# The Exploration of Ecosystem Management Options to Support Sustainable Livelihoods in the Phnom Kulen National Park, Cambodia





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Bottom left (© Chhin Sophea) Training for local communities on bamboo for ecosystem restoration and livelihood improvement

Bottom right (© Chhin Sophea) Integration of black ginger under cashew nut plantations

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# Abbreviations

ACB	ASEAN Centre for Biodiversity
ADF	Archaeology Development Fund
BBP	Biodiversity-Based Products
CPA	Community Protected Area
GDANCP	General Directorate of Administration for Nature Conservation and Protection,
	Ministry of Environment, Cambodia
GDLC	General Directorate of Local Community, Ministry of Environment, Cambodia
GEF	Global Environment Facility
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GSSD	General Secretariat of the National Council for Sustainable Development,
	Ministry of Environment, Cambodia
IUCN	International Union for Conservation of Nature
MoE	Ministry of Environment, Cambodia
NGO	Non-Governmental Organisation
NR	National Road
NTFP	Non-Timber Forest Product
PDAFF	Provincial Department of Agriculture Forestry and Fishery, Ministry of Agriculture
	Forestry and Fishery, Cambodia
PDoE	Provincial Department of Environment, Ministry of Environment, Cambodia
PDWRAM	Provincial Department of Water Resources and Meteorology, Ministry of Water
	Resources and Meteorology, Cambodia
PKNP	Phnom Kulen National Park
SPA	Strategic Programme Areas
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP-IEMP	UNEP-International Ecosystem Management Partnership
USD	United States Dollar
UTM	Universal Transverse Mercator
WGS	World Geodetic System

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### 1. Introduction

#### 1.1. Geography and land-use

The Phnom Kulen National Park (PKNP) extends over an elevation ranging from 56 to 498 m a.s.l. (Figure 1A) (Hayes et al., 2013) In the north, the flat floodplain landscape of the Tonle Sap Great Lake is a unique and predominantly sandstone geographical feature. According to the Siem Reap Provincial Department of Water Resources and Meteorology (PDWRAM), the annual average temperature is 28°C with an average minimum of 25°C in the rainy season and an average maximum of 34°C in the dry season. The annual average rainfall is 1,580 mm. Compared to the records from the plateau in the last three decades, the most recent average temperature (24°C) is higher and the average rainfall (2,050 mm) is lower (Ashwell, 1993; Chim et al., 2021A; Chim et al., 2021B; Marajh & He, 2022). The park is divided into two distinct plateaus and is the source of the Stueng Siem Reap River and a critical part of the upper watershed for Siem Reap Province (Figure 2).

The soil of PKNP area is divided into 4 categories. Dystric Leptosol covered 85% of the total area, Haplic Acrisol accounted for 14% of the total area and Dystric Cambisol and Gleyic Plinthic combined covered 1% of the total area (Oeurng, 2019) (See Figure 1B).



Figure 1: The elevation (A) and soil type (B) of PKNP area [Source: Oeurng, 2019]



Figure 2: Location of the PKNP area in the Stung Siem Reap Watershed [Source: Oeurng, 2019]

The result of the land use image in 2020 (Sentinel Image 2020 and Google Image 2019) shows forest covers about 62% (forest plus shrubland) of the total land of PKNP, while various cropland covers (including cropland, orchard, and tree plantation) about 35% and paddy field covers about 0.3% (Table 1 and Figure 3).

Land use class name	Area (ha)	Percent
Bare land	38.14	0.1%
Cropland	2,943.85	7.9%
Forest	10,755.90	28.8%
Shrubland	12,687.34	33.9%
Grassland	285.49	0.8%
Orchard	9,664.69	25.9%
Rice paddy	117.60	0.3%
Tree plantation	377.89	1.0%
Village	463.52	1.2%
Water	24.39	0.1%

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Figure 3: Land use in PKNP in 2020 [Source: Biodiversity Department, 2020]

#### 1.2. Demography

Four districts of Siem Reap province are located within PKNP. The eastern part of the Kulen Plateau is in Svay Leu district (Khnorng Phnom commune). The western part is partially inside the Varin district (Srae Nouy commune). The northwest part of the Kulen massif is in the lowlands between the two ranges of the National Park Phnom Hop. The eastern part of the western range is partly in Banteay Srey district (Khun Ream and Tbeng commune). The southernmost tip of the plateau, part of the PKNP, is located in Sot Nikum district (Chan Sa commune). The commune councils are responsible for planning and implementing the socio-economic development plan within their commune administrative boundaries.

