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The value of ecosystem services obtained from the protected forest of Cambodia: The case of Veun Sai-Siem Pang National Park

Abu S.M.G. Kibria [a,*], Alison Behie [a], Robert Costanza [b], Colin Groves [a], Tracy Farrell [c]

[a] College of Arts & Social Science, The Australian National University, ACT 2601, Australia
[b] College of Asia Pacific, The Australian National University, ACT 2601, Australia
[c] Conservation International, Greater Mekong Region, Phnom Penh Center, Sothearos Corner Sihanouk Blvd, Phnom Penh, Cambodia

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ABSTRACT

This research provides for the first time a valuation of Veun Sai-Siem Pang National Park (VSSPNP) in Cambodia, which is a forest largely unfamiliar to the international community yet extremely significant in terms of biodiversity value. This study aimed to measure the monetary and non-monetary values of ecosystem services (ESS) of the forest. We estimated the total annual contribution of VSSPNP was US $129.84 million. Its primary contribution was air purification (US$56.21 million yr^{-1}) followed by water storage (US$32.31 million yr^{-1}), soil-erosion reduction (US$22.21 million yr^{-1}), soil-fertility improvement (US$9.47million yr^{-1}), carbon sequestration (US$7.87 million yr^{-1}), provisioning services (US $1.76 million yr^{-1}) and recreation (US$0.02 million yr^{-1}). Traditionally the forest is used for timber and non-timber forest products, which in fact, composed only 1.36% of the total benefits. By analysing the published articles and reports on VSSPNP we determined the area had generated valuable academic and non-academic knowledge on natural resources. This forest had also created a diverse network among scientists and different organizations worldwide. We also identified the forest to be of cultural importance for indigenous people as they believe that their ancestors live inside the forest and protect them from vulnerabilities. Despite being part of one of the most important eco-regions in the world VSSPNP is undervalued and facing multiple threats such as illegal logging, poaching, population pressure and corruption. The current estimation of ESS would thus assist in the sustainable management of VSSPNP.

1. Introduction

Forest ecosystems are capital assets that yield many vital services for humans (Costanza et al., 2011). Their importance, however, is often determined by comparing their value with that which could be obtained from converting forests for other land uses (i.e. agriculture) (Costanza et al., 1997). The ecosystem services (ESS) of forests identified by previous researchers are food, water, fuel, timber, fibre, climate regulation, flood regulation, disease regulation, water purification, and spiritual and recreational considerations (MEA, 2003; Fisher et al., 2014). These are broadly categorised in four groups- provisioning, regulating, cultural and supporting services.

Despite large potential ecosystem values, the increasing conversion of native ecosystems into agricultural land to meet ever increasing food demands worldwide is a major cause of habitat destruction and losses of valuable ecosystems (Tilman et al., 2001; Sunderlin et al., 2005). Land for agricultural expansion comes from forest, grassland and other natural ecosystems. If current global trends continue, net loss of natural ecosystems to agriculture would amount to 10^9 ha by 2050 – larger than the total area of the USA (Tilman et al., 2001). Tropical forests, by nearly all means, account for the richest biodiversity found anywhere in the world, yet, ironically, these forests are also among the most threatened (Valiela et al., 2001). Tropical forests are more than just a combination of flora and fauna; they are home to many indigenous people, and are vital source of numerous services such as flood amelioration, soil erosion control, fresh water supply, air purification, recreation, education and so on (Laurance, 1999; Costanza et al., 2014). The most prominent impact of tropical forest destruction is the loss of these precious ESS (Costanza et al., 1997; Daily et al., 2009; de Groot et al., 2012). This issue, however, has been largely ignored in forest and environmental policies, and conventional economic justifications have often underestimated the true contributions of forests. This has often led to the conversion

* Corresponding author at: AD Hope, 14 Ellery Crescent, The Australian National University, Canberra, ACT 2601, Australia.
E-mail addresses: abu.kibria@anu.edu.au, kibria.asmg@gmail.com (A.S.M.G. Kibria).

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of forests to agricultural land uses, as well as to lower investment in forest conservation (Costanza et al., 1997; Daily et al., 2009).

Forest ecosystems are great sources of knowledge and destinations for diverse research efforts. Scientific articles, reports, popular articles and visits to forest ecosystems can serve to increase awareness about the ecological importance of a region with the wider community (Costanza et al., 1997). Every year countless meetings, conferences, workshops and symposia are organized worldwide to share knowledge and determine priorities in social, economic and environmental policies. Climate change from carbon emission, rapid biodiversity loss, local and national dependence, conversion into commercial plantation and numerous management challenges (Laurance, 1999; Bawa, 2006; Boon, 2013) make it more important than ever to make connections and start a dialogue among researchers and public and private land owners (Andersson et al., 2000). The field of ESS is one such platform where these discussions can be had as they support millions of people worldwide and have the potential to contribute to the economic and social development of local communities (Adhikari et al., 2004; MEA, 2005; Babulo et al., 2008) through the provisioning of food and water security along with other cultural and social benefits.

Given the importance of ESS to sustainable human development, it is time for some important questions to be addressed: How important are ESS? And At what scale? The answers to these questions are not entirely academic. We make choices among the competing options by comparing ‘benefit to be gained’ from them which implies ‘valuation’. In most cases environmental benefits are not properly evaluated and, thus, tend to be underestimated in the cost-benefit analysis of any proposed action (Costanza, 2000). Valuation of all the possible ESS would not only increase the economic value of the ecosystem, it also will highlight the socio-cultural services of natural ecosystems (Daniel et al., 2012; Barrena et al., 2014). Communities have their own considerations in valuing the ecosystems and often the socio-cultural values are not adequately incorporated in decision making (van Riper et al., 2012). Monetary and non-monetary values can complement each other and generate greater ESS by facilitating communications between stakeholders and enabling comprehensive evaluation that frames all the aspects of an ecosystem’s contribution within the broader ESS framework (deGroot et al., 2010; Daniel et al., 2012). The decline of any type of ESS in and outside the sources of services often create conflicts within communities (Zarandian et al., 2016).

