Research article

Spatial Assessment of Ecosystem Services by New City Development – Case Study in Nay Pyi Taw, Myanmar

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Abstract Ecosystems provide many services not only for the environment, but also for human well-being. Land use and land cover change caused by development activities, have been increasing rapidly, and these are recognized as key factors for human-induced impacts on ecosystems. During the past few decades, ecosystem services (ESs) have deteriorated, especially as a result of urban development at the global scale, and changes have been severe in developing countries. For example, in Myanmar, the new capital city was developed on previously rural land during 2006. Consequently, large land use changes took place and many ESs were destroyed. To compare the loss of ESs before and after the development, spatial analyses of ESs were conducted in Nay Pyi Taw, Myanmar, as a case study. For the spatial analyses, two satellite images; namely Advance Land Observing Satellite (ALOS) for 2010 and Landsat 7 for 1999 were used for land classification. Information on ESs was collected through literature surveys, and existing unit values for ESs were estimated by using simple methods. Then, priority areas for conservation of ESs were identified by evaluating the spatial analysis results with the Zonation software. Finally, the overall changes in ES provisions due to land use changes were estimated along with the changes in priority areas.

Keywords ecosystem services, landuse, spatial analysis, conservation prioritization

INTRODUCTION

Ecosystem services (ESs) are the benefits that ecosystems provide to people both directly or indirectly, and they can be classified into four types, namely, provisioning, regulating, supporting, and cultural services (Millennium Ecosystem Assessment (MA), 2005).During the past few decades, ESs have deteriorated because of extensive land use change despite increases in economic and societal prosperity (MA, 2005). Manandhar et al. (2009) demonstrated that land use change is a key driver of environmental change and influences the provisioning of ESs. Methods to identify priority areas for ES conservation need to be developed (Casalegno et al., 2014). This study attempts to identify priority conservation areas in Nay Pyi Taw, Myanmar. Kong et al. (2013) evaluated land use change in Nay Pyi Taw and found that forests have gradually decreased due to agriculture expansion, dam construction, urban development, and so forth; Nay Pyi Taw is a site of new urban development and thus represents a good area to analyse the changes in ESs.

OBJECTIVE

The present study aims to understand the spatial distribution patterns of ESs in Nay Pyi Taw, Myanmar, and to identify priority areas for conservation. Comparisons were conducted before and after new urban development in order to understand the changes in ESs throughout the city and in priority areas.

METHODOLOGY

Study Area

This study was conducted in Nay Pyi Taw which is the new capital city of Myanmar (Fig. 1). It is situated at19°44′42.4"N, 96°07′46.8"E (Nay Pyi Taw City Hall). The population size of the city was approximately 1.56 million as of 2014 (Department of Population, 2014) and the city covers a total area of 7,054 km^2.

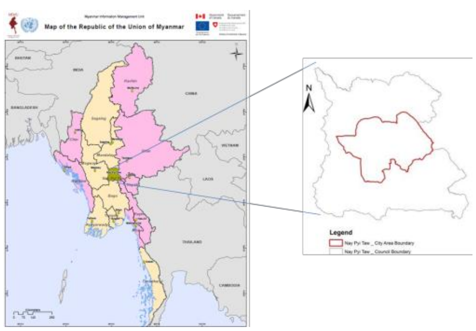


Fig. 1 Overview map of Myanmar and Council and city boundaries of Nay Pyi Taw in black and red respectively
Source: Myanmar Information Management Unit (MIMU)

(a) (b)

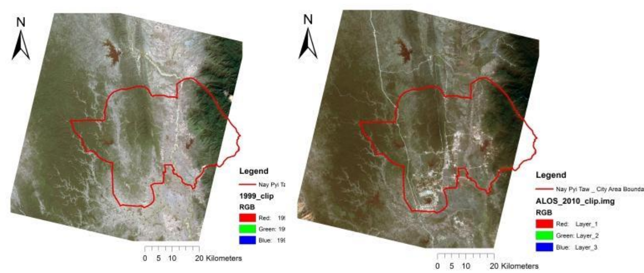


Fig. 2 (a) Landsat imagery and (b) ALOS imagery in Nay Pyi Taw City in red line
Source: (a) University of Maryland, NASA and GOFC-GOLDand (b) JAXA/Distribution RESTEC

Research Flow

This research study was conducted in four parts. The first part involved the collection of satellite images and the development of land use classifications by supervised and unsupervised classification procedures. The second part involved the determination of unit values for ESs by literature surveys and estimation of land surface temperatures by using Landsat7 data. For the third part, spatial analyses of ESs were conducted; and for the fourth part, a comprehensive assessment was conducted by using Zonation software (Moilanen et. al., 2012) to determine the priority areas for the conservation of ES provisioning potential.

