Research article

Impact of Forest Cover Change in Phnom Kulen National Park on Downstream Local Livelihoods along Siem Reap River, Cambodia

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Abstract National parks play important roles in the conservation of biodiversity, environmental protection, and provision of resources for local livelihoods. This research aims at examining the effect of forest cover change in Phnom Kulen National Park (PKNP) on water quality and downstream local livelihoods along the Siem Reap river. Forest cover change in the park was collected from the United States Geological Survey from 2000 to 2016 through the Multi-Temporal Satellite Imagery (MTSI). The study used livelihood approach to interview with 120 households and four key-informants to elicit local perceptions on effect of forest lost on their livelihoods. The research found the forest cover in PKNP decreased by 22% from 2000 to 2016. The loss of forest cover has affected downstream local people whose daily livelihoods depend on Siem Reap River. Scores on local perceptions were low. Livelihood capital were performed low; only 0.48 score on natural capital, 0.44 score on human, and 0.24 score on financial capital, in which correspondent perceived their livelihood did depend significantly on those capitals. However, we found that the physical and social capitals were not significantly affected by the forest cover change because forest clearing created stable access to infrastructure and social network. As forest cover declined impacted on the declined of crop production, fish availability, water quality and access to clean water. As local needs to adopt new skills for living, human and financial capitals were low. The study confirmed the forest cover change at national park had a serious impact on the downstream local livelihoods.

Keywords Phnom Kulen National Park, forest cover change, sustainable livelihoods approach, upstream-downstream issue, perception analysis

INTRODUCTION

Forest provides direct and indirect of good and services to human well-beings by ecosystem functions (Robert et al., 2002). Moreover, it was totally essential for water storage because when the natural forest was damaged, rainfall would be declined, reduced infiltration of water, increased run-off, and

reduced water quality (Robert et al., 2002). Existence of watershed areas in protected forests and national parks played the vital functions for water purification and water resources for both upstream and downstream livelihoods. National park was one of the great tools for forest and biodiversity conservation. The PKNP was one of famous sacred tourist zones with immense spiritual, cultural, historical value. Moreover, it was the main source of water provision for downstream people almost the whole year. However, weak law enforcement and higher market demands on timber and other forest products caused serious forest lost in Protected Areas (Sanchez-azofeifa et al., 2002). Approximately 70% of downstream local people were semi-subsistence farmers and fishers who heavily depended on river-based livelihood activities (Hayes et al., 2013). Lastly, present Siem Reap river had faced water shortage, soil fertility problems, and water pollution (UNDP, 2014).

OBJECTIVES

In overall, the study aimed at investigating the perception of local people on impact of forest cover change in PKNP on Siem Reap river and their livelihood. The specific objectives are i). analyzing the trend of the forest cover change in PKNP between 2000 and 2016; and ii). assessing the livelihood capital of downstream people affected by upstream forest cover change. The limitation of the study did not access to measure economic comparation between before and after the forest cover change due to uncertainly of household's livelihood diversity.

METHODOLOGY

Study Area

Figure 1 showed PKNP, targeted area, located at Siem Reap province, Cambodia (Hayes et al., 2013). Over centuries, the PKNP provided not only main source of water for the city use throughout full year, but also for underground water, which support Angkor Wat temple basement and its scenery (Gaughan, Binford, & Southworth, 2009). Recently, the water from the park contributed importantly daily consumption and agriculture of provincial population. However, there were concerned on the deforestation, led to cause on both water quality and quantity from the park.