Although local inhabitants are scattered in various parts of the park, more people are concentrated in two communes: Khnorng Phnom commune (Svay Loue District) in the eastern plateau with nine officially recognised villages and in Khna Roveang village of Khun Ream commune (Banteay Srey District) along Road No. 67, nearby Kbal Spean. Based on 2017 report data from the Ministry of Interior, the people in five out of the nine villages on the eastern plateau have been traditionally living in the villages of Anlong Thom, Ta Penh, Sangke Lak, Khla Khmum, and Thmor Chruogn with 572 families (2,812 individuals) (Table 2). Approximately 418 families with about 1,753 individual villagers of Popel, Preah Ang Thom, Phum Thmey, and Ta Han have been moved in and settled there in the past 15 years.

Villages	Number of families	Total population
A. Khnang Phnom commune * villages		
1. Anlong Thom	218	1,142
2. Ta Penh	127	607
3. Sangke Lak	87	413
4. Khla Khmum	68	310
5. Thmor Chrouch	72	340
Subtotal	572	2,812
B. Khnang Phnom commune** villages		412
1. Popel	97	853
2. Preah Ang Thom	217	255
3. Phum Thmey	51	233
4. Ta Han	53	***
Subtotal	418	1,753
TOTAL	990	4,565

Table 2: Population data for villages on the plateau of PKNP

Source: Ministry of Interior (April 2017)

\* Traditional villages officially registered by the Ministry of Interior

\*\* The new villages (established in the past 15 years) under the process of registry

\*\*\* No info provided

#### 1.3. Culture

Phnom Kulen (Kulen mountain) is a national park and also one of the most sacred mountains in Cambodia. The mountain is in close proximity with Angkor, the great capital (IX-XIV<sup>th</sup> century), and there is a unique hydrologic relationship between the two sites. Numerous archaeological sites in Phnom Kulen indicate ancient settlements. Recent research has shown the originality and complexity of these sites, reinforcing the historically sacred nature of Phnom Kulen (Chevance et al., 2019).

Khmer studies commenced at the beginning of the XX<sup>th</sup> century and over time scholars have progressively identified the mountain as Mahendraparvarta (the Sanskrit name of Phnom Kulen settlement), one of the earliest capitals in the region. By extension, Phnom Kulen became the "birth place" of the Angkorian period (802-1432 A.D) and the Khmer Empire, even though many pre-Angkorian sites such as Sambor Prey Kuk (VII<sup>th</sup> century) predate this capital. Other epigraphic sources show King Jayavarman II was the unifier of smaller independent kingdoms at the end of the VIII<sup>th</sup> century, before settling in Phnom Kulen and the Angkor region (Jacques, 1972).

Successive kings during the Angkor era, particularly from the X<sup>th</sup> and XI<sup>th</sup> century, referred to themselves as successors with direct lineage to King Jayavarman II, with inscriptions often quoting Mahendraparvata. Two carved river beds indicated King Udayādityavarman II (XI<sup>th</sup> century) visited the site and offered a golden linga, the phallic representation of God Shiva. The carved riverbeds are spectacular sites, giving a sacred nature to the water irrigating Angkor Wat, as these rivers were associated with the Ganges.

#### 1.4. Biodiversity

PKNP was derived from the name of the typical evergreen tree species *Litchi chinensis*, named lychee in English and Kulen in Khmer. The main forest type of PKNP is comprised of evergreen forest, accounting for approximately 20% of the total park area (Bonheur, 2008). The area is also comprised of deciduous dipterocarp forest and wetland/riparian vegetation. As a result of human activity, there is a secondary growth forest inside the evergreen forest zone. Prior to the secondary forest growth, there was a cashew nut plantation. A lot of time and effort will be needed to regenerate total characteristics of an evergreen forest (Vieira et al., 2009). Lack of data on pre-regeneration conditions makes comparisons challenging (Hayes et al., 2013).

PKNP vegetation provides shelter for different types of lower and higher plant species promoting diversity and supporting various fauna species. Based on an assessment in 2013, the first study to provide an overview of the PKNP's wildlife (Hayes et al., 2013), a total number of 779 plant, 267 bird, 25 amphibian and 61 reptile species were accounted for. A preliminary list of 12 fish species was recorded. With 25 known bat species, PKNP is home to nearly 40% of Cambodia's bat species (25 of 68 species). 28 animal species are IUCN-listed as a conservation concern, including the global endangered Bengal slow loris (*Nycticebus bengalensis*), pileated gibbon (*Hylobates pileatus*), and the Indochinese silvered langurs (*Trachypithecus germaini*). The wildlife in PKNP has reduced substantially due to the recent deforestation and systematic hunting (Hayes et al., 2013). The forest ecosystems of PKNP, even though fragmented at many

sites, provide a critical habitat for crucial globally threaten species and could serve as a gene pool for biodiversity conservation.