Decision makers require better information on the comprehensive values of nature for weighing human actions on the ecosystem (Bingham et al., 1995). Millions of people in developing countries live adjacent to forests and their wellbeing is closely linked with forest resources (Smith et al., 2013). Moreover, many services are of benefit to humans at national and regional levels, which suggests that forest destruction would cause irretrievable damage to general human wellbeing (Daily et al., 2009). Unless we drastically improve our understanding of the values offered by ecosystems in conservation efforts, we cannot hope to improve forest conservation and thus the sustainability of human wellbeing cannot be ensured (Smith et al., 2013).

Cambodia has one of the highest rates of land-use change globally (Hansen et al., 2013; Davis et al., 2015). The country is of global conservation importance because it contains the largest remaining examples of habitats that were previously spread across much of Indochina and Thailand, and which still contain nearly intact species assemblages, albeit at heavily reduced densities (Loucks et al., 2009). Veun Sai-Siem Pang National Park (VSSPNP), which was granted National Park status on May 9, 2016, before which it was a Conservation Area, has been listed as a Key Biodiversity Area in the World Biodiversity Database and is also part of the Virachey Important Bird Area (Chan et al., 2004). VSSPNP contains significant populations of rare and endangered species (e.g. the red shanked douc langur and the giant ibis) and is home to several indigenous hill tribes and other people including Brao, Lao, Kavet and Kinh. Due to chronic poverty, illegal logging and poaching activities are threatening the site’s ecological integrity which when paired with other human induced ecosystem changes and general impacts of climate change, may result in catastrophic consequences (POH-KAO, 2012). Conservation International has been implementing conservation projects in the forest, but in the absence of an estimation of ESS for the area to justify greater investment and attention provided towards its protection, this has been challenging. To address this research gap and to improve management of the area our study aimed to estimate ESS values derived from VSSPNP.

2. Methodology

2.1. Study site

VSSPNP is located in North-eastern Cambodia at 14°01′N, 106°44′ E and consists of approximately 55638.72 ha of evergreen (54486.81 ha) and semi-evergreen (1151.91 ha) forest (Fig. 1). This area experiences two distinct seasons: the wet season from May through October and the dry season from November to April. It has a mean annual temperature of 28 °C (ranges from 38 °C in April to 17 °C in January) while the mean annual precipitation ranges from 1200–2000 mm and is governed by monsoons (Thoeun, 2015). Topographically the area is mixed with hilly and plain lands with red sandy soil. VSSPNP is a large mostly pristine forest in the Veun Sai District of Ratanakiri Province and Siem Pang District of Stung Treng Province of North-eastern Cambodia. It is contiguous with Virachey National Park which borders Vietnam and Laos. The forest is characterized by patches of mixed deciduous and semi-evergreen forests (Chan et al., 2004). Ecologically, the area is located within the Indo-Burma hotspot (Myers et al., 2000), and is part of the 200 globally most important ecoregions, the Eastern Indo-China Dry and Monsoon Forest (Olson and Dinerstein, 1998) and part of the Critical Ecosystem Partnership Fund’s (CEPF) Cambodia-Lao PDR-Vietnam Tri-border Forests priority corridor (Critical Ecosystem Partnership Fund, 2012).

In VSSPNP 255 animal species have been recorded of which four are classified as Critically Endangered, 12 as Endangered, and 19 as Vulnerable on the IUCN Red List of Threatened Species (Ramachandra et al., 2012). Primates of this area are of special conservation concern. The population of gibbons at the site is considered globally significant (Rawson and Bach, 2011) as it is believed to be the biggest population of the species *Nomascus annamensis* in existence. Other species of concern include black-legged douc langur (*Pygathrix nemaeus*), dhole (*Cuon alpinus*), malayan sun bear (*Helarctos malayanus*), gaur (*Bos gaurus*), banteng (*Bos javanicus*), eastern Eld’s deer (*Panolia siamensis*), and two species of slow loris (genus *Nycticebus*). The site is also home to rare birds such as: white-winged duck (*Asarcornis scutulata*), giant ibis (*Thaumatibis gigantea*) and white-shouldered ibis (*Pseudibis davisoni*) (Ramachandra et al., 2012).

2.2. Valuation of ESS

We considered food, water, non-timber forest products (NTFPs) and timber as provisioning services; water purification and soil erosion reduction as regulating services; recreation, education, traditional ethno-cultural belief as cultural services; and nutrient improvement as a supporting service (MEA, 2003; Fisher et al., 2014; Maynard et al., 2015). These ESS were chosen for this study as they were flagged by local people and NGO officials as being of particular importance. In this research we used simplified methods

