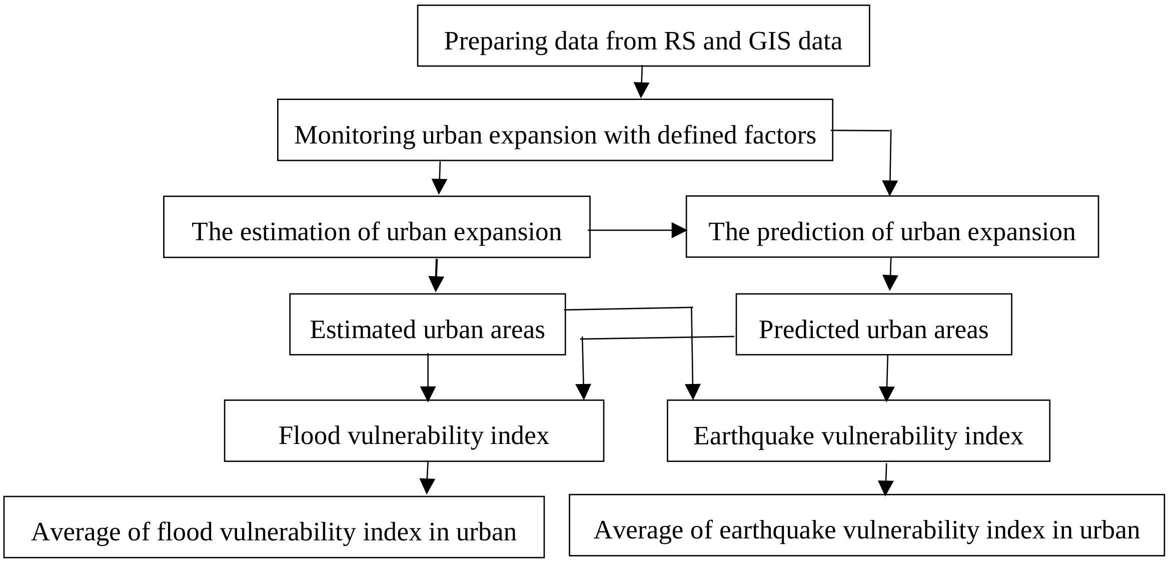


Figure 1. Flowchart of modeling urban expansion with regard to flood and earthquake vulnerability

2.2 Preparing data for modeling urban expansion

For RS data, the multispectral Landsat images with a 30 m.-resolution and 1,000x1,000 pixels from 1978 to 2009 were used to provide land cover change. Using the result of land cover change, we obtained urban expansion data, urban area in the past, class translation and separated lands by the rivers. Next, stereo GeoEye images with a 0.5 m.-resolution were employed to obtain the height of the building. Using the height of the building, the multi-centers of the urban areas were extracted. Then, SRTM DEM was used to get land elevation. The details of the satellite imagery dataset are shown in table 1.

Table 1. The details of satellite imagery dataset.

No.	Satellite	Bands	Resolution	Acquired Date
1	Landsat -3	4	60m. x 60m.	1978-11-22
2	Landsat -4	7	30m. x 30m.	1990-11-12
3	Landsat -7	8	30m. x 30m.	2000-11-7
4	Landsat -5	7	30m. x 30m.	2009-11-08
5	GeoEye-1	3	0.5mx0.5m	2013-11-08 and 2013-11-16

For GIS data, the information of roads and railways were provided by ICUS (International Center for Urban Safety Engineering, The University of Tokyo, Japan).

2.3 Monitoring urban expansion with the defined factors

We monitored urban expansion with the defined factors to understand the mechanism of urban expansion. By relating urban expansion to the defined factors, we found that the urban areas grew up from the close to far distances from the multi-centers of the urban areas. The urban areas grew up near the urban area in the past. The urban areas grew up along the roads. The urban areas grew up from railways. The urban areas grew up following the class translation that it is easier to grow from vegetation areas. The urban areas grew up from the high to low elevations. The urban areas grew up in each separated land following the effects of the rivers and the bridges. Then, we also obtained all the parameters such as the mean and the variance of the distance from the multi-centers of the urban areas, the translation matrix of land cover change etc.

2.4 The estimation of urban expansion

We used the maximum likelihood estimator to estimate urban expansion. By using the estimator, the probabilities with the defined factors by observing urban expansion are maximized to calculate the locations of urban expansion. The equation of estimating urban expansion is expressed in equation 1.