Land use / land cover classification of satellite image: Land classification was conducted in ArcGIS10.1. For reference data, Google Earth and original satellite images were used and as an ancillary data, Normalized Difference Vegetation Index (NDVI), Digital Elevation Model (DEM), and slope data, calculated from the DEM, were applied. Before final land classifications were made, the NDVI was used to classify forested and non-forested areas. As there were overlapping values for forested and non-forested areas in the NDVI dataset, slope data were used to further refine the data. After that, unsupervised classification was used for the Landsat7 1999 image and supervised classification was used for the Advanced Land Observing Satellite (ALOS) 2010 image. In this study, land classifications were categorized into mainly four types, forest, water, urban, and agriculture areas. Then, an accuracy assessment for the 2010 land classification was conducted. The overall accuracy was 94.67% based on the ancillary data, such as, google earth.

Satellite images: In this study, two satellite images were used for the analysis. The first satellite image was taken with the Advanced Visible and Near Infrared Radiometertype2 (ANVIR-2) on board the ALOS (dated 20101110, here in after, ALOS2010) image and the second image was a Landsat7 image (dated 19991230, here in after, Landsat7-1999). The source of ALOS2010was cited as "satellite image by JAXA/Distribution RESTEC"; its resolution was 10mx10m (Fig. 2(b)). The source of Landsat7-1999 was "satellite image by University of Maryland, NASA and GOFC-GOLD"and its resolution is 30mx30m (Fig. 2(a)). In this study, as the resolution of two satellite images is different, land use classification and spatial analysis of ecosystem services were conducted separately for two images. After that, the comparison was conducted based on each result of spatial analysis of ecosystem services and priority maps for two periods.

Types of ESs analyzed in this study and the unit values for each ES: Table 1 shows the types of ESs and the unit values used for the ESs. For the unit values of ESs, except for temperature regulation, data were collected through literature surveys. Because the unit values of ESs for Myanmar were limited in the literature, much of the data was estimated from other Asian regions to have enough information for the analysis. These data were based on elevations, forest types and slope conditions similar to those in Myanmar. In this study, three major types of ESs, namely, provisioning, regulating and supporting, were used and cultural services were not included in this study due to data limitation.

Table 1 Types of ESs and the unit values of ESs used in this study

Types of ESs	Forest	Agricultural area	Urban	Water	Source
Supporting Services:					
GPP (t/ha/yr)	30.7	12.093			Chenetal. (2013), Hirata et al. (2013)
Carbon stock (t/ha)	433.7	31.02			Oo(2009), Takeuchi (2012)
Regulating Services:					
CO_2 absorption (t/ha/yr)	2.737	3.250			Chen et al. (2013)
Soilerosionfactor (t/ha/yr)	0.038	3.9			Sidle et al. (2006)
Water infiltration (mm/h)	100	38.5		15	Chaplot et al. (2002)
Temperature regulation (°C)	3.86	1.14	2 0	4.73	Calculated by Landsat7 ETM+
Provisioning Services:					
Agriculture Products (t / ha)	-	5.38	-	-	FAO (2009)
Habitat (GDI)	-	-	-	-	Li (2014)

**GPP, gross primary production*

Estimation of temperature regulation: Estimations of land surface temperatures were calculated by using Landsat7'sEnhanced Thematic Mapper Plus (ETM+) band 6. First, the digital number of band 6 was converted to radiance by using Eq. (1) as follows (Kumar et al., 2012):

$$L_{\gamma} = \left\{\frac{L_{MAX}-L_{MIN}}{QCALMAX-QCALMIN}\right\} * DN - 1 + L_{MIN} \quad (1)$$

The value of L_{MAX}, L_{MIN}, Q_{CALMAX} and Q_{CALMIN} were obtained from the metadata file of Landsat image.Secondly, black body temperature was calculated by using Eq.(2) as follows (Kumar, et.al, 2012):

$$T_B = \frac{K_2}{\ln(1+\frac{K_1}{L_{\gamma}})} \quad (2)$$

The value of calibration constant K_1 and K_2 were obtained from the Landsat data user's manual. Finally, land surface temperatures were calculated based on the Eq. (3) as follows (Yue, et al., 2007):

$$LST = \frac{T_B}{1+\left(\gamma \frac{T_B}{\rho}\right) ln\varepsilon} \quad (3)$$

As land surface temperatures change depend on elevation level, an adjustment was conducted. Adjustment was made based on "going up 1000 m vertically, temperature goes down 6 degree".Then, the average temperature in each land use type was calculated and the differences of temperatures among land use types were obtained as temperature regulation units (Table 1).

