Research article

Comparative Spatial Assessment of Regulating and Supporting Ecosystem Services in Nay Pyi Taw, Myanmar

KAY KHAING LWIN*
Nagoya University, Nagoya, Japan
Email: kaykhaing.moecaf@gmail.com

KIICHIRO HAYASHI
Nagoya University, Nagoya, Japan

MAKOTO OOBA
National Institute for Environmental Studies, Japan

Received 13 December 2014 Accepted 31 October 2015 (*Corresponding Author)

Abstract Rapid urban development may induce deterioration in biodiversity and ecosystem services (BD/ESs) at the global scale. According to Millennium Ecosystem Assessment (MA) 2005, it is well known that biodiversity provides benefits in the form of ESs. In particular, four types of ESs (namely, provisioning, regulating, supporting, and cultural services) were defined in a previous study. Here, a case study was conducted in Nay Pyi Taw, Myanmar. First, the primary unit values of each ES were obtained based on a literature review. Second, by utilising a satellite image of Nay Pyi Taw from the Advanced Land Observing Satellite, land-use types were classified into five categories: forest areas, urban areas, agricultural land, water areas, and bare land. Then, the unit values of each ES were applied to develop seven types of ESs and habitat maps and a priority layer map was created using the Zonation software. The results revealed the spatial distribution of ESs and the priority areas for conservation. In future, this method can be used to consider a wider range of ESs.

Keywords ecosystem services, land-use, zonation, Myanmar, biodiversity

INTRODUCTION

Ecosystem services (ESs) are the benefits provided by ecosystems and can be classified into four types according to MA (2005): provisioning, regulating, supporting, and cultural services. ESs can help for not only the environment, but also human's livelihoods. During the last decades, ESs has been destroyed owing to development and increased economic and societal prosperity (MA, 2005). So the methods to identify priority areas for the provision of ESs need to be developed (Casalegno et al., 2014). Although scientific and political interest in ESs has increased, there are gaps in knowledge of the spatial distribution of ESs (Garcia-Nieto et al., 2013). In this context, spatial assessment of ESs provides some indication of the role of spatial flows in the delivery of ESs (Serna-Chavez et al., 2013). Although many studies have been conducted to assess ESs globally, few such studies have focused on Myanmar, where 68% of the population live in rural areas (World Bank, 2012). This rural population typically relies on ESs such as firewood, wood, food, etc. A new capital city, Nay Pyi Taw, was developed in Myanmar in 2006, with degradation of ESs occurring in the region during the course of the development. Accordingly, an understanding of the characteristics of ES provision is important for conservation in this region.

OBJECTIVE

The present study aims to understand the status of ES provision for different land use types in Nay Pyi Taw, Myanmar. To achieve this, spatial analysis of ESs was conducted for the region. In mapping ESs, land use/land cover classification was undertaken to help assess ES provision.

MATERIALS AND METHODS

Study Area

Myanmar, which was formerly known as Burma, is a country in Southeast Asia. Nay Pyi Taw (19°44′40.3"N, 96°07′46.1"E; city hall in Nay Pyi Taw) is a new capital city in Myanmar and was founded in 2006 in a previously undeveloped area. The city lies at elevations of 0-500 m and has slope conditions of approximately 1-20° (FAO, Myanmar country profile). Its population is approximately 1,558,367 as of 2014 (Department of Population, 2014), and it covers a total area of 7,054.37 km^2.

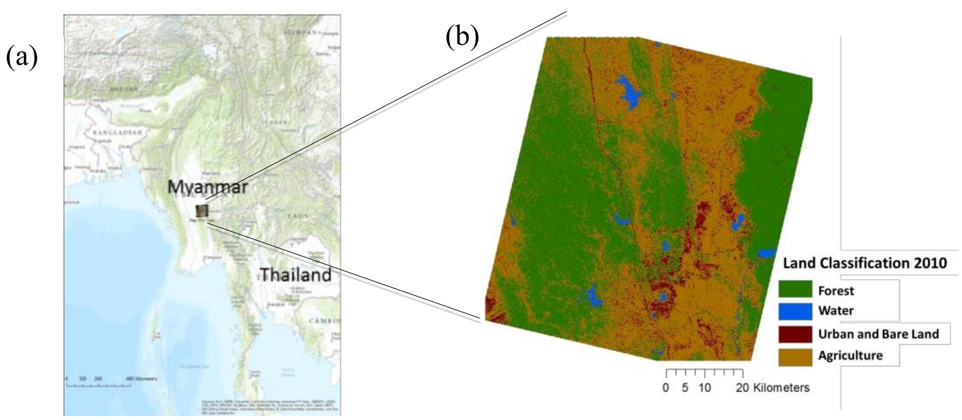

Fig. 1 (a) Location map of Myanmar and study area and (b) land use/land cover classification map produced by the authors of the present study
Source: satellite image by JAXA/Distribution RESTEC

Research Flow

In the present study, the Advanced Visible and Near Infrared Radiometer type 2 (ANVIR-2) of the Advanced Land Observation Satellite (ALOS, dated 20101110) was used to classify land use types in the ERDAS Imagine software version 2014 (Intergraph Corporation) and accuracy assessment was conducted. Second, primary unit data for several ESs were collected and then applied to the land classification maps using the ArcGIS10.1 software (ESRI). Third, seven ES maps were developed and a priority layer map was made using Zonation (Lehtomaki and Moilanen, 2013).

Land Use/Land Cover Classification of Satellite Image

Different land use types have different functions and capacities to provide ESs (Burkhard et al., 2012). Land use classification was conducted using satellite image and was classified into five land use types using the ERDAS IMAGINE: forest areas, agricultural land, urban areas, water bodies, and bare land

(Fig. 1 (b)). The land use classification was conducted using a supervised classification method, which is a type of land use classification that uses maximum likelihood criteria as parametric rules. The overall accuracy assessment of the land classification was approximately 91% by comparing with Google earth in ERDAS Imagine software and 2010 forest cover map of Myanmar (Forest Department, FRA 2010) in ArcGIS 10.1.

Literature Survey of Ecosystem Services Unit Value

The area-based primary unit values for each ES were obtained based on a literature survey (Table 1). In particular, unit values regarding provisioning services, regulating services, supporting services, and habitat were collected. For provisioning services, the unit value of agricultural products (such as rice and pulses) was collected. For regulating services, CO_2 absorption, soil erosion control, and water infiltration were selected. For the soil erosion data, low values were considered favourable and high values were unfavourable; this is in stark contrast to the other ESs considered. Accordingly, the soil erosion data were inversed before being used for analysis. The unit of water infiltration was mm/h and the percentage of water infiltration by different land use types was calculated by using unit value of water infiltration. For supporting services, carbon stock, and gross primary production (GPP) were selected. According to Rui (2014), Green Distance Index (GDI) evaluates how much green area is concentrating in each cell for habitat distribution and the GDI is calculated from Green Index (GI) which extracts forests and water as green areas and assigns it as "255" and other land use as "0". Data describing the primary unit values of ESs in Myanmar were limited for this analysis. In the unit value of ESs in this study, the unit values of carbon stock and agricultural product (food production) were the data of Myanmar. The other unit values were for other Asian countries in which the forest types, the elevation, and the slope conditions were similar to Nay Pyi Taw Area and were used in this study.