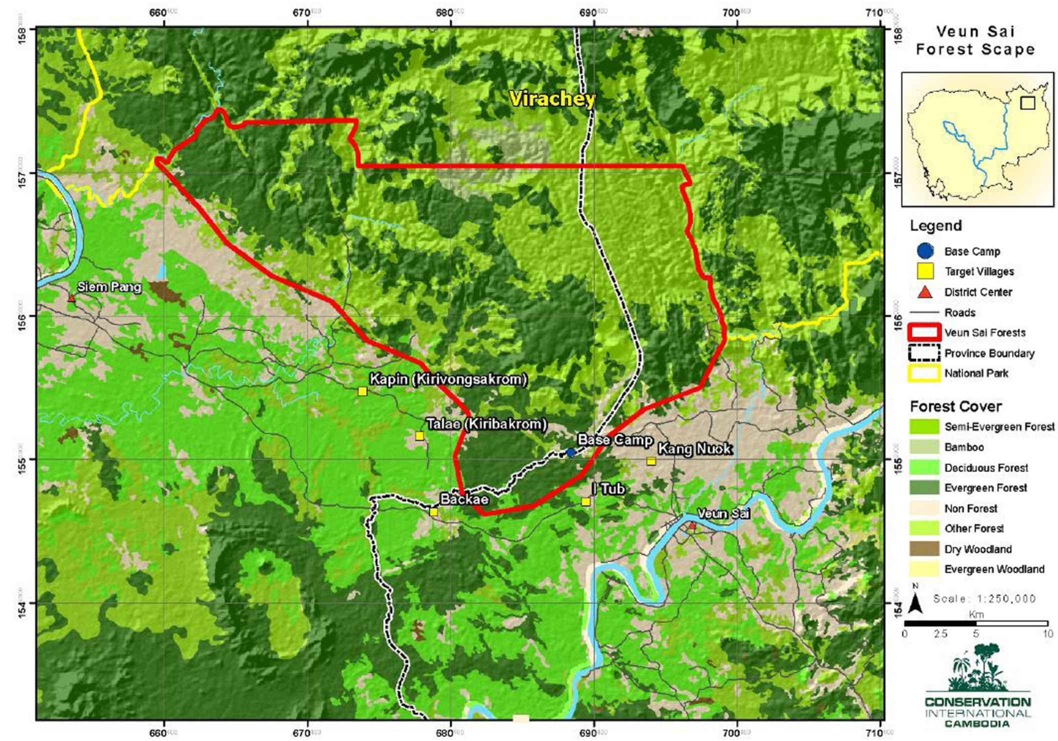

Fig. 1. The Veun Sai-Siem Pang Conservation Forest (red boundary); source: Ramachandra et al. (2012).

to measure the value of major ESS of VSSPNP which is easily understandable and can be used by a person with little technical knowledge.

2.2.1. Provisioning services

Rural people in the villages adjacent to VSSPNP collect timber, resin, malva nut, bamboo, mushroom, and wild animals from the forest. Data regarding income from provisioning services were collected by interviewing 35 indigenous households selected at random. Quantitative and qualitative data were collected from key informant interviews and group discussions with local indigenous people, research assistants and village elders (Persson et al., 2010; POH-KAO, 2012; Ramachandra et al., 2012) and then supplemented with information from published sources. Direct market valuation methods were used to calculate the value of these services of the forest (Hein et al., 2006; Costanza et al., 2011).

2.2.2. Carbon sequestration

At present there are few carbon flux measurements in tropical forests over a period long enough to generate the annual estimate. The average net carbon sequestration rates of selectively logged evergreen rain forest and semi-evergreen forest are used in this study (Malhi et al., 1999; IPCC, 2000; Cao et al., 2006; Xi, 2009). Carbon tax is used to determine the price of carbon emission (Creedy and Wurzbacher, 2001; Huang and Kronrad, 2001). For this study carbon tax of South Korea is used as it is situated in Asia and the only country that has introduced the carbon tax in this region (Table 1) (World Bank and Economics, 2016). The carbon sequestration value of VSSPNP is calculated by using the following formula (IPCC, 2000; Creedy and Wurzbacher, 2001; Xi, 2009; Ninan and Inoue, 2013):

$$V_c = Q \cdot P \cdot S$$

where V_c = Service value of carbon sequestration (US$), Q = Net carbon sequestration rate ($\text{t ha}^{-1}\,\text{yr}^{-1}$), P = International carbon price (US$/tC), S = Area of forest (ha).

2.2.3. Water storage

The forest is often referred to as a "sponge and green" reservoir for its immense osmosis effect and watershed protection capacity. By regulating runoffs, forests can contribute to delays in flood peaks and reducing flood volumes; in dry seasons, forests gradually release absorbed water that maintains river flow and relieves droughts. Subtracting evaporation from the total rainfall overestimates the water storage capacity of the forest, because part of the rainfall is used by plants or stored in soil (Capillary and Hygroscopic water). Therefore, the ratio of rainfall and runoff must be considered to overcome this problem (Xie et al., 2010) (Table 1). The runoff coefficient method is one of the most simple and widely used methods to measure the runoff yield of the catchment (Negassi et al., 2002). One commonly adopted valuation method is the rainfall storage method, which was used for this valuation (Xi, 2009; Biao et al., 2010). The equation is:

$$V_w = Q \cdot C_{rc} = S \cdot J \cdot R \cdot C_{rc} \quad \left[here,\ J = K \cdot J_0 \ and\ R = (R_0 - R_g) \right]$$

where V_w = Annual economic value of forest ecosystems in watershed protection (US$); Q = Increase in water preserved in forest ecosystems, compared to bare land (or non-forested area) (m^3); C_{rc} = Cost of reservoir construction per m^3; S = Area of the forest (ha); J = Annual average precipitation runoff yield of the study area (mm); R = Benefit coefficient of reduced runoff in forests compared to bare land (or non-forested area) (%); J_o = Annual average precipitation of the study area (mm): K = Ratio of precipitation runoff yield to total precipitation of the study area; R_0 = Precipitation runoff rate under precipitation runoff condition in bare land (or non-forested area) (%); R_g = Precipitation runoff rate under precipitation runoff condition in forests (%).

The reference of R parameters was selected for subtropical evergreen broadleaf forest, and subtropical evergreen deciduous forest categories (Xi, 2009) (Table 1).

Table 1
Data used in measuring the values of ESS of VSSPNP.