#### 1.5. Threats

The increase in economic activities due to increases in ecotourism within the park has subsequently increased the number of people moving into and living in Khnorng Phnom Commune. According to the Ministry of Environment (MoE) data, the population has increased from 2,845 to 3,278 people between 2003 and 2008. According to Ministry of Interior (MoI), the total population as of mid-2017 increased to 4,465 inhabitants with 990 families, representing average annual growth rate of 4% from 2003. Among the villages in this commune, Preah Ang Thom attracts more in-migrants due to economic opportunities linked to the area, especially tourism. The significant changes related to economic activities and the natural resources conditions of water and forests took place in 2005 when one of the villages in PKNP, Anlong Thom, began cashew farming. This agricultural activity spread to other villages in the commune, except the village of Preah Ang Thom where the villagers are dependent on tourism activities (e.g. one thousand lingas, the reclining Buddha, and waterfalls). In addition, the village has no proper agricultural pieces of land for farming purposes.

According to MoE (2017), the changes in PKNP forest cover (compared to the total park area) occurred primarily from 2006 to 2016 with following data: 86.9% in 2006 (32,463 ha), 87.6% in 2010 (32,725 ha), 77.40% in 2014 (28,930 ha) and 55.5% in 2016 (20,747 ha). Over ten years, PKNP lost 31.3% forest cover, equivalent to 11,716 ha. Between the year 2006-2016 the average annual rate of change was 3.13% of the total land area. At the watershed scale, "satellite image analysis revealed that between 1993 and 2005, almost all of the forest (30,000 ha) was converted into non-forest, predominantly into slash and burn, areas." The deforestation of PKNP is mostly due to the extension of the cashew nut cultivation on the Kulen plateau and encroachments in the lowlands. In remaining parts of the forest, large to middle sized trees are subject to illegal logging (Figure 4).



Figure 4: Causes and effects of the cashew nut plantation and environmental impacts at PKNP [Source: Ministry of Environment, 2017]

#### **1.6.** Purpose and scope

In order to support policy makers, practitioners and researchers to collectively address the challenges related to ecosystem management and sustainable livelihoods at the Phnom Kulen National Park, this report compiles the key interventions implemented by different organisations and offers potential options related to ecosystem management that can support sustainable livelihoods of the communities living inside the Phnom Kulen National Park.

This study is based on interviews with village chiefs, elder villagers and other key stakeholders. Additionally, this study reviewed existing literature, reports and case studies which identified as good practices and provided an understanding of the current ecosystem and livelihoods situation in or around the Phnom Kulen National Park. This report also highlights the key challenges and feasible options to address gender mainstreaming.

# 2. Major local livelihoods and cashew nut farming

About 20 years ago, most of the villagers living in this mountain were subsistence farmers, growing rainfed upland rice supplemented by cassava, taros, beans, and other crops. Traditionally, farmers practiced shifting cultivation/rotation farming (Chamkar). These farming strategies involved clearing and burning plots of land, farming for one year and then vacating the plot allowing the area to regenerate. Each household had about 5 plots (each plot about 1 ha) for this practice. A key driver accounting for changes in economic activities and the environment, namely water and forest, is the arrival of cashew nut farming in 2005 at Anlong Thom village. This practice later spread to all villages of Khnorng Phnom commune to the point where almost all forested lands in large parts of the eastern plateau have now been converted to permanent cashew plantations.