Maximizing *The probability of class translation + The probability of the distance from the multi-centers of the urban areas + The probability of the distance from urban areas in the past + The probability of the distance from roads + The probability of the distance from railways + The probability of land elevation* (1)

The probabilities of class translation with the multi-centers and the separated lands by rivers was defined as Markov chain. The probabilities of the distance from the multi-centers of the urban areas, the distance from urban areas in the past, the distance from roads, the distance from railways, and land elevation were assumed as Gaussian distribution. By considering on independent term, the equation 1 can be separated into two equations (equation 2 and equation 3)

Maximizing *The probability of class translation* (2)

Maximizing *The probability of the distance from the multi-centers of the urban areas + The probability of the distance from urban areas in the past + The probability of the distance from roads + The probability of the distance from railways + The probability of land elevation* (3)

Then, in order to estimate urban expansion, equation 2 and 3 are independently calculated.

The land cover result in 1978 in preparing data step was set as the initial land cover image. We used the initial land cover image with observed parameters as input for the estimator to estimate land cover image in 1990. Next, we used the estimated land cover in 1990 with observed parameters to estimate land cover image in 2000. We repeated the same step to estimate land cover image in 2009.

2.5 The prediction of urban expansion

Since the parameters in the future could not be observed, they are required to estimate. For the amount of urban areas in the future, there are two steps for prediction. Firstly, we calculated the relationship between urban areas and population data (United Nations, 2015). We found there is a high relationship between urban areas and population data with R-squared value of 0.98. Secondly, we used the relationship with the predicted population data in the future (Hoornweg, 2014) to predict the amount of the urban areas in the future. For predicting the locations of urban expansion in the future, we used the previous parameters with polynomial regression to calculate the parameters used for prediction in the future.

In this research, we predicted the urban areas in 2020, 2030, 2040. We used the estimated land cover in 2009 with the estimated parameters as input for the estimator to predict land cover image in 2020. Then, we used the predicted land cover in 2020 with the estimated parameters to predict land cover image in 2030. We repeated the same step to predict land cover image in 2040.

2.6 Relating urban expansion to disaster vulnerability

Urban expansion data with (1) the reference land cover images from 1978 to 2009, (2) the estimated land cover images from 1990 to 2009, and (3) the predicted land cover images from 2020 to 2040 were related to flood and earthquake vulnerability maps (Sritarapipat, 2015). The flood vulnerability map (figure 2 a) was based on land elevation and floodways, and the earthquake vulnerability map (figure 2 b) was based on the distance from the faultline, land slope, the age of the building. By relating the urban expansion to the flood and earthquake vulnerability maps, the averaged values of the flood and earthquake vulnerability index in the urban areas were shown as the situations of flood and earthquake from the past to the present.

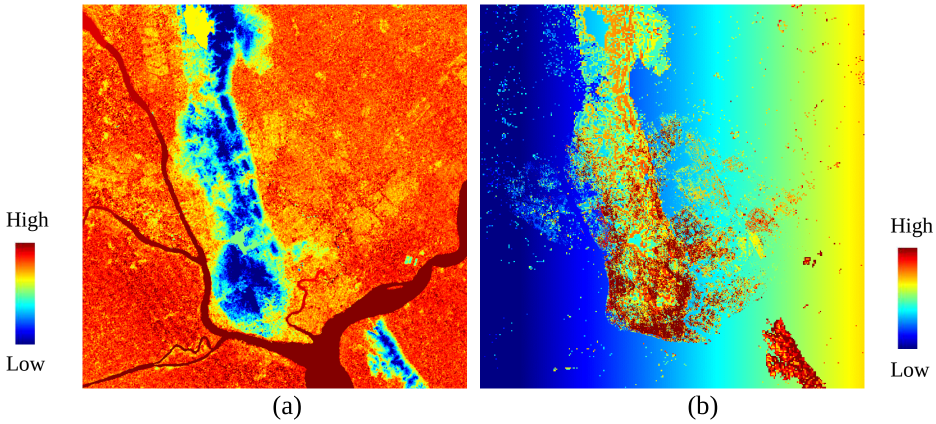


Figure 2. (a) Flood vulnerability map (b) Earthquake vulnerability map.

3. RESULTS AND DISCUSSIONS

3.1 Urban expansion

For estimation of urban expansion, the classification results in preparing data step were defined as referenced land cover images (figure 3 a, b, c). Then, we compared the estimated land cover images by using our model (figure 3 d, e, f)) with the referenced land cover images. For comparison, we only used two classes with urban and non-urban (vegetation and water) to calculate the resultant accuracy. The accuracies with true positive rate (TPR) and true negative rate (TNR) of referenced versus estimated land cover images in 1990, 2000, and 2009 are expressed in table 2.

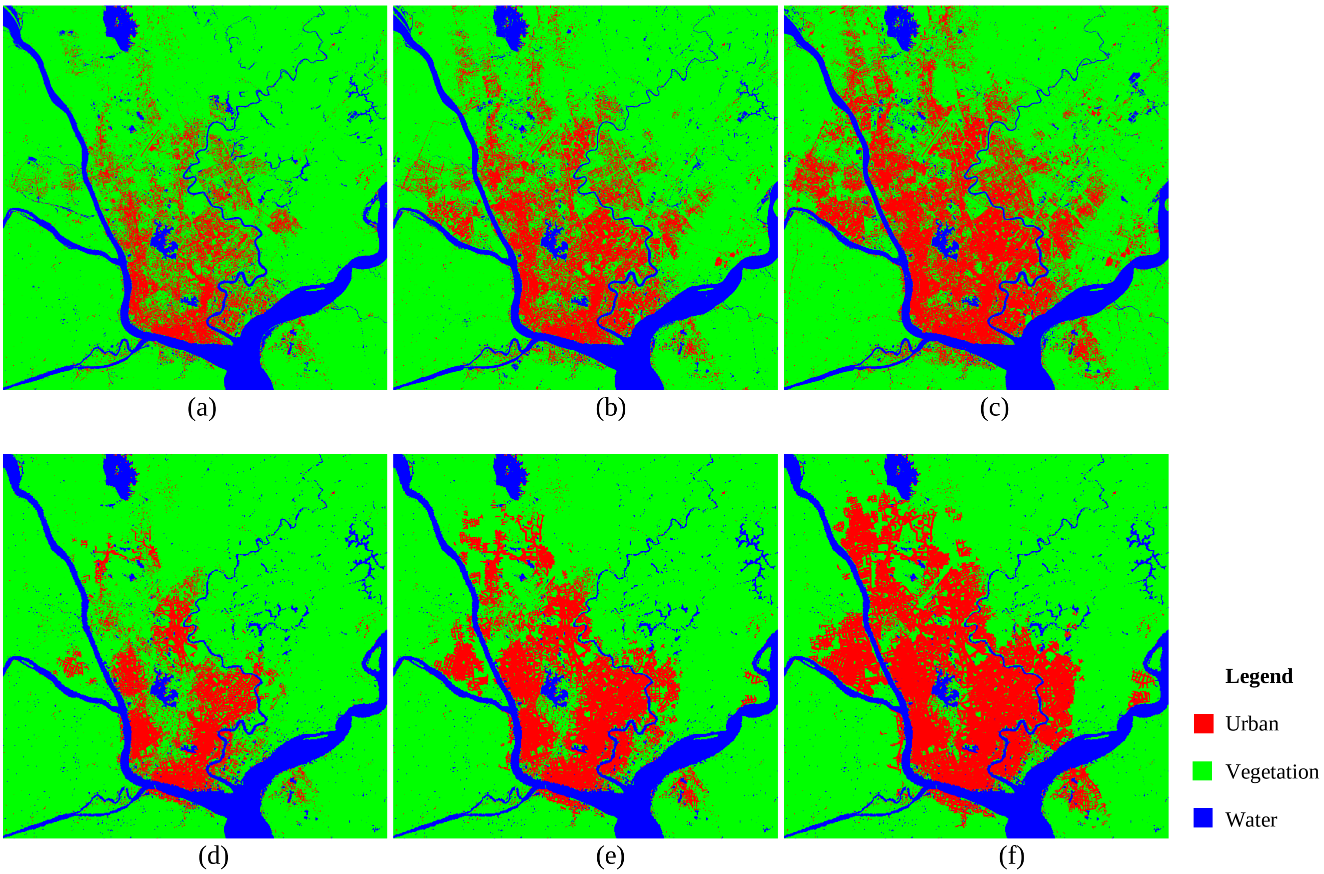


Figure 3. (a) Referenced land cover image in 1990, (b) Referenced land cover image in 2000, (c) Referenced land cover image in 2009, (d) Estimated land cover image in 1990, (e) Estimated land cover image in 2000, (f) Estimated land cover image in 2009.

Table 2. The accuracies of the estimation of urban expansion.

Year	Accuracy (%)	True positive rate (%)	True negative rate (%)
1990	93.37	64.65	96.40
2000	88.15	60.99	93.10
2009	84.38	65.30	89.99
Average	88.63	63.65	93.16

For prediction of urban expansion, there are three predicted images in 2020, 2030, 2040 (figure 4 b, c, d). For validation, the Landsat image on November 25, 2015 was selected and classified to be a land cover image as an unseen land cover image (figure 4 a). We compared the predicted land cover image in 2020 with the unseen land cover image in 2015. The accuracy is 81.14% with TPR of 74.66% and TNR of 83.88%.

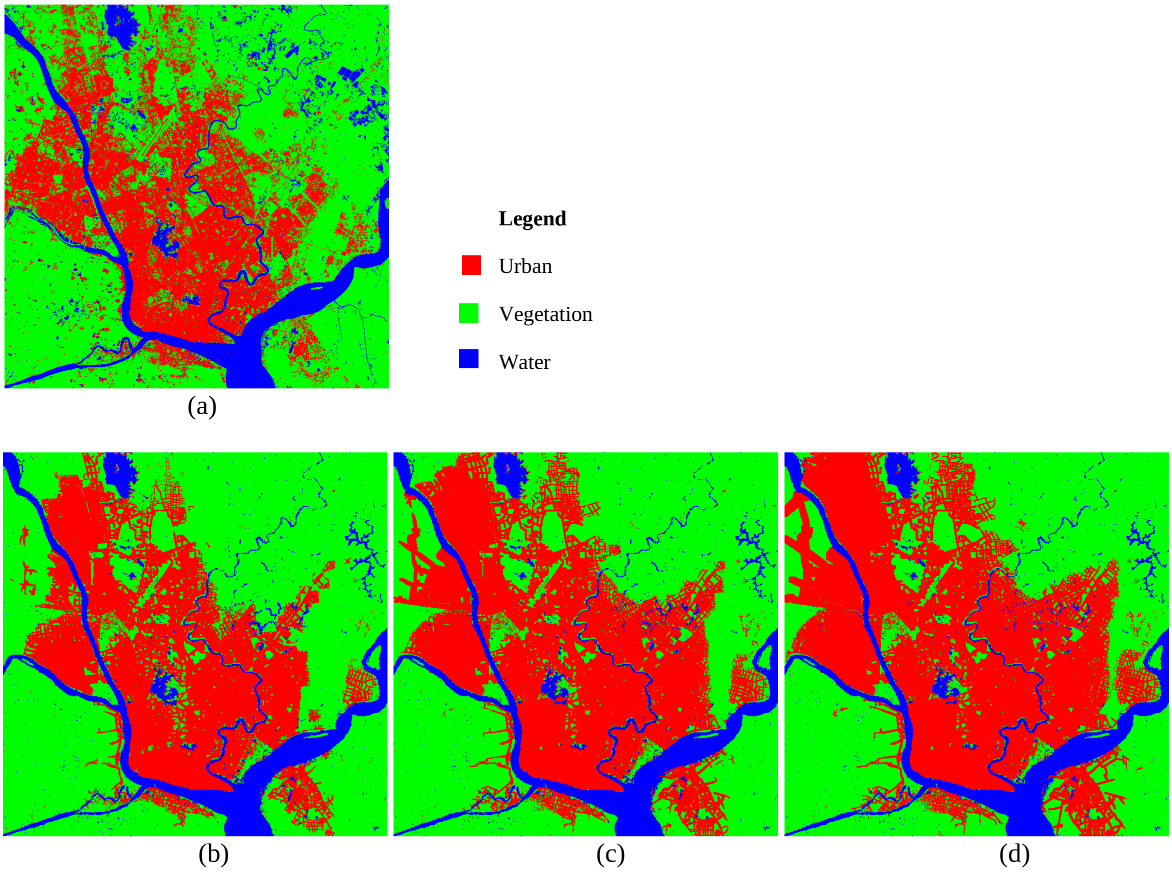
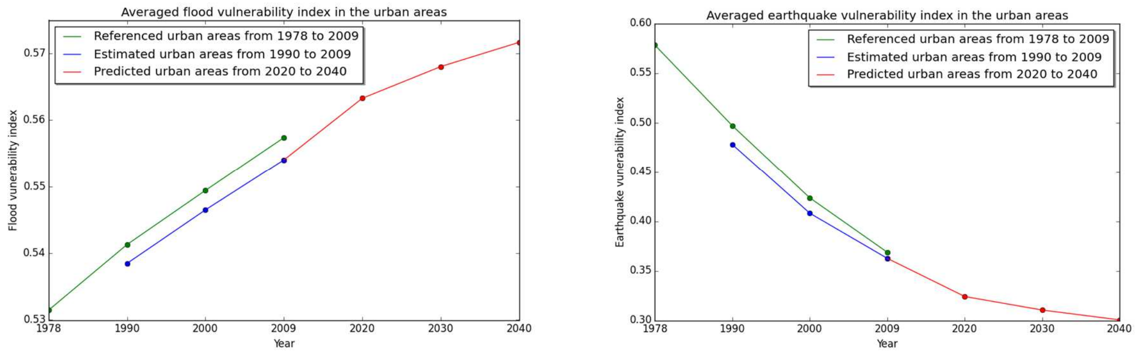