ESS	Names of data	Values	Sources	Assumptions
Carbon sequestration	i) Area of evergreen forest	54486.81 ha	Ramachandra et al. (2012)	The forest is contributing the CO_2 removal from the atmosphere and thereby reducing the effect of global warming
	ii) Area of semi-evergreen forest	1151.91 ha		
	iii) Total area	55638.72 ha		
	iv) Net carbon sequestration in logged evergreen rain forest	2.65 tC ha^{-1} yr^{-1}	IPCC (2000)	
	v) Net carbon sequestration of logged semi evergreen forest	1.1 tC ha^{-1} yr^{-1}		
	vi) Carbon price	US$54/tC	World Bank et al. (2016)	
Water storage	i) Ratio of precipitation runoff yield	0.60	Xi (2009)	The forest saves development costs of water storage
	ii) Benefit coefficients of reduced runoff in forests	0.39; 0.34		
	iii) Annual perception of Veun Sai	2405 mm	Someth et al. (2010)	
	iv) Cost of reservoir construction	US$0.12 m^{-3}	Xi (2009)	
Soil erosion prevention	i) Sediment removal cost	US$2.5 t^{-1}	PPWS (2015)	The forest saves development cost of sediment removal from the watershed
	ii) Rate of erosion of broad leaved forest	0.5 t ha^{-1} yr^{-1}	Xi (2009)	
	iii) Rate of erosion of non-forest land	319.8 t ha^{-1} yr^{-1}		
Soil fertility improvement	i) Total N in forest soil	1.31 g kg^{-1}	Cao et al. (2006), Xi (2009)	The forest saves the extra investment required to apply fertilizers to produce food and NTFP for the dependent communities
	ii) Total P in forest soil	0.26 g kg^{-1}		
	iii) Total K in forest soil	7.33 g kg^{-1}		
	iv) Price of N-fertilizer	US$0.20 kg^{-1}	World Bank (2016)	
	v) Price of P-fertilizer	US$0.07 kg^{-1}		
	vi) Price of K-fertilizer	US$0.20 kg^{-1}		

2.2.4. Soil erosion prevention

As a protection layer of the ground, forests help to prevent soil erosion and minimize sedimentation in reservoirs and rivers, thus extending reservoir life. The function of forests in rainwater retention and reduction of rainfall volume and velocity reaching the ground serves to regulate runoff quantity and speed soil loss. One method of estimating the value of reduction in soil loss is equivalent to the cost of sediment removal from rivers and reservoirs. In this study, the soil erosion in the non-forest area and the erosion of broadleaf forest (Xi, 2009), and cost of per ton of sediment removal are used (PPWS, 2015) (Table 1). The formula for calculating the value of soil erosion prevention by forests is as follows (Xi, 2009; Ninan and Inoue, 2013):

$$V_{sc} = C_{sr} \cdot G \sum S_i \cdot D \;\; [\text{here}, \; D = (d_i - d_0)]$$

where V_{sc} = Economic value of soil conservation (US$); C_{sr} = Cost of 1 ton of sediment removal (US$); S_i = Area of the respective type of forest (ha); D = Erosion reduction in forest land (t ha^{-1}); G = Ratio of amount of sediments entering rivers or reservoirs to total soil lost; d_i = Rate of erosion of broad leaved forest (t ha^{-1}); d_0 = Rate of erosion of non-forest land (t ha^{-1}).

2.2.5. Soil fertility improvement

The forest also helps to maintain fertility since soil erosion may result in losses of N, P, K and organic substance which can be regarded as proxy for nutrient cycling function. Thus, the nutrient cycling valuing formula is as follows (Xi, 2009; Ninan and Inoue, 2013):

$$V_f = D \cdot S_i \sum P_{1i} \cdot P_{2i} \cdot P_{3i}$$

where D = Erosion reduction in forest land compared to non-forest land (t ha^{-1}); S_i = Area of the respective type of forest (ha); P_{1i} = Content of N,P,K in forest soil (%); P_{2i} = Ratio of pure N, P, K to their fertility counterparts. The ratio of N, P, K to their fertilizer counterparts are 60/28,406/62,74.5/39 respectively (common fertilizers used are urea for N, Calcium Superphosphate for P and Potassium Chloride for K); P_{3i} = Price of fertilizers (i.e. Price of urea, Calcium Superphosphate and Potassium Chloride in US$).

Due to lack of sufficient data for VSSPNP, the soil nutrient data of the Xishuangbanna monsoon forests of Yunnan, southernmost China, were used. This area is ecologically very similar to our study site as it is also included in the Indo-Burma biodiversity hotspot and experience tropical climate (Table 1).

2.2.6. Air purification

Forest purification includes the following functions: i) Absorption of harmful gases such as SO2, NOx, HF, ii) reduction of particulates of the air. The method commonly adopted involves area absorption (Xi, 2009). The formula is:

$$V_{aq} = \sum_{i=1}^{n} S \cdot Q_i \cdot C_i$$

where V_{aq} = Value of air quality improvement (US$), S = Area of the forest (ha); Q_i = Absorption or adsorption of the ith pollutant per unit area (kg^{-1} ha^{-1}); C_i = Treatment cost of the ith pollutant (US $/kg); V_e = Value of air purification by forest (US$ yr^{-1}).

For this formula data regarding absorption capacity of broad leaved forest has been used. The treatment cost of the pollutants China is used for this study (Xi, 2009) (Table 1).

2.2.7. Recreational value

We have fist calculated each year revenue generated by VSSPNP and then the average annual value of the forest was calculated (Adams and Infield, 2003; Baral et al., 2008). Hence, recreational value per year was measured by the following formula:

$$V_r = \sum_{i=1}^{n} V_{r_i} = \sum_{i=1}^{n} N_i \cdot P_i$$

where V_r = Total recreational value of the forest (US$); V_{ri} = Recreational value of ith year; N_i = Number of tourist in ith year; P_i = Average price of the tour package paid by the tourist in i^{th} year.