Prior to the arrival of cashew nut farms, interviews from villagers in Khnorng Phnom commune confirmed they practiced rotational farming for household uses. Crops farmed through this practice included rice, banana, potato, pineapple, taro, corn, cassava, and home garden (mainly for vegetable, spices and herbs). Crops were supplemented by raising livestock (mainly chicken), hunting, fishing, and the collection of non-timber forest products, including wild lychee (Litchi chinensis), kuy (Willughbeia edulis), honey, mushroom, romdul (Melodorum ruticosum), and phnhieve (Baccaurea ramiflora). Since 2010, some villagers reported once cashew nut farming became a dominant practice in the commune, rotational farming practices were no longer possible since farming areas were converted to permanent plots for cashew nut farms. Villagers also linked the impacts of cashew nut farming to the decreasing forest cover, reduction in water quantity and quality, changes in wildlife diversity, and the disappearance of non-timber forest products (Figure 5). However, some studies argue the introduction of the cashew nut plantation could help to improve soil erosion and carbon storage compared to lands under continual cultivation and tilling. In terms of soil fertility and erosion, further arguments indicate that cashew farming is preferable over cassava farming because it does not require seasonal ploughing. Additionally, cashew trees produce cashew apples and provide habitats and sources of food for the local biodiversity. Furthermore, many studies conclude cashew trees would contribute to the sequestration of greenhouse gases and increase forest cover of a particular site (Arulselvi, 2011; Malhotra, 2017). Such arguments may be true for deforested, degraded, and non-protected areas, but Phnom Kulen National Park is an exception. Cashew nut farming expansion has been identified as driver of deforestation and forest land conversion at the park for the last 15 years. Cashew trees were not introduced to the PNKP for those potential restoration benefits.

Except Preah Ang Thom, the other 8 villages share similar experiences regarding change in livelihood options with different timings of cashew farming introduction. For example, cashew nut farming first started in Anlong Thom in the early 2005 and for Ta Han in 2010. The causes of livelihood changes and impacts on the environment (e.g. forest, water, and non-timber forest products) are very similar. In terms of process, the switch from subsistence/rotational farming often started with the introduction of cashew nut trees within rice fields. Once the rice is harvested, to not create competition for the cashew nut trees, the trees were left to grow, and no rice was re-planted. This transformed rice fields into permanent cashew nut farms. Villagers had to find other areas to farm rice and simultaneously cashew nut. As a result, the number of cashew nut farms has increased exponentially within the PKNP, resulting in villagers abandoning rice farming. Some families, from communes in Svay Leu and Banteay Srey district, are now farming at fields illegally claimed at the bottom of the mountain.



Figure 5: Causes and effects of the cashew nut plantation and environmental impacts at PKNP

In the lower part of the PKNP very few flooded areas for rice fields exist. Some are located northwest of Svay Leu, others in the central part of the park, particularly to the north, northwest and west of Phnom Hop and to the north and the west of Kbal Spean. An increasing number of large mango and cassava plantations have been planted along the lower course of Siem Reap River and along the National Road 67 (NR67), within PKNP. The Siem Reap River and the O'Russey River course are excluded from the park boundaries.

Recently, the primary source of income for villagers at the PKNP is cashew nut farming. The harvesting period of cashew nut is from March and April. A few middlemen from PKNP villages centralise the production and selling to a wholesaler in the Siem Reap city. Farmers sell cashew nuts at a price of 4,000 to 8,000 riels (USD 1 to USD 2) per kg. A plot is approximately one hectare and can produce about 500 kg to 1 ton. In 2016, herbicides were introduced to PKNP and has become a critical problem for watershed and soil. Most farmers in PKNP with cashew plantations face the following constraints:

- Limited knowledge of crop practices, especially around excessive use of herbicides
- Limited knowledge of post-harvest handling, leading to price decreases during peak production
- Market price volatility depending on wholesalers from Thailand and Vietnam

## 3. Other livelihood activities

Secondary to cashew nut faming, sources of income across the eight villages include: selling products from their homes, vegetable farming, raising livestock (pig and chicken), farming rice and other crops (banana, corn, taro), providing homestay services, and harvesting in-season non-timber forest products (Chhin, 2019). However, all interviewees argued no other livelihood options generate the same amount of money as cashew nuts. While the concept of nature/ cultural-based tourism sounds attractive environmentally, it is not a lucrative option in terms of economic return for the villagers. Villagers stated they would not trade cashew nut farming for ecotourism, simply because ecotourism does not generate the same incomes as cashew nut farming. Villages involved in providing ecotourism services, such as homestay and trekking, reported the income received is minimal compared to cashew nut farming. For example, a family charges USD 20 per night for a group (between 4 to 10 people) to stay at their house and USD 4-5 per person for food. Families providing homestay services keeps 50% of the cost and the other 50% goes to the tour operator. Homestays are highly seasonal and, in general, a family hosts less than 10 groups per year.