Table1 Types of ESs and primary unit value of ESs in this study

Types of ecosystem services	Forests	Agricultural area	Urban	Water	Bare land	Source
Supporting Services:						
GPP (t/ha/yr)	30.7	12.093	0	0	0	Chen et al. (2013), Hirata et al. (2013)
Carbon stock (t/ha)	433.7	31.02	0	0	0	Oo (2009), Takeuchi (2012)
Regulating Services:						
CO2 absorption (t/ha/yr)	2.737	3.250	0	0	0	Chen et al. (2013)
Soil erosion factor (t/ha/yr)	0.038	3.9	31	0	94.5	Sidle et al. (2006)
Water infiltration (mm/h)	100	38.5	2	15	2	Chaplot et al. (2002)
Provisioning Services:						
Agriculture Products (t/ha)	-	5.38	-	-	-	FAO (2009)
Habitat (GDI)	-	-	-	-	-	Rui (2014)

Mapping using Arc GIS

Spatial analysis was conducted using ArcGIS to understand the spatial distribution of ES provision and its relationship to land-use type. To develop seven ES maps, the land-classified map and the unit values of ESs for each land use type were used. Before applying unit values for the land classification mapping, a grid with a mesh size of 1 km ×1 km was developed for the land classification map.

Determination of Priority Areas for Conservation

Zonation is an approach and software for spatial conservation prioritisation, and is used primarily for the efficient and effective allocation of conservation action. Spatial conservation prioritisation is also a form of conservation assessment (Knight et al., 2006) and incorporates decision support for conservation planning (Ferrier and Wintle, 2009). Zonation firstly sums the value of each ES layer and discards the least valuable cell one by one until all cells are removed. Zonation includes four types of cell removal rules, namely, core area zonation, additive benefit function (ABF), target-based planning, and generalised benefit function; moreover, many parameters are available for analysis (Moilanen et al., 2012). Of the available rules, the present study used ABF to account for the proportions of all map layers proportions in a given cell. ABF tends to produce a higher average proportion of feature distributions retained. To weight the ESs in this Zonation analysis, equal weights were selected for all ESs. Moreover, although the units of the ESs were different, the normalisation of data was conducted automatically by Zonation. By using ABF, the present study achieved the best performance on average for all features or ESs. The main result of this Zonation analysis was a priority ranking map for the entire landscape.

RESULTS AND DISCUSSION

In the present study, GIS-based spatial analysis was conducted for the assessment of ES provision for different land use types. Fig. 1 (b) shows that forest and agricultural land were the dominant land use types in the study area, whereas Fig. 2 demonstrates the spatial distribution of ESs in the Nay Pyi Taw region.