2.2.8. Educational and scientific value

It is recognised worldwide that forests are great sources of knowledge (Costanza et al., 1997; MEA, 2003; Xie et al., 2010; Maynard et al., 2015). VSSPNP has received great attention from local and international scientists. We explored scientific and educational values of the forests by examining: a) How many schools/institutes visited the area as study tours, b) How many people from different countries visited the site, c) How many researchers were involved, d) How many theses (MSc, PhD) were produced based on data from the site, e) How many articles and reports have been published on VSSPNP and what contributions have been made to the existing knowledge of natural resource management from such studies (deGroot et al., 2010)

3. Results

3.1. Monetized value

It was found that indigenous people harvested 12 different goods from the forest. All the villagers were involved in collecting firewood as it was the only source of household cooking energy. VSSPNP was a great source of different food items and crops. Almost all the households were engaged in extracting two of the most important food items, including 'mushroom' (98%) and 'rattan shoot' (92%). The total market value of these two items collected by the villagers were US\$2230 yr^{-1} (mushroom) and US \$4579 yr^{-1} (rattan shoot). The majority of the families were also engaged in collecting malva nut (80%) as cash crops, which were worth US\$14,220. Some families (20%) extracted resin from *Dipterocarpus* spp. which was considered a vital source of household income. Timber harvesting for income and house-building was performed by 96% villagers at an average of 6.37m^3 yr^{-1} which was valued as US\$3503. Several families reported that they used to earn about US\$5000 just from a single luxury timber tree, rosewood, however due to over exploitation, the rosewood is no longer available; hence, they have shifted to other less valuable trees. Watersheds (river and streams) in the forest area were found to be vital sources of various fish for the villagers (90%), which were worth US\$53,325 yr^{-1}. People also hunted for different wild animals for consumption and sometimes to sell for profit at the local market. Thus, in total, the value of the provisioning services supplied by VSSPNP was calculated to be US\$1.76 million yr^{-1} where each household earned US\$3720 yr^{-1} (Table 2).

We found that the conservation forest of VSSPNP sequestrates carbon worth US\$7.87 million yr^{-1} at a rate of US\$141 ha^{-1} yr^{-1} which is removing 13.76 tCO_2 ha^{-1} yr^{-1} (Table 3). The water storage benefit of the forests per hectare was US\$581 yr^{-1} which was worth US\$32.31 million yr^{-1} by the whole forest. In our study we found that the total value of soil erosion prevention provided by VSSPNP was US\$22.21 million yr^{-1} (US\$399 ha^{-1} yr^{-1}). The forest of VSSPNP plays an important role in nutrient cycling, equal to US\$9.47 million yr^{-1}. The value of nutrient cycling in unit area (ha) of forest is US\$170 ha^{-1} yr^{-1}. Four major components including NO_x, SO_2, HF and particulate are considered in estimating the value of VSSPNP in regards to air quality improvement by absorbing these harmful elements. The value of air purification by the forest was estimated at US\$56.21 million yr^{-1} at a rate of US \$1010 ha^{-1} yr^{-1}. By removing harmful gases and particles from the atmosphere this forest not only reduces the cost of air purification, it also saves a large expenditure for public health and safety. The main attraction of VSSPNP is 'gibbons' along with the forest, indigenous people and birds. This makes the recreational value of the ecosystem to be US\$0.02 million yr^{-1} (Table 3).

Table 3
Major ecosystem services and their values of the conservation forest.

Services	Value (US\$ yr^{-1})	
	Per hectare	Total (million)
Provisioning	32	1.76
Carbon storage	141	7.87
Water storage	581	32.31
Soil erosion prevention	399	22.21
Soil fertility improvement		
N	18	1.0
P	19	1.05
K	133	7.42
Subtotal	*170*	*9.47*
Air purification		
SO_2	9	0.48
HF	0.46	0.03
NO_X	1	0.03
Particulate	1001	55.67
Subtotal	*1010*	*56.21*
Recreational	0.37	0.02
Total	2334	129.84

3.2. Non-monetized value

3.2.1. Academic and non-academic knowledge

Table 4 shows the analysed the methodological limitations of spatial and non-spatial models for predicting future deforestation in VSSPNP. Based on a non-spatial model, deforestation would be close to 0.8% in the first year while a non-spatial model shows no deforestation over five years. This valuable output would assist scientists to develop more precise methods for predicting deforestation rates worldwide. Ramachandra et al. (2012) also checked the viability of the REDD+ project in VSSPNP. Cash flow from

Table 2
Major provisioning services harvested from the forest and their values.

Services	Collected amount (unit yr^{-1})	Household income (US\$ yr^{-1})	% of households collected	Total value (US\$ yr^{-1})
Timber (m^3)	6.37	3503	96	1594233
Mushroom (kg)	12	4.8	98	2230
Rattan shoot (kg)	30	10.5	92	4579
Bamboo shoot (kg)	65	65	100	30810
Fish (kg)	50	125	90	53325
Resin (kg)	75	60	20	5688
Jungle fowl (kg)	3	12	5	284
Lizard (kg)	10	25	50	5925
Frog (kg)	20	52	10	2465
Snake (kg)	7	175	5	4148
Malva nut (kg)	15	37.5	80	14220
Fire wood (kg)	60	96	100	45504
Total				1763410

Note: Values in parenthesis represent number of household.

Table 4
Contribution of VSSPNP in generating academic knowledge.