Preah Ang Thom is the only village not depending on revenue from cashew nut farms as a main source of income. This is mainly due to the village's location. Preah Ang Thom is a main hub for tourism activities as the village is near the main waterfall, the thousand lingas, and the reclining Buddha. Also, residents of Preah Ang Thom do not have enough land areas for farming. Most villagers only have enough land to build houses. Therefore, the main income sources for the villagers include selling souvenirs and traditional medicines, operating food stalls and restaurants at the waterfall, photography, and motor taxi for tourists. A few families in this village still have cashew nut farms. However, labourers are hired to maintain the farms so they can also operate their business (e.g. selling souvenir at the waterfall). On average, villagers who sell products at the waterfall can make about USD 25 to USD 100 per day, while photography and motor-taxi makes between USD 10 and USD 25 per day.



# 4. Ecosystem management and livelihoods intervention projects

Cashew nut plantations have been dominating the natural forest since introduced into PKNP. To address issues arising from cashew nut farming, several projects have been implemented in PKNP with an overall aim to improve the ecosystem management and restoration of the natural habitat. The projects include:

 Enhancing Climate Change Resilience of Rural Communities Living in the Protected Areas of Cambodia (2013-2018). The project was funded by the Adaptation Fund and implemented by the United Nations Environment Programme (UNEP) in cooperation with MoE. The overall objective is to increase food supply and reduce soil erosion in Chiork Beungprey, Chom Thlork, Skor Mreach (all located in the Beung Per Wildlife Sanctuary, Preah Vihear province), Ronouk Khgeng (Phnom Prech Wildlife Sanctuary, Mondulkiri province) and Chop Tasok (PKNP, Siem Reap province) through three project components:

1) Conducting biophysical, ecological, and socioeconomic research to develop restoration protocols for eco-agriculture interventions

2) On-the-ground forest restoration (i.e. establish multi-use forests) and conservation agriculture interventions in the targeted sites

3) Institutional capacity, awareness raising, and up-scaling of eco-agriculture interventions.

In Chub Tasok, the project built a tree nursery with thousands of tree seedlings to be grown and planted in the forest. However, when the project ended in 2018 the nursery was no longer functioning (Figure 6).



Figure 6: Nursery in Chop Tasok, established by the project (Photo by Chhin 2022)

- 2. Enhancing natural resource conservation and local community livelihood in PKNP for REDD+ Action (2015-2017) was implemented by UNDP, MoE and Archaeology Development Fund (ADF) to plant trees in 188 ha in Popel Community Protected Area (CPA<sup>1</sup>). The project also supported law enforcement rangers to ensure successful forest replanting. The Popel CPA community gave up cashew nut farming to prohibit cashew nut farm expansion in CPA.
- 3. Sustainable conservation of watershed and improving livelihood of CPA in the top of Kulen Mountain (2013-2014) was funded by the UNDP GEF Small Grants Programme and implemented by ADF. The aim was to help CPA adapt to climate change and make villagers more aware of important forest and ecosystem services provided through stream water use. The project provided training courses to committee leaders and members of 5 CPAs on: forest management concepts, management planning, and conflict resolutions. Also, the project established water storage tanks, water-pipe distribution, and spillway canals in 4 villages with 150 household beneficiaries in the park.
- 4. Protection and rehabilitation of spring water sources (Toeuk Chup) on the top of Kulen Mountain landscape (2017-2018) project was funded by Sida through UNDP and implemented by ADF and Siem Reap Department of Environment (PDoE). The project replanted 6,250 trees in 25 ha at 5 CPAs and provided training to CPA committees and members on forest protection, problem solving and developmental planning.
- 5. Biodiversity Based Products (BBP) Project 2015-2019 (only implemented in late 2019) was funded by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) through the ASEAN Centre for Biodiversity (ACB). A gap analysis was conducted to obtain a baseline assessment of potential biodiversity-based products in PKNP's forest. The gap analysis was also used to determine the socioeconomic profile of the communities that were economically dependent on the natural resources of the forest lands of the park. The study identified 10 potential BBPs including honey, mushroom, bamboo, rattan, climbing vine (fern), Zingiberaceae (black ginger), Zingiberaceae (Prateal Reudongbat), wild lychee, Amomum sp. and Smilax glabra (Meum Thnam Chen). The top-three most lucrative BBPs species were: black ginger, bamboo sp, and honey. Black ginger (Kaempferia sparviflora) and climbing fern (Lygodium salicifolium) were selected as the BBPs to pilot within the two villages in PKNP, Anlong Thom and Thmey. The project aimed to indicate the potential of BBPs, black ginger and climbing fern, as commodities for socioeconomic and ecological value chain development in PKNP. The short period of project implementation allowed communities (product suppliers) and companies (product buyers) to form; however, the outbreak of COVID-19 broke the contracts and diminished the market for products.