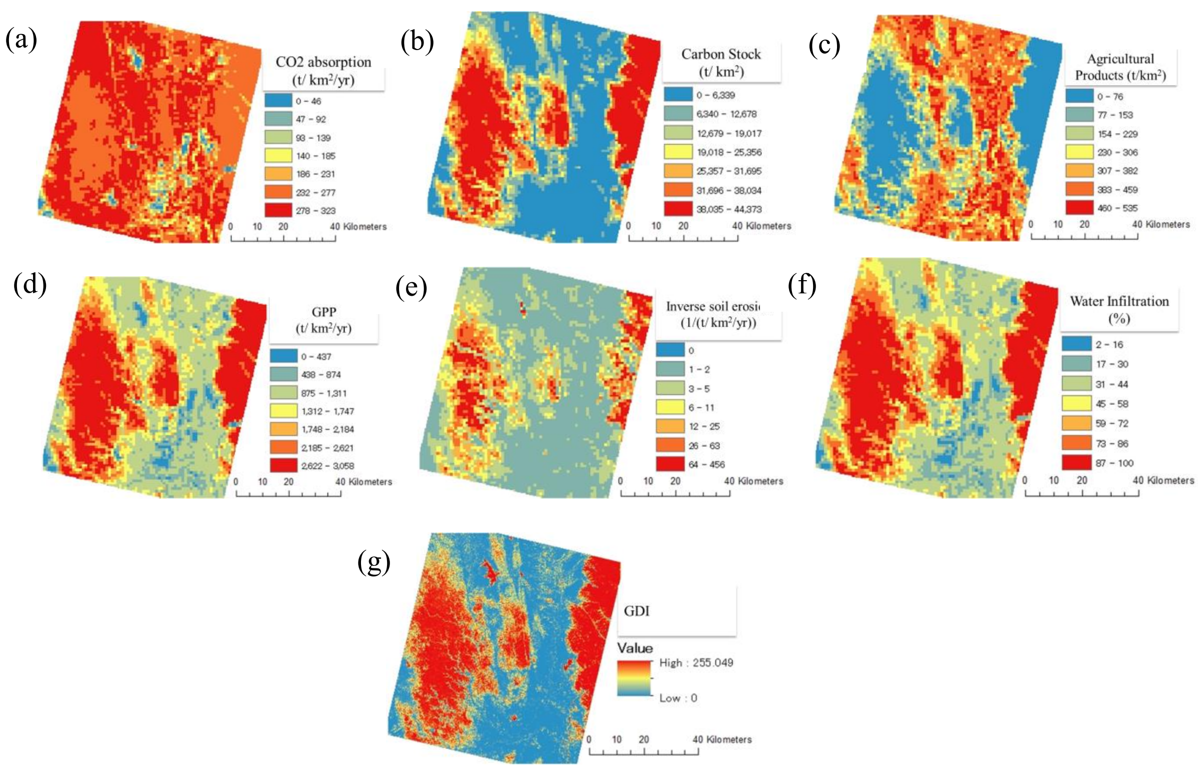

Fig. 2 Maps of seven ESs in Nay Pyi Taw, showing (a) CO_2 absorption, (b) carbon stock, (c) agricultural products, (d) GPP, (e) soil erosion control, (f) water infiltration and (g) habitat (GDI)

In Fig. 2, the red and blue colours indicate high and low values, for ES provision. Overall, relatively high provisions of ESs, except agricultural products and CO_2 absorption, were found in forest areas. Fig. 2 (a) and (c) illustrate the high provision of CO_2 absorption and agricultural products in agricultural areas. In particular, the map in Fig. 2 (a) indicates that agricultural land had a net uptake of atmospheric CO_2. Chen et al., (2013) noted that the carbon sink function of Asian cropland was likely related to cropland management practices and cropping systems that supplied adequate nutrients, abundant residues, and organic matter to the soil. This explains the high rates of CO_2 absorption for these agricultural areas. Fig. 2 (b, d, e, f, g) shows the ES provision of carbon stock, GPP, soil erosion control (inversed value), habitat, and water infiltration. In particular, Fig. 2 (g) shows that habitat is the greatest in the mesh dominated by forest and water areas. For habitat, GDI was calculated by extracting the forests and water areas as green area because those areas were good for habitat of the wildlife. In supporting and regulating services, all of ESs provision is high in the forest areas. So, the forests are the most important area to conserve to provide ESs and conservation activities of forests need to be promoted to be sustainable use of ESs.

The main output of the Zonation analysis was a priority rank layer map (Fig. 3 (a)). These results show the important areas in terms of ES provision, with the priority rank of the site illustrated by a colour scale. The most important and valuable areas in terms of the potential distribution of ESs and conservation of ESs are shown in Fig. 3 (a), and these data were derived from the Zonation analysis. In Fig. 3 (a), the dark red color represents the top priority areas for conservation and the violet color represents the lowest priority areas. In Fig. 3 (a), the top priority areas were mostly forested areas and the areas located close to forest areas had relatively high priority. It is well-known that forest ecosystems are the main providers of ESs. Therefore, it makes sense that forested areas were identified as the top priority areas for the conservation of ESs. In general, the lowest priority areas were urban developed areas and bare land. Priority maps were made to identify the most important areas for ES conservation; many of this land consisted of forested areas. Fig. 3 (b) and (c) illustrate another output of Zonation analysis and Fig. 3 (b) shows the performance of each ESs during prioritization analysis; and Fig. 3 (c) shows the performance of minimum, maximum, and average distribution of all ESs. Fig. 3 (b) represents that according to the algorithm of prioritization analysis, the lowest valuable cells were firstly removed and the highest were removed lastly until no cell remains. The horizontal line of Fig. 3 (b) means the percentage of the removal of cells (landscape) and the vertical line means the remaining percentage of each ESs when cells are removed. In horizontal line, “1” means 100% of landscape which means “there is no removal of cells” and the dotted line represents the 20% remaining of landscape before all cells are removed. When the 20% of landscape were remaining, the proportion of agricultural product was nearly 10% and of soil erosion remained nearly 90%. Fig. 3 (b) and (c) are not the main results of the analysis and can not be used as effective results. The main result of this analysis is presented in Fig.3 (a) priority rank map.