Green index (GI): In this study, the GI was calculated to determine the habitat distribution. The GI was calculated based on the results of land classification maps for Landstat7-1999 and ALOS2010 by using the resample tool in ArcGIS (Li, 2004). In the GI, green areas and non-green areas were separated and assigned values of 255 and 0, respectively. In this study, forest and water areas were determined to represent green areas and other land uses were categorized as non-green areas.

Mapping with ArcGIS: Spatial analysis was conducted with ArcGIS to understand the spatial distribution of ES provisions. Seven ES maps were developed in total, and the land classification map data and unit values of ESs were applied. Before applying the unit values, a grid with a mesh size of 300 m × 300 m was developed for the land classification maps.

Determination of priority areas for conservation: Zonation is a software that can be used for the prioritization of conservation areas (Moilanen et al, 2012) The approach used by this software firstly sums the value of each ES layer and then discards the least valuable cells one-by-one until all cells are removed. There are four cell removal rules (Moilanen et al., 2012), and the present study used the additive benefit function (ABF). The ABF tends to produce a higher average proportion of feature distributions. In this study, equal weight was used for all ESs. By using the ABF, the present study achieved the best performance on average for all features or ESs. The main result of the Zonation analysis was a priority ranking map for the entire landscape.

RESULTS AND DISCUSSION

In the present study, geographic information system (GIS) based spatial analysis was conducted for the assessment of ES provision potential based on land classifications. Figure 3 shows the results of land classifications for 1999 and 2010.

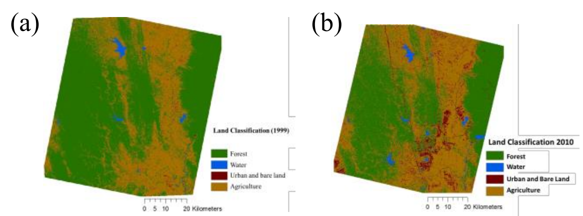
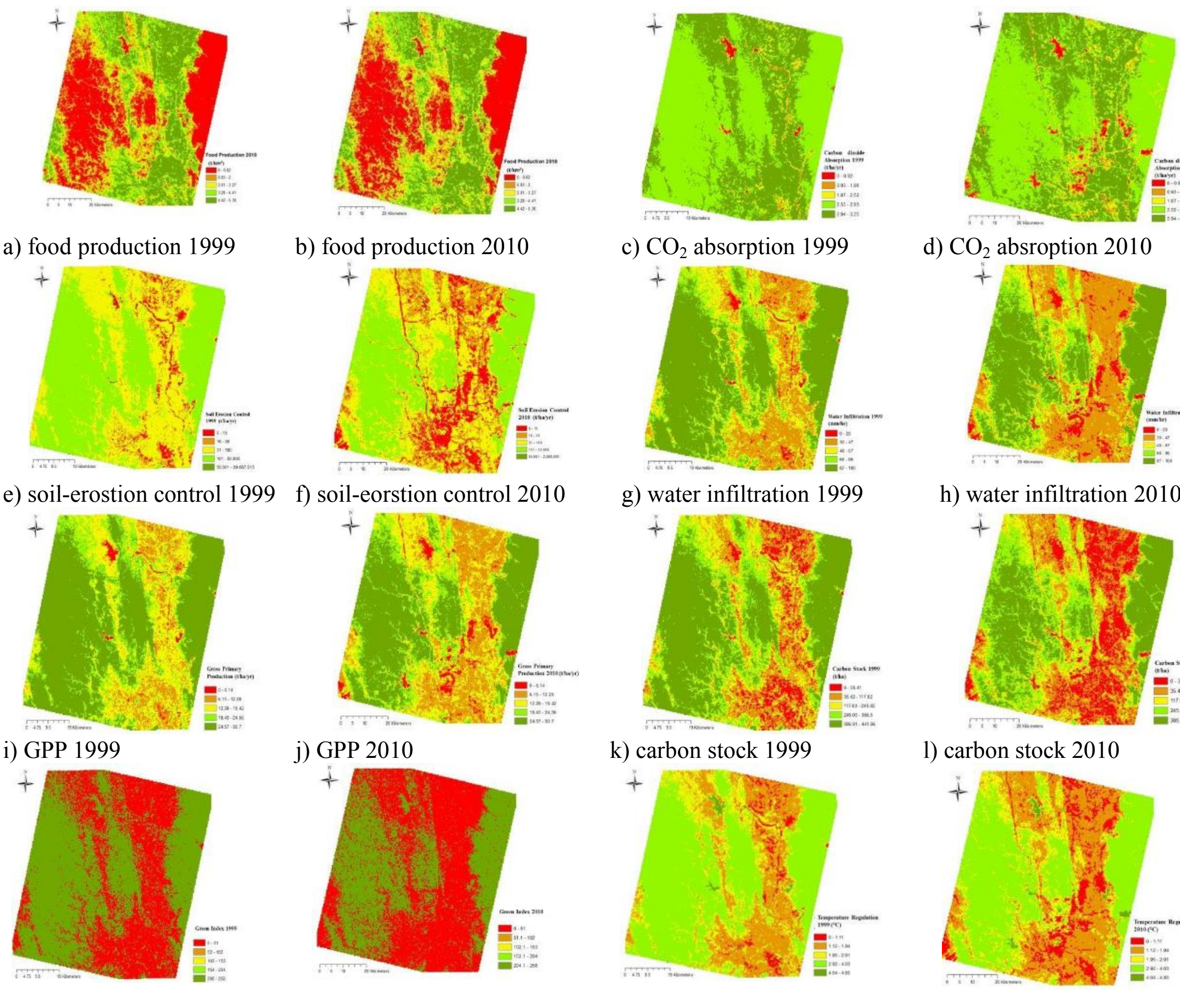