Figure 4. (a) Unseen land cover image in 2015, (b) Predicted land cover image in 2020, (c) Predicted land cover image in 2030, (d) Predicted land cover image in 2040.

Since our model relies on the defined factors, especially the distance from the multi-centers of the urban areas, the almost estimated urban areas grow up near the multi-centers of the urban area. However, In particular, some urban areas grow up far from the multi-centers of the urban areas. As a result, our method cannot estimate the urban areas that grow up far from the multi-centers of the urban areas with an accuracy.

3.2 Relating urban expansion to disaster vulnerability

The figure 5 a shows the averaged value of flood vulnerability index in the urban areas as the past to the present situations of flood. The figure 5 b shows the averaged value of earthquake vulnerability index in the urban areas as the the past to the present situations of earthquake.



(a) (b)

Figure 5. (a) The averaged value of flood vulnerability index in the urban areas from the past to the present, (b) the averaged value of earthquake vulnerability index in the urban areas.

4. CONCLUSION

This research introduced a methodology to model urban expansion using RS and GIS and relate to disaster vulnerability in Yangon, Myanmar. The Multispectral Landsat images from 1978-2009 were used to provide land cover change. Stereo GeoEye images were employed to extract the height of the building that can detect the multi-centers of the urban area. The model of urban expansion was defined based on seven factors of (1) the distance from the multi-centers of the urban areas, (2) the distance from the urban areas in the past, (3) the distance from roads, (4) the distance from railways, (5) the class translation, (6) land elevation, (7) the separated lands by the rivers. In the experimental results, our method estimated urban areas from 1990 to 2009 with the averaged accuracy of 88.63% and predicted urban areas in 2020 with the accuracy of 81.14%. To perceive the past to the future situations of flood and earthquake, the averages of the flood and earthquake vulnerability indexes from the past to the future are calculated.

For the future work, in the prediction step, the other information such as government policy, economic growth can be used to estimate the parameters in the future. Next, an action plan can be set up to reduce the effect of the disaster in the future. Comparing the prospect situations of the disaster with the action plan and without action plan can be proposed to support urban planning management and decision-making.

References

Batty, M., 1997. Cellular automata and urban form. Journal of the American Planning Association, 63 (3), pp. 264-274

Benenson, I., 1998. Multiagent simulations of residential dynamics in the city. Computers Environment and Urban Systems, 22 (1), pp. 25-42.

Cho, S. H., Chen, Z., Yen, S. T., Eastwood, D. B., 2006. Estimating effects of an urban growth boundary on Land development, Journal of Agricultural and Applied Economics, 38 (2), pp. 287-298

Hoornweg, D., Pope, K., 2014. Socioeconomic Pathways and Regional Distribution of the World's 101 Largest Cities, Global Cities Institute, Working Paper No. 04

Lowry I. S., 1964. A model of metropolis Santa Monica. CA (Rand Corporation)

Morley, I., 2013. Rangoon. Cities, 31, pp. 601–614.

Sklar, F. H., Costanza ,R., 1991. The development of dynamic spatial models for landscape ecology. A review and prognosis, pp. 239-288

Sritarapipat, T., Takeuchi, W., 2015. Estimating Land Value and Disaster Risk in Urban Area in Yangon, Myanmar using Stereo High-resolution Images and Multi-temporal Landsat Images, 36th Asian conference on remote sensing (ACRS): Manilla, Phillippines, Oct. 20, 2015.

Swe, U. M., 2015. Yangon flood losses top K11 billon, Accessed 2016, June 20, from http://www.mmtimes.com

United Nations, 2015. World Urbanization Prospects The 2014 Revision, Department of Economic and Social Affairs, Population Division

Zhang, X., Wang, Y., 2001. Spatial dynamic modeling for urban development. Photogrammetric engineering and remote sensing, 67 (9), pp. 1049-1057.