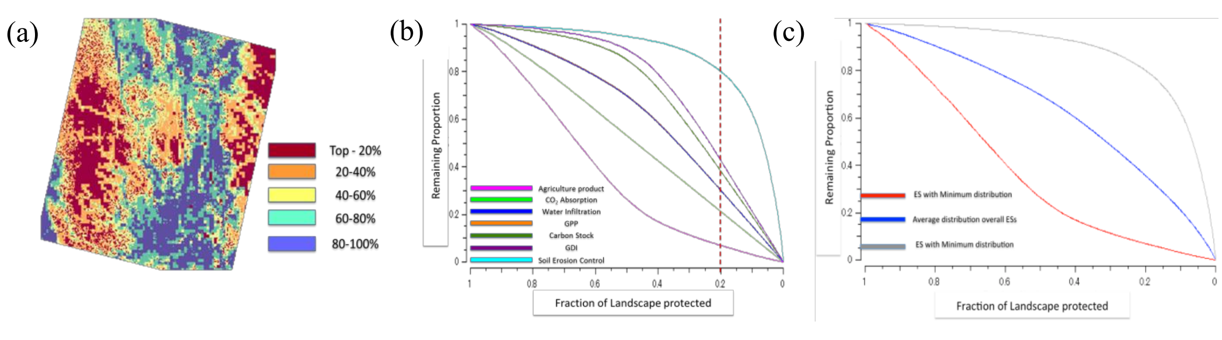

Fig. 3 Results of Zonation analysis showing (a) priority rank map and (b), (c) performance curves, the top 20% of priority areas remain at a level of 0.2 (vertical dashed line)

Finally, using the Zonation conservation planning tool, the priority areas for ES provision were determined. Based on the results of the present study, this method will be useful in determining the conservation areas required for ESs and in selecting habitat for multiple biodiversity conservation.

CONCLUSION

Land use change and urban development are likely to accelerate in the coming years. Therefore, the protection of BD/ESs will become increasingly necessary, particularly in urban areas. In the present study, according to the resulted land use map, the study area is covered primarily by forests and agricultural areas. Based on the results of mapping of ES unit values, forest and agricultural areas had the highest provisions of ESs. Furthermore, according to the Zonation results, the high priority areas should be conserved for the sustainable use of ESs in the future. And then, the priority maps should be useful for land use planning, policy development, and protected areas establishment in the Nay Pyi Taw region. Also, by using these results, we can remind not to extend the development activities in the priority areas of ESs provision.

ACKNOWLEDEGMENTS

This work was performed by using the fund from the EcoTopia Science Institute, Nagoya University.

REFERENCES

Burkhard, B., Kroll, F., Nedkov, S. and Muller, F. 2012. Mapping ecosystem service supply, demand and budgets. Ecological Indicators, 21, 17-29.

Casalegno, S., Bennie, J.J., Inger, R. and Gaston, K.J. 2014. Regional scale prioritisation for key ecosystem services, renewable energy production and urban development. PLOS ONE, 9 (9), e107822.

Chaplot, V., Boonsaner, A., Bricquet, J.P., De Rouw, A., Janeau, J.L., Marchand, P., Phommassack, T. and Valentin, C. 2002. Soil erosion under land use change from three catchments in Laos, Thailand and Vietnam. 12th ISCO Conference, May 26-31, 2002. Beijing, China.