Fig. 3 Land use classification for (a) 1999 and (b) 2010

Based on the results of the land classification, spatial analysis was conducted by using unit values of the ESs on a 500 m mesh. The results are shown in Fig. 4. For food production services, the highest provisioning of the service was in agricultural areas. For the CO_2 absorption service, agricultural areas had higher levels of service provisioning than the forest areas. Perhaps this was related to the unit value used for CO_2 absorption, which was from Chen et al. (2013). Chen et al. (2013) mentioned that agricultural areas have high unit values because of the chemicals used for the crops. Even though many peer-reviewed papers were collected and studied to define the unit values, nevertheless, suitable data for Nay Pyi Taw were difficult to find. Therefore, we just applied the unit value for CO_2 absorption from Chen, et al. (2013). For temperature regulation, water areas had the highest regulation rates followed by forest area. For the other remaining ESs in this study, forests were the highest providers of services.

The most important and valuable areas in terms of the potential distribution of ESs and conservation of ESs are shown in Fig. 5, and these data were derived from the Zonation analysis. In Fig. 5, the dark red color represents the top priority areas for conservation and the violet color represents the lowest priority areas. The top priority areas were mostly forested areas. 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.

Comparisons of 1999 and 2010 data showed that the amount of priority area decreased in some forested areas and increased in other areas. In 1999, some parts of agriculture areas were sparsely included in the top priority areas and some parts (mostly northern parts of the study area) were included in the least valuable areas. Sparse priority areas in 1999 were converted to the least priority areas in 2010 because of urban development. According to these results, the priority areas identified in 2010 should be protected for ES sustainability. Therefore, if infrastructure development projects are being planned, these priority areas should be avoided if at all possible.



a) food production 1999 b) food production 2010 c) CO_2 absorption 1999 d) CO_2 absroption 2010

e) soil-erostion control 1999 f) soil-eorstion control 2010 g) water infiltration 1999 h) water infiltration 2010

i) GPP 1999 j) GPP 2010 k) carbon stock 1999 l) carbon stock 2010

m) GI 1999 n) GI 2010 o) temperature regulation 1999 p) temperature regulation 2010

Fig. 4 Spatial analysis results of ESs in Nay Pyi Taw in 1999 and 2010

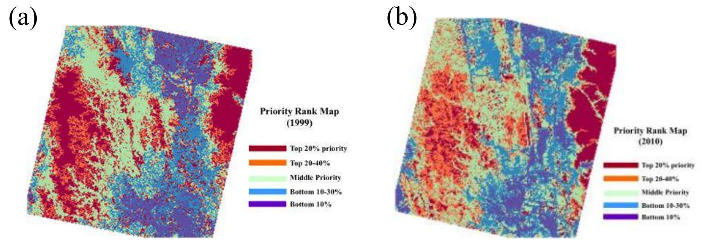


Fig. 5 Priority rank layer map for (a) 1999 and (b) 2010

CONCLUSION

In this study, a spatial analysis of ESs was conducted in Nay Pyi Taw, Myanmar, which is an area of rapid urbanization. Most of the ESs analyzed decreased over time, but food production services increased because of the expansion of agriculture areas. ES provisioning was at the lowest level in the urban development areas. Priority maps were made to identify the areas most important for ES conservation; much of this land consisted of forested areas.These priority maps should be useful for land use planning, policy development, and protected areas establishment in the Nay Pyi Taw region.Comparisons between 1999 and 2010 data showed that ES provisioning had decreased, especially in urban development areas, and several high priority areas in 1999 had changed to low priority areas in 2010 because of urbanization. Therefore, before any new development projects are initiated, we should seek to avoid construction in priority areas for ES provisioning as much as possible. In future study, we seek to include cultural services in this study and also the demand and supply of ESs will be estimated to be sustainable use of ESs in Nay Pyi Taw region.

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