<sup>&</sup>lt;sup>1</sup> CPA is a part of sustainable use zone of a national park or protected area that the Ministry of Environment has the authority to allocate to communities to manage according to the Protected Area Law (2008), Article 25.

Black ginger (Prateal Thloeun Chhke in Khmer) (K. parviflora), a terrestrial species with medicinal rhizome, can be preserved underground for several months without rotting. The rhizomes grow new shoots 2-3 weeks after the ground becomes wet from rain or manual watering. Leaves and flowers are usually produced simultaneously. Naturally, growth occurs between April and May and the rhizomes begin to develop throughout the rainy season from April to November. Vegetative part (leaves) die in November and December, leaving only rhizomes under the ground. Therefore, black ginger is usually planted between April and May. If the plant is cultivated late in the rainy season, the chance for a rhizome to develop is short, which impacts the yield. Black ginger grows well in open areas or sparsely shady areas with 60% of light penetrating to the ground. For this reason, black ginger is recommended for agroforestry, especially for integration in existing cashew nut farms. Farmers and local traders report one clump of the plant normally produces 0.15 kg and up to 0.25-0.5 kg if planted in good conditions (fertile soils and full light or partial shade) and enough care. This species is known to be grown in Thailand, Myanmar, India (Assam & Nagaland), Bhutan, South China, Malaysia and Laos. An old woman who lives at the Anlong Thom village reported this species has been planted since her parent's generation at this village but did not know the origin. They planted in small quantity (5-10 clumps) and shared with their neighbour but the use of the species is not known. Based on average yield of 5 kg per 1 kg of rhizome seed, 50 kg of rhizome is produced. On a basis of USD 3.65 per kg of rhizome in 2017, farmers are able to earn USD 75 per 10 kg of rhizome seed cultivation. The yield of rhizome can reach up to 10 kg per 1 kg of rhizome seed if planted in fertile soil and well cared for. If so, the maximum income can increase to USD 365. The net profit after the cost of seeds and labour (USD 110) is USD 255. The BBP project helped form contracts between the villagers and the buyers. However, the COVID-19 pandemic disturbed the contracts and there is no more market demand for this product.



Black ginger is planted under the cashew nut plantation in PKNP (Photo by Chhin 2022)

Climbing fern (Voir Lelor in Khmer) (*L. salicifolium*) is a clumping fern species and grows nearby springs, low-lying areas, and hill slopes. The plant grows in the margin of the forest or in open areas, where the ground receives enough sunlight. Climbing fern is utilised in ornament baskets, handbags, and produces many other types of souvenir products. A similar species, locally known as "Yan Lipao" in Thailand, has been used to weave baskets for over 100 years. In PKNP, stems of *L. salicifolium* are mainly collected and sold to a trader located at the Preah Ang Thom tourism site. The trader resells the stems to a main trader or wholesaler located in Khvien village, Kok Chork commune, in the west of the Angkor Toch. The main trader sells the stems to souvenir processors in the villages of Kok Chork commune, Krong Siem Reap, Siem Reap province. On average, each primary collector can earn USD 2.74 per day for a gross income or USD 1.76 for a net income per day. However, harvest of the vine for selling purposes has been suspended since 2019 until now because COVID-19 has stopped all tourist activities both in PKNP and in Siem Reap.



L. salicifolium grows along the stream and water sources of the park (Photo by Chhin 2022)

6. According to the Siem Reap Provincial Department of Agriculture Forestry and Fishery (DAFF), the project "A Tree for You" encouraged local people to begin growing vegetables, especially leafy greens and small tomatoes. The project also encouraged locals to raise chicken to supply markets in Siem Reap city. However, the number of households producing vegetables remains limited due to the lack of labour and investment capital. According to Siem Reap Provincial Department of Environment (PDoE), the ADF has collaborated with Agrisud International and local authorities in promoting livelihood programmes encouraging farmers to grow vegetables and raise livestock instead of planting new cashew trees which degrade the soil and pollute the water. However, farmers have faced many constraints while adopting sustainable agriculture:

- Water availability is the main challenge because vegetables need daily water for growing.
- Expensive inputs for fertiliser and pesticide
- Limited knowledge of crop practices to increase productivity, improve climate resilience, response to pests and diseases, and organic fertiliser or pesticide application.
- Ineffective farming agreements such as crop insurance or early warning systems
- Unstable prices and significantly lower returns compared with cashew nuts
- 7. "Improving Ecosystem Management for Sustainable Livelihoods in the Framework of Lancang-Mekong Cooperation" (2021-2022) funded by the UNEP-China Trust Fund and implemented by the UNEP through UNEP-International Ecosystem Management Partnership (UNEP-IEMP) in collaboration with MoE. The project piloted interventions on ecosystem management and improving livelihoods of local communities in PKNP. Based on consultations with local stakeholders, five interventions have been implemented. Local members of the CPA and villagers in the park were trained on intervention implementation. The interventions aim to supplement the needs of local people with the expectation to reduce pressure on the ecosystem and natural resources of the Phnom Kulen. The interventions include: organic vegetable farming, agroforestry (integration of black ginger under cashew nut plantations), free-range chicken farming, beekeeping, and bamboo for restoration and livelihoods.

#### Organic vegetable farming

Organic farming helps prevent the loss of topsoil, toxic runoff, water pollution, soil contamination, soil poisoning, death of insects, birds, critters and other beneficial soil organisms, eliminates pesticide, herbicide, and fungicide residues on food from synthetic fertilisers. Organic vegetables have strong, realistic flavours and higher vitamin and mineral contents. Organic farming increases soil organic matter which reduces erosion and conserves water. In PKNP, vegetables from organic farming will supplement villager families with organic food. The remaining vegetables will be sold to market and local communities can earn money to support their families. Organic farming reduces groundwater pollution by limiting the amount of synthetic fertilisers and pesticides entering the water systems. As the villagers replace chemicals with organic fertilisers (e.g. compost, animal manure, green manure), harm to the Siem Reap River will be reduced. This livelihood option requires farmers with a strong commitment to protect soil; however, observable impacts will take time.

#### Agroforestry (integration of black ginger under cashew nut plantations)

Ginger can be grown as an intercrop in cashew plantations. This is more suitable in steep slope areas with forest surroundings. More than 30 species of Zingiberaceae have been recorded from PKNP. However, black ginger is the common species being integrated within many cashew nut farms in PKNP as there are available markets and

technical support from the local NGO. Therefore, the cashew nut farm owner can obtain benefits from both cashew nut and gingers. This practice will benefit soil recycling.

#### Free-range chicken farming

In rural Cambodia, people's livelihoods are dependent on agriculture and the poverty incidence remains relatively high. Female-headed, poor, and landless households are the most vulnerable. More than half of all rural Cambodian households keep poultry. Local bird breeds are highest in demand for the local market, especially during festivals and celebrations. Poultry production is a profitable component of a diversified rural farming system. Typical rural households consume about 154 grams of poultry meat and 5 to 11 eggs per week on average. With this demand, poultry farming can be an important source of nutrition and cash revenue for low-income households. Primarily women accrue most of this income allowing money for household expenses, education, re-investments, repairs, medicines, clothes, shoes and additional grocery items at shops and markets. In Phnom Kulen, a popular tourist destination, chicken is a potential option for improving livelihoods as tourism often requires a lot of chicken for food supply. This option requires less effort in comparison with planting and taking care of cashew nut farms.

#### Beekeeping

Honey is highly nutritious and has medicinal benefits. Farmers at risk for crop loss, due to inconsistent rainfall, drought, or crop price crisis, can generate income from honey. Beekeeping products are sources of income and have the potential to enhance livelihood opportunities for small scale beekeepers. The practice of beekeeping can take place on small farms, as bees do not compete with livestock and crops for space. This project provides farmers with modern beehives, buckets, gloves, safety boots, smokers, and safety head covers. In terms of ecosystem services, bees facilitate pollination over great distances, increase the genetic diversity of plants, and stimulate the reproduction and resilience of native species in degraded ecosystems. For PKNP, bees play an important role in lychee and cashew nut pollination. Based on interviews, local communities recognised the role of bees in lychee, yield of those products would increase compared to yields without bees.