Chen, Z., Yu, G., Ge, J., Sun, X., Hirano, T., Saigusa, N., Wang, Q., Zhu, X., Zhang, Y., Zhang, J., Yan, J., Wang, H., Zhao, L., Wang, Y., Shi, P. and Zhao, F. 2013. Temperature and precipitation control of the spatial variation of terrestrial ecosystem carbon exchange in the Asian region. Agricultural and Forest Meteorology, 182-183, 266-276.

Department of Population. 2014. The population and housing census of Myanmar 2014, Summary of the provisional results. Ministry of Immigration and Population, 2014, Myanmar.

FAO. 2009. Special report, FAO/WFP. Crop and food security assessment mission to Myanmar. 22 January 2009, FAO and WFP, ROME.

FAO website (http://www.fao.org/countryprofiles/maps/en/?iso3=MMR), Food and Agriculture Organization of the United Nations, country profiles, Myanmar.

Forest Department, Ministry of Environmental Conservation and Forestry. 2010. Forest resource assessment 2010 Country Report, Myanmar.

Ferrier, S. and Wintle, B.S. 2009. Quantitative approaches to spatial conservation prioritization, Matching the solution to the need. In: Moilanen, A., Wilson, K.A., Possingham, H.P. (Eds.) Spatial Conservation Prioritization, Quantitative Methods and Computational Tools. Oxford University Press, Oxford.

Garcia-Nieto, A.P., Garcia-Llorente, M., Iniesta-Arandia, I. and Martin-Lopez, B. 2013. Mapping forest ecosystem services, From providing units to beneficiaries. Ecosystem Services, 4, 126-138.

Hirata, R., Saigusa, N., Yamamoto, S., Ohtani, Y., Ide, R., Asanuma, J., Gamo, M., Hirano, T., Kondo, H., Kosugi, Y., Li, S.G., Nakai, Y., Takagi, K., Tani, M. and Wang, H. 2013. Spatial distribution of carbon balance in forest ecosystems across East Asia. Agriculture and Forest Meteorology, 148, 761-775.

Knight, A.T., Cowling, R.M. and Campbell, B.M. 2006. An operational model for implementing conservation action. Conservation Biology, 20, 408-419

Lehtomaki. J. and Moilanen, A. 2013. Methods and workflow for spatial conservation prioritization using Zonation. Environmental Modelling and Software, 47, 128-137.

Millennium Ecosystem Assessment MA. 2005. Ecosystems and human well-being: synthesis. A report of the millennium ecosystem assessment. Island Press, Washington.

Moilanen, A., Meller, L., Leppanen, J., Pouzols, F.M., Arponen, A. and Kujala, A. 2012. Zonation version 3.1 - user manual. Biodiversity Conservation Informatics Group, Department of Biosciences, University of Helsinki, Finland.

Oo, T.N. 2009. Carbon sequestration of tropical deciduous forests and forest plantations in Myanmar. Ph.D, dissertation. Department of Forest Sciences, Graduate School, Seoul National University, Korea.

Rui, L. 2014. The potential distributions of mammalian by Maxent model – Case of Nagoya City. M.Sc Thesis, Department of Civil Engineering, Nagoya University, Japan.

Serna-Chavez, H.M., Schulp, C.J.E., van Bodegom, P.M., Bouten, W., Verburg, P.H. and Davidson, M.D. 2013. A quantitative framework for assessing spatial flows of ecosystem services. Ecological Indicators, 39, 24-33.

Sidle, R.C., Ziegler, A.D., Negishi, J.N., Nik, A.R., Siew, R. and Turkelboom, F. 2006. Erosion processes in steep terrain – Truths, myths and uncertainties related to forest management in Southeast Asia. Forest Ecology and Management, 224, 199-225.

Takeuchi, K. 2012. Forest carbon stocks in shifting cultivation of Thailand and Lao PDR. APN Science Bulletin, 2, 2012.