References	Key areas	Comments
Ramachandra et al. (2012)	Deforestation model	Analysed the methodological limitations of spatial and non-spatial models
Rawson and Bach (2011)	Primate ecology	Discovered that geophagy is a common behaviour of douc langurs and silvered langurs
Jackson (2014)	Primate ecology	Explored the effects of species-specific seed dispersal patterns
	Method for species abundance	Develop a method to assess the presence of animals and estimate their population sizes
Hill (2011)	Indigenous knowledge	Explored the local knowledge and uses of primates
Geissler et al. (2012)	A new lizard species	Discovered *Lygosoma veunsaiensis* in VSSPNP
Csorba et al. (2011)	A new bat species	Discovered a new bat species *M. walstoni*
Thinh et al. (2010)	A new gibbon species	Identified a new gibbon species (*Nomascus annamensis)*
Nelson (2013)	Primate ecology	Observed sleeping tree selection by northern yellow-cheeked crested gibbons
Williams (2016)	Primate ecology	Explored predictors of the likelihood of northern yellow-cheeked crested gibbon calling
Morley (2015)	Primate ecology	Investigated key resource use of northern yellow-cheeked crested gibbon

REDD+ was found to be sensitive to the prediction of deforestation of the area, but they argued that it could deliver significant benefits.

Rawson and Bach (2011) discovered that geophagy is a common behaviour of douc langurs and silvered langurs which are predominantly arboreal primate species. These primates visit salt licks frequently and pass some time on the ground, where they are exposed to an increased risk of predation. These two species use the salt lick at different times of the day, and this opened up scope for research on the function of geophagy for colobines in VSSPNP. Moreover, this provided guidelines to determine measures for conserving these two taxa (Table 4).

Jackson (2014) explored the effects of species-specific seed dispersal patterns on seedling recruitment of *Microcos paniculata.* He found that the main dispersers were bulbuls (three species) and gibbons. Williams (2016) investigated how ecotourism and chainsaw activity impacts gibbon behaviour and calling in VSSPNP and found that both had potentially negative impacts on energy budgets. Nelson (2013) and Morley (2015) studied resource use by gibbons in VSSPNP and identified key feeding, calling and sleeping trees and how they are distributed in the forest (Table 4). All of these studies on gibbons are essential for a wider understanding of the ecology of this newly described species and designing better informed conservation plans.

Hill (2011) conducted a survey to understand the local knowledge and uses of primates in the villages around VSSPNP (Table 4). Distance of the village from the forest and the level of knowledge on primates had a reverse relationship, which means that the people in the villages have the most knowledge about the primates. The majority of local people could recognize the primate species. Only in the nearby Chinese village were people aware of a few primates as they were involved in trading a couple of them. Pygmy slow loris (*Nycticebus pygmaeus*) was in high demand for traditional medicine, and macaques and gibbons were preferred for the pet trade. Hill (2011) also explained the local wild life trading channel as: indigenous people→ traders in the Chinese village→ Vietnamese in Ban Lung. These results would guide us in designing a program for primates and their habitat conservation.

Geissler et al. (2012) discovered a new species of lizard in VSSPNP named *Lygosoma veunsaiensis*. This is the third new species in the last two years to be discovered in the area. In 2011, a new bat species *Murina walstoni* was described by Csorba et al. (2011) a new gibbon species (*Nomascus annamensis)* was identified by Thinh et al. (2010) (Table 4). These highlight the uniqueness of the biodiversity of VSSPNP which is yet to be adequately documented.

The Australian National University runs a field school at VSSPNP to teach both undergraduate and postgraduate students effective and precise methods of data collection and build capacity to utilize this data in biodiversity conservation plans and strategies. This course is also designed to enhance the adaptability of the future research in facing the likely challenges of studying forest vegetation and primates in field conditions under threats.

3.2.2. Network development

This forest has offered research opportunities and connected researchers from Oxford Brooks University, University of Florida, The Australian National University, Victoria University of Wellington, Zoologisches Forschungs Museum, Stockholm Environment Institute, Hungarian Natural History Museum, Harrison Institute, Royal University of Phnom Penh and Royal University of Agriculture of Cambodia. In providing logistic and financial support to those research and activities many non-academic organizations were also engaged notably Conservation International (CI), Fauna and Flora International (FFI), IUCN, Poh Kao, des tigres et des Hommes, Maisons Du Monde, McArthur Foundation, Ensemble Foundation, Critical Ecosystem Partnership Fund and Foundation Le PAL Nature. This is a great example of how a patch of forest can establish such enormous research, network and familiarize a country worldwide in a new dimension. Working with international experts, research institutes, other NGOs, local community members and Cambodia's Forestry Administration have learned valuable research skills. These skills may help to provide future employment, research, and higher education on natural resource management.

3.2.3. Ethno-cultural

Indigenous communities have intimate spiritual attachment with the forest. Animism is the dominant religion of the ethnic communities, was apparently originated due to their dependency on forest. Indigenous people, especially Lao and Kavet, believe that the spirits (locally called Araks) of their ancestors live inside the forest. Araks are believed to guide villagers for their livelihoods. Deforestation or conversion of forest for economic development enhances their concerns of losing protection from Araks, and this is often blamed for increased flood and drought. Every year each community organizes a village ceremony in which every family must join. In the village ceremony every family prepares traditional Jai Wine and contributes rice or money to buy a buffalo to offer their ancestors' spirits during the ceremony. This celebration lasts three days, with traditional music, dancing and singing. They believe that this ceremony would bring happiness to them.

These local people offer a chicken, pig, and a jar of wine to the spirits before commencing any major event such as shifting cultivation, logging for building a house or a wedding. If a man is bitten by a snake inside the forest it is considered as a punishment by the Araks for ill thoughts. If someone gets sick, they believe their ancestors are angry with that person due to cutting trees and wildlife hunting in the sacred places, or someone did something wrong to anger the spirits. They offer a chicken or pig or buffalo (based on the decision by the religious leader) and wine to make their ancestors happy and to cure the patient, as well as to halt the spread of the disease. After about three days if the patient does not get better than they consult doctors. The families who cannot afford hospital

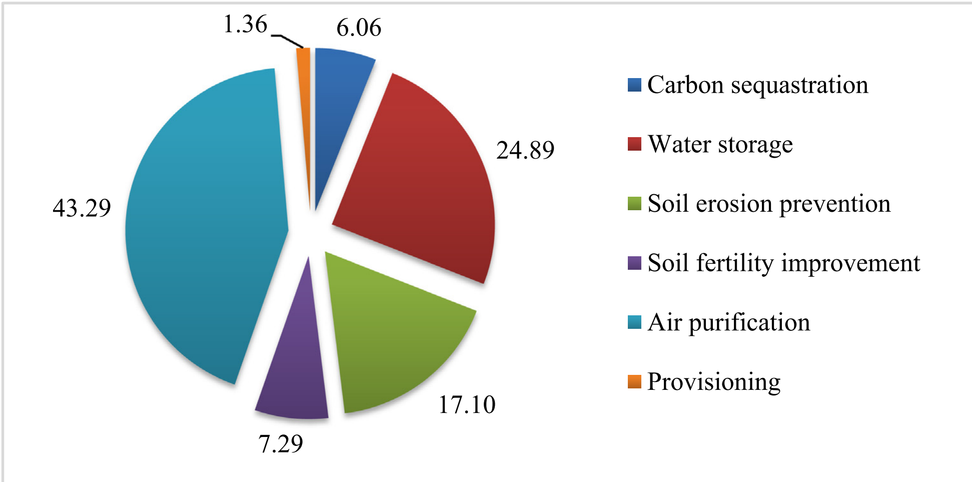

Fig. 2. Contribution percentage of different ESS in relation to the total benefit.

treatment wait longer to be cured. All these beliefs have been weakened, however, because timber traders offer chainsaws, money and political back-up to the villagers to engage them in illegal logging, and eventually the marginalised villagers have started to ignore their cultural beliefs in order to earn money. Thus, continuous deforestation has eliminated many of the cultural elements of local indigenous people, and this cultural loss may increase deforestation and hunting.

3.3. Total value of ESS and its composition

The total value of ESS generated by VSSPNP is estimated at US $129.84 million yr^{-1} (Table 3). Air purification is the largest contribution (43%) of VSSPNP followed by water storage (25%), soil erosion prevention (17%), soil fertility improvement (7%), carbon sequestration (6%) and provisioning services (1.36%). The recreational value is not included in the composition chart (Fig. 2) because this is too tiny to present as a percentage of total value. Nonetheless, the gibbons living in the forests have attracted tourists from around the world, and thereby increased the recreational value of the forest as a whole. Many tourists reported that if there were no gibbons they would not visit VSSPNP – i.e. the recreational value of the forest would be nearly zero. The community based ecotourism (CBET) program thus has enormous potential to increase the perceived value of the forest by tourists, which in turn can create actual increases in forest value, although to achieve this the program needs to expand.

4. Discussion

This research provides, for the first time, a valuation of a forest that while being largely unfamiliar to the international community is very significant in terms of richness of biodiversity. The value of the provisioning services supplied by VSSPNP was calculated to be US$1.76 million yr^{-1}. This high economic contribution of the forest clearly demonstrates the richness of the forest. According to the Ministry of Planning (2014) of Cambodia, the average annual income of the households in rural Cambodia is US$2793 yr^{-1}. Our study, however, estimated an income of US$3720 yr^{-1} for only forest products from VSSPNP. This difference is mainly due to the high value timber in VSSPNP that is in great demand in Vietnam and China. Almost all the villagers were involved in illegal timber harvesting for both selling and self-use The Chinese village near the forest area was the centre for timber trading of VSSPNP. Collectors reported that traders from this village supplied expensive chainsaws and money to continue cutting trees. Collectors then sold timber openly to the traders in the Chinese village, which were then transported out of the area, often in the middle of the night, to Ban-lung city and then to Vietnam and China. Such logging has already led to the disappearance of rosewood from the forest, which is also occurring at other forests in the region (Frewer and Chan, 2014). Without increased protection from international demand it will be very difficult to slow down illegal logging practices in heavily corrupt Cambodia (Burgos and Ear, 2010). Destruction of VSSPNP would also worsen food security among indigenous people who are heavily dependent on VSSPNP for the collection of their most important food items including mushrooms, rattan shoot and fish (Kim et al., 2008; Baja-Lapis, 2009) along with for the income produced through collecting malva nut and extracting resin from *Dipterocarpus spp*.

VSSPNP's sequestrated carbon was worth US$7.87million yr^{-1} by removing 13.76 tCO_2ha^{-1}yr^{-1} from the atmosphere which is equal to total the emission from driving 536 automatic gasoline cars 100 km (Sullivan et al., 2004). Thus, conservation of the forest would be a low cost abatement option for CO_2 emission in the atmosphere (Kindermann et al., 2008). The water storage benefit of forests per hectare was US$581 yr^{-1}. Biao et al. (2010) also found the value of water conservation by the forests of Beijing is US $855 ha^{-1}yr^{-1} which is close the current study. In our study, we found that the total value of soil erosion prevention provided by VSSPNP was US$22.21 million yr^{-1}. If the costs of off-site effects of soil erosion including siltation, water flow irregularities, reduction in irrigation, and water pollution are considered, the total value of soil erosion would be very high (Ananda and Herath, 2003). Pimentel et al. (1995) estimate that the total investment for US erosion control is about US$8.4 billion per year which is small price to pay in comparison to the total economic loss from soil erosion as every US$1 investment would save US$5.24. The forest of VSSPNP also played an important role in nutrient cycling, which equals US$9.47 million yr^{-1}. Higher numbers of tree species accelerate nutrient cycling and related activities, which generates more ESS (Hooper and Vitousek, 1998; Gamfeldt et al., 2013). To increase the nutrient cycling value it is essential to maintain the diversity of species VSSPNP.

Four major components including NO_x (Oxides of nitrogen), SO_2 (Sulphur dioxide), HF (Hydrogen fluoride) and particulate absorption are considered in estimating the value of VSSPNP in regards to air quality improvement. The value of air purification by absorbing harmful gases and particles was estimated US$56.21 million yr^{-1}. Thus, this forest not only reduces the cost of air purification, it also saves large expenditure for public health and safety. Taking into account the health benefits of these harmful elements, Nowak et al. (2014) measured the value of the forest in rural areas of the US states is US$2.2 billion yr^{-1}.

The main attraction of VSSPNP to tourists is 'gibbons' along with the forest, indigenous people and birds generating US$0.02 million yr^{-1}. Xiang et al. (2011) reported a snub-nosed monkey tourism project in Shennongjia National Nature Reserve in China generated US$0.22 million yr^{-1} after the same period of time of VSSPNP. While these revenues are scanty in comparison to the other successful flagship species tourism projects the projects are at the early stage of development. Given that Spenceley et al. (2010) found that in 2009 the Parc National des Volcans in Rwanda, gorilla based eco-tourism generated US$42.7 million ecotourism at VSSPNP could generate significant funds if more effort is taken to improve the program. Our finding that villagers close to the forest have improved knowledge of the primates, indicates that engaging these villagers in conservation activities may provide increased benefit from this increased knowledge base.

In addition to monetary value, VSSPNP served as an important research site for the study of a variety of species and for cooperation among academic researchers, NGOs and funding organizations. Researchers discovered new species including *Lygosoma veunsaiensis*, *M. walstoni* and *Nomascus annamensis* in VSSPNP which eventually created great research interests for scientists from across the globe. This valuable output increased our knowledge of deforestation, carbon sequestration, ecology of douc langur (*Pygathrix nemaeus*), silvered langur (*Trachypithecus cristatus*), and northern yellow-cheeked crested gibbon (*Nomascus annamensis*), and indigenous use of primates. Moreover, field school programs, and tourist visits created great awareness about the need to conserve forests both in Cambodia and other countries. These activities brought researchers from 11 research organizations and facilitated cooperation among 10 different funding organizations and NGOs working with the international experts, the capacities of local people were also improved. Thus, this forest has established enormous research, network and familiarize Cambodia worldwide in a new dimension. Moreover, the forest has ethno-cultural and spiritual values to the indigenous people. This forest is essential to conserve to protect the cultural diversity of the area.

In monetary value, the ESS of VSSPNP generated US$129.84 million yr^{-1}. In Mundulkiri and Koh Kong, the biodiversity corridor is worth US$3815 ha^{-1} yr^{-1} (ADB, 2010). Although there two more ESS are included in this study, per hectare value of VSSPNP's ESS (US$2334 ha^{-1} yr^{-1}) suggests that the site is equally comparable with other nationally valuable ecosystems. The non-monetized values are also adding great importance to the local and national interests of Cambodia. Kubiszewski et al. (2013) also argued that if the intangible benefits of the ecosystem are included, the composition of the values changes drastically. This research demonstrates what a valuable resource we are going to lose if the current threats to the forests are not addressed immediately.

5. Conclusion

VSSPNP supplies benefits worth about US$129.84 million yr^{-1}. Timber and many NTFPs values are traditional parameters which are used to compare the profitability of the forest ecosystem with agricultural land uses. Our research suggests that this kind of cost-benefit analysis (CBA) in fact covers only 1.36% of the total value. If all the services can be accommodated in a total ecosystem value measurement, which we could not do due to data deficiency, the value of timber and NTFPs would account for even less. This significant information would be a valuable element in deciding trade-offs between forest conservation and utilization. Moreover, there are several services which cannot be monetized, and this also has a strong influence on the wellbeing of dependent societies.

Indigenous communities' cultural elements for life and livelihood are heavily influenced by the forest, and existing research at VSSPNP constitutes a valuable resource for the academic community as well as for non-academic communities worldwide. Yet little has been done thus far by the international community to effectively conserve the unique biodiversity of this region, and the total ESS values are fundamentally relevant for sustainable policy formulation as well as having large impacts on human wellbeing. In comparison to the value of the Mundulkiri and Koh Kong biodiversity corridor, the VSSPNP forest is equally important and in many cases more important than other protected biodiversity conservation areas in Cambodia. Recently, VSSPNP is declared as 'protected area' by the Cambodian government. These estimations would greatly support NGOs (e.g. Conservation International) in convincing the policy makers to ensure proper management of the valuable biodiversity hotspot.

The results obtained in this study regarding the value of various ESS present in VSSPNP can be extrapolated out to other forests in SE Asia with similar resource bases. This would assist in trade-offs for ecosystem conservation in the face of palm oil and rubber plantations, mining, infrastructure development and other ecosystem uses in Cambodia or other countries. This kind of evaluation could provide essential guidelines Environmental Impact Assessment of any development project to achieve sustainable development. Moreover, increased awareness on the value of natural resource would motivate the politicians to follow sustainable development approach, popular short-term economic gain instead.

6. Limitations of the study

A lack of data is one of the most common constraints for conducting research in developing countries (Asiedu, 2002; Kim Phat et al., 2004; Mahar et al., 2009). Due to lack of specific data we used benefit transfer method to collect the data required to measure the values of carbon storage, water storage, soil erosion prevention, soil fertility improvement and air purification. Ecological and geographical proximity were the priorities in collecting data from the secondary sources. Despite some shortcomings, benefit transfer method is useful especially when the desired data are unavailable and this method can generate reasonably accurate results (Rosenberger and Loomis, 2000; Piper and Martin, 2001). However, these findings are valuable because roughly precise values are better than having no values at all.

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