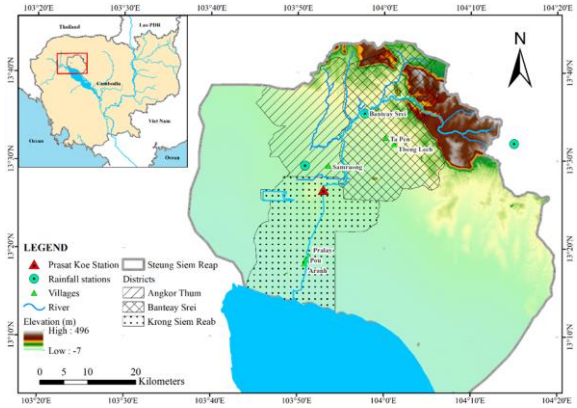

Fig. 1 Phnom Kulen National Park boundaries and administration

Forest Cover Change Detection in PKNP between 2000 to 2016

This study utilized Landsat Satellite Imagery (LSI) from 2000 to 2016. Multi-temporal satellite data were downloaded from the United Stare Geographical Satellite including Landsat 5, Landsat 7 ETM+, and Landsat 8 OLI with a 30 meters resolution. ArcGIS software (ArcGIS 10.6) was utilized for digital image processing, classification, and analysis as well as forest cover change maps generation. Two types of land use and land cover (LULC) were classified including forest, and non-forest areas. In addition, these satellite imageries were selected with less than 10 % of cloud. The band

combination of mosaic and masking were used to analysis and merge the images and clip the boundary. Indeed, Regions of Interest (ROI) was used for supervising classification for forest change detection. Band Combination false color of Landsat was used to take ROI which is forest or non-forest. Therefore, Band 4, 3, 2 was used for Landsat 5 from 2001 to 2011, and Band 7, 4, 2 was used for Landsat 7 ETM+ from 2000 to 2013 and Landsat 8 OLI from 2014 to 2016.

Accuracy Assessment

Accuracy assessment was conducted for all classification to prove the accuracy of each classified image. Moreover, it used to compare the classification from one to another, assumed to be accurate i.e. aerial photo (Parece et al., 2011). An error matrix was accomplished for this task. To assess the accuracy of classification, there were four main steps: 1) create random point on image classified in ArcGIS (100 sample), 2) convert layer to KML to assess the point in Google Earth, 3) insert the point in Google Earth and compared the classification task and Google Earth, and 4) created the error matrix table and calculate with the formula.

Cohen's kappa co-efficient was an essential component of accuracy assessment, it provided the accurate result how well our classification performed.

$$\hat{k} = \frac{\text{observed accuracy - chance agreement}}{1 - \text{chance agreement}}$$

where, The **KHAT** value ranges from 0 to 1,**0** indicates the classification is not any better than a random assignment of pixels, **1** indicates that the classification is 100% improvement from random assignment.

$$\hat{k} = \frac{N \times \sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} (X_{i+} \times X_{+i})}{N^2 - \sum_{i=1}^{r} (X_{i+} \times X_{+i})}$$

where, **r** number of rows in the error matrix, $\mathbf{X_{ii}}$ number of observations in row i and column i (the diagonal cells), $\mathbf{X_{i+}}$ total observations of row i, $\mathbf{X_{+i}}$ total observations of column I, **N** total of observations in the matrix (Parece et al., 2011).

This study calculated the error matrix formulations of two years: 2010 and 2016 to verify the accuracy of forest cover change analysis. After calculating the error matrix of supervised classification in 2010, the overall accuracy of image classification is 96% and the Kappa was 91%. In 2016, the overall accuracy of the image classification was 91% in 2010 and 82% in 2016.

Assessment of Livelihood of Downstream Local People Affected by Upstream Forest Cover Change

120 households were selected with purposive sampling for the questionnaire survey. Four key-informants from forestry administration office, department of environment, department of meteorological and few rangers in Siem Reap province were interviewed for the confirmation of both qualitive and quantitative survey.

Adapted from Qian et al. (2017), livelihood approach has five capitals including; Physical capital which had indicators: household fixed assets (Land, Machinery, etc.); Natural capital had indicators: forest coverage (changing), necessary for forest protection (important of forest), forest protection activities in National Park, and biodiversity (quantity of water, quality of water, crop fishing in natural place); Human capital had indicators: skill and knowledge (improvement), health status (illness or not); Financial capital has indictors: household income (income of agricultural production, forest and NTFPs), and Social capital had indictors: community membership (participant), social network (relationship), and family decisions. The total scores of local livelihood assets were calculated by: