



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 comparison 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.

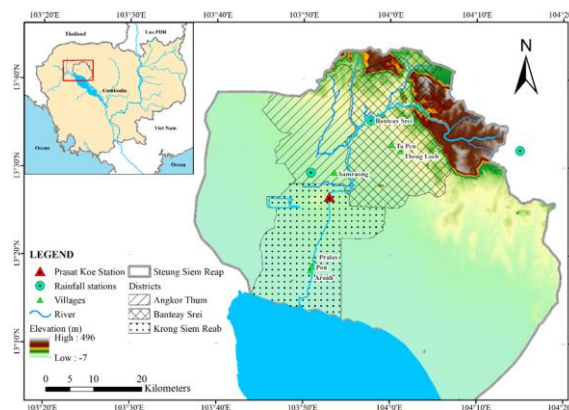


Fig. 1 Phnom Kulen National Park boundaries and administration

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 State 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.

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

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, **X_{ii}** number of observations in row **i** and column **i** (the diagonal cells), **X_{i+}** total observations of row **i**, **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 qualitative 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 indicators: household income (income of agricultural production, forest and NTFPs), and Social capital had indicators: community membership (participant), social network (relationship), and family decisions. The total scores of local livelihood assets were calculated by:

$$LA = \frac{C_{Pc} + C_{Nc} + C_{Hc} + C_{Fc} + C_{Sc}}{5}$$

where; **LA** Livelihood Assets, **C_{Pc}** Physical capital, **C_{Nc}** Natural capital, **C_{Hc}** Human capital, **C_{Fc}** Financial capital, **C_{Sc}** Social capital.

RESULTS AND DISCUSSION

Trend of Forest Cover in Phnom Kulen National Park

In Fig. shown in 2000, PKNP covered by 31000 ha of forest area. Between 2009 and 2016³, forest was dramatically declined about 2800ha. The forest in PKNP had lost huge amount at the same trend of forest cover in whole (ODC, 2016). According to the interview with rangers reported the main reasons of population growth (both people who migrated in and population growth naturally inside the village), people expanded land for settlement, agricultural activities. Moreover, it was because of inadequate knowledge of local people regarding forest conservation and forest management, illegal logging. The perpetrators cut trees and killed the wildlife for selling at nighttime, which was difficult for rangers to take action. In addition, limitation of logistic and incentive of ranger affected on less patrolling activities.

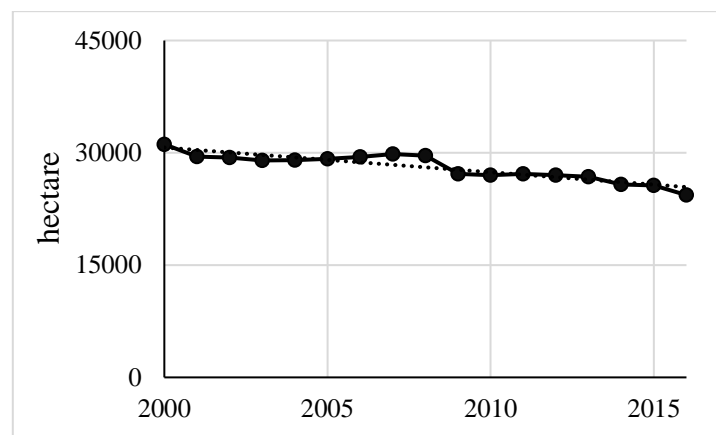


Fig. 2 Land surface of forest cover change in Phnom Kulen National Park from 2000 to 2016

Between 2009 and 2013 is the period of creating the policy on economic land concession (ELC) by the government in the National Strategic Development Plan (NSDP). The purpose of creating the ELC policy was to develop the industrial agricultural sector, sustain economic growth and reduce poverty (ODC, 2015). By contrast, our study found there was impact on the forest cover change in Siem Reap province. Based on the NGOs reported ELC was a hot very topic for land conflict including land grabs, evictions and exploitation of natural resources (ODC, 2016).

In a line, the result of forest cover from the LSI from 2000 and 2016 shown in Fig. , forest lost about 22%, equal to 6780 ha and the rate of deforestation was 1.3%, account to big amount of forest lost that had to be consideration of the Cambodian government and development agencies. Recently, over 4,600 people had settled in PKNP, caused to forest land conversion to residential, crop cultivation mainly rice and cashew nut and the area was mainly used for rice (A&D Foundation, 2018).

The analysis found that 65% of local people perceived that forest cover in the upstream of PKNP had decreased, while 35% reported not. The score of forest coverage was 0.35, suggesting a

³ In 2008, forest cover increased because of the cloud problem which made some error in calculation. In 2012 and 2013, the imagery of land 7 was selected to use because it is the clearest one but there has many gaps on the image so the research applied Shoreline Extraction (Landsat 7 ETM+) to fix it.

significant decline. Our analysis of satellite imagery found that sharp decline in Banteay Srei district, where local people depended mostly on timber and non-timber production for daily livelihoods.

The result shown in Table 1, the percentage of local people perceived the forest at upstream was declined, water quantity in the region decline is 76.7% especially. Moreover, there are 23.3% of correspondents reported water was not declined due to the forest cover change at upstream. The score of this water quantity was 0.23, which means deforestation impacted the decline of water quantity at downstream area.

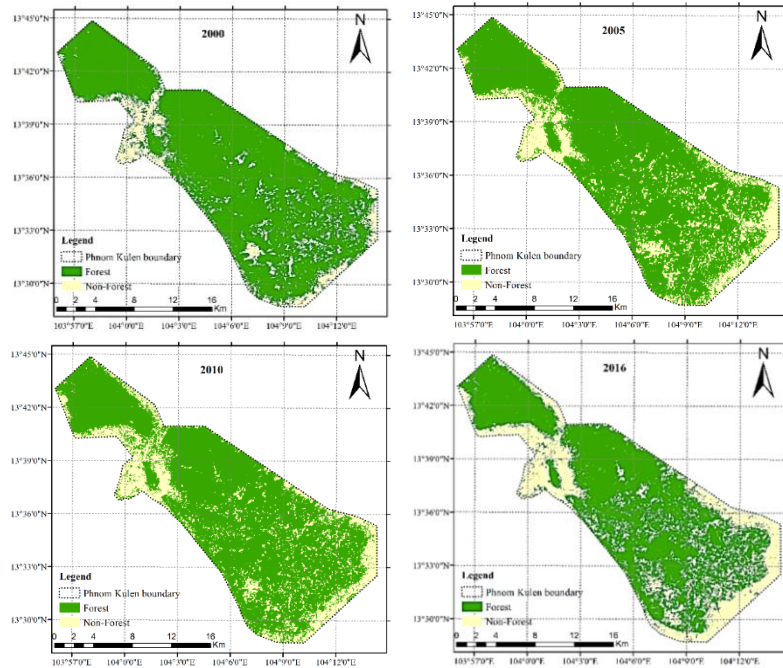


Fig. 3 Comparison of forest cover change in Phnom Kulen National in 2000 and 2016

Table 1 Percentage of correspondent on livelihood capital

Statement	Respondents (n=120)		
	No (%)	Yes (%)	Score
Do you know that forest in the upstream national park has decreased?	35	65	$= 35*1+65*0$ $= 35 \% = 0.35$
Do you think that since forest from upstream declined, water quantity in your region has also declined?	23.3	76.7	$= 23.3*1+76.7*0$ $= 23.3 \% = 0.23$
Do you think since forest from the upstream decreased, water quality in your region also decrease?	28.3	71.7	$= 28.3*1+71.7*0$ $= 28.3 \% = 0.28$
Do you think since forest from the upstream decreased, your crop production also declined?	40.8	59.2	$= 40.8*1+59.2*0$ $= 40.8 \% = 0.41$
Do you think since forest from the upstream declined, the amount of fish in the river also decreases?	25.0	75.0	$= 25.0*1+75.0*0$ $= 25 \% = 0.25$
Scaling:			
0.00 – 0.25	Largely decreased		
0.26 – 0.50	Decreased		
0.51 – 0.75	Increased		
0.76 – 1.00	Largely Increased		
	Total score		0.30

Another result shown 71.7% of downstream people perceived the decreased forest at upstream impacted on water quality. The score of water quality was 0.28. Correspondents reported last seven years ago before 2013, water in river and lake could be used for drinking, taking shower, and using for daily. In addition, 59.2% of the downstream people perceived the decreased forest at upstream impacted on a decrease of crops productions due to water shortage, badly in dry season.

There were 75% of the downstream people perceive the decreased forest at upstream, impacted on the decline of natural fish stock in the river. The decline of fishery significantly affected on income and food insecurity of the local livelihood.

Livelihood Assets of Downstream Local People in Relation to Siem Reap River Affected by Upstream Forest Cover Change

Although forest cover change occurred in upstream but physical capital was required to use for daily life. Natural capital was reported decreasing in biodiversity with 0.48 score. Local people perceived there was decreased in upstream forest cover led to decrease the water quality, water quantity, impacted on yield decreasing of crops and fish production. People in Banteay Srei, Tbaeng Lech, Ta Pen, and Samraong villages raised the same aspect on decline of water quality and quantity impacted on reduction of crop production and fishery.

As shown in Fig. 4, the result indicated, physical capital was not impacted regarding the forest cover change in upstream with score 0.61. Similar change of physical capital because people required to use for their daily live.

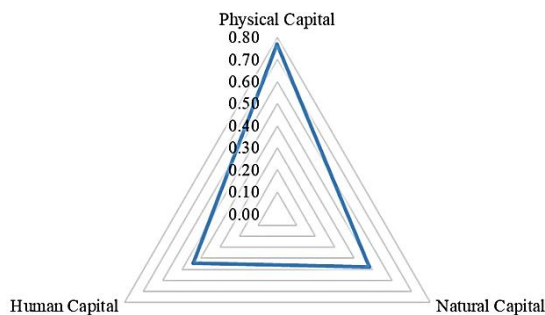


Fig. 4 Downstream local perception in term of change of livelihood capital

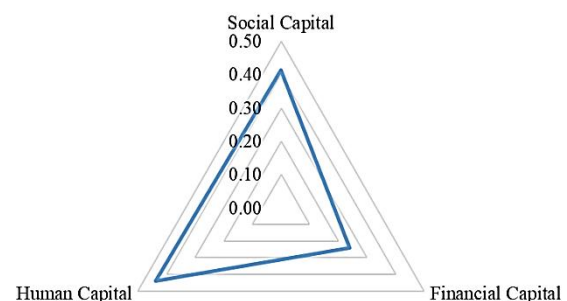


Fig. 5 Downstream local perception on current situation of the livelihood capital

In Fig. 5, the result illustrated that the current situation shown score of financial capital was very with score 0.24, local people mostly depend on agriculture. The mean score human capital and social capital in term of current level was medium mean score 0.44 and 0.41 because people did not have any serious case of their health and both of man and woman had decided together for decision making.

CONCLUSION

The research found forest cover in PKNP was declined 22% from 2000 to 2016 due to illegal logging, inadequate knowledge regarding forest conservation, population growth, increase in cashew nut, and rice fields. A strong link between natural capital and forest cover have found. As local people need to change to new skills in order to survive after decline of forest cover. Low scores on human capital was observed, indicating the need for interventions of the local or national authority to assist local people. Similarly, for the current situation of their financial capital had low income and high expenditure.

Therefore, this study provided very important evident base of the forest cover change thought the satellite imagery maps from 2000 to 2016 and result of perceptions of local people about the impacts of the forest cover change in PKNM, which contributed direct and indirect impacts to natural capital, human capital and influenced on the current situation of financial capital.

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