#### Bamboo for ecosystem restoration and livelihood improvement

Bamboo is a perennial crop providing year-round income and generating jobs for women and men. This plant is cheap, fast growing, and easy to cultivate. Bamboo grows on degraded land and reduces erosion and reliance on threatened forests and can be processed into a huge variety of products, including furniture, boats, kitchen utensils, incense sticks, charcoal, and footwear. Food and nutrition security for villager food supply and animal feed can be sourced from bamboo. Bamboo is earthquakeproof, has greater tensile strength than steel, and withstands compression better than concrete making bamboo valuable in construction. Used as a substitute for concrete, bamboo reduces emissions of greenhouse gases. For these reasons, bamboo is sometimes referred to as the "poor man's timber". The biological characteristic and growth habits of bamboo are an ideal economic investment utilized in many different manners with enormous potential for ecosystem restoration of degraded lands. Bamboo communities rapidly colonise disturbed lands due to their adaptability and nutrient conservation ability. Bamboo protects steep slopes, soils, water ways, prevents soil erosion, sequesters carbon, among many other ecosystem benefits. The impact of bamboo growth on the soil may be different on a species level and there is an expectation for large increases in the microbial biomass, particularly, in the rhizosphere zone. The important role of microbial biomass in enhancement of soil fertility has been evaluated in various terrestrial ecosystems and found to play crucial role in nitrogen and phosphorous dynamics. In PKNP, restoring degraded lands with bamboo will help local people with food options. Bamboo shoots can also serve as alternative family income through bamboo collections and ecosystem restoration by protecting steep slopes, soil erosion and carbon storing.

### 5. Women and social return

The main social return from cashew cultivation is employment for the actors involved in the cashew value chain including: the producers, middlemen, transporters, and hired labourers. As reported in the 2015 Agricultural Census, agriculture is an important source of employment for the large group of men and women (75% women) who are primarily engaged in subsistence production in small farms. The majority of rural Cambodian women work in agriculture on their own land or carry out unpaid agricultural work. Women farmers play a crucial role in the conversion of agricultural products into food and nutritional security for their households. Women are responsible for food production, selection and preparation, care and feeding of children, and are the key to food security for their households. Women are increasingly involved in commercially-oriented agricultural production especially in the horticulture value chain. In terms of cashew nut value chain at PKNP, women are central in the wholesale and retail marketing of harvested cashew nuts. They are involved as collectors and/or traders and are the principal retail sellers, working in markets at local, provincial, and national levels. For example, the biggest middleperson at PKNP is a woman.

However, there are gender-based constraints to land registration at PKNP. As a national protected area, accessing information about the land titling process is a challenge and is even more difficult for female-headed households to obtain paperwork proving their single status will not hinder their ability to register land. Women farmers increasingly supply local markets with traditional and high-value produce. However, compared to men, women producers at PKNP still face several disadvantages including lower mobility, lower level of literacy, and less access to training, market information, and productive resources. The lower financial literacy and higher risk related to travel safety for women compared to men are identified as the main gender gaps in the cashew nut value chain at PKNP.

Traditionally, the first stages of field cultivation are male-designated and the later stages are female-designated. Men generally perform land preparation tasks, while seedling preparation and weeding are commonly assigned to women. Other activities are generally shared tasks. These roles are presently changing with the adoption of mechanised farming and the migration of young men out of PKNP in search of other livelihood options. Therefore, women are increasingly more involved in all cashew nut farming tasks such as land preparation, irrigation, threshing, labour recruitment, farm management, and trading. The contribution from women in secondary crop farming, such as vegetables and raising livestock, is much greater than in the past. Grown and raised mainly in home gardens, these crops and livestock provide essential nutrients contributing to household food security while they wait for the cashew trees to mature. Therefore, local markets increasingly offer a good opportunities for women to earn through small-scale sales of vegetables and livestock.



## 6. Park management

PKNP is under the authority of the Siem Reap Provincial Department of Environment (PDoE) and the General Directorate of Administration for Nature Conservation and Protection (GDANCP), MoE. Five CPAs were demarcated in 2001 within the boundaries (Table 3 and Figure 6) (ADF, 2015). However, based on the environmental reform, which took place in 2015, the CPAs are mandated by General Directorate of Local Community (GDLC) and the development of biodiversity-related policies, framework, regulation, strategies and plans are under the jurisdiction of General Secretariat of the National Council for Sustainable Development (GSSD), MoE.

Village name	Number of families	Size (ha)					
Sangke Lak	63	77					
Ta Penh	99	82					
Anlong Thom	158	270					
Popel	59	188					
Khla Khmum	48	306					
Total	427	923					
	Village name Sangke Lak Ta Penh Anlong Thom Popel Khla Khmum Total	Village nameNumber of familiesSangke Lak63Ta Penh99Anlong Thom158Popel59Khla Khmum48Total427					

		<b>•</b>				
Table	3: The	Communit	v Protected	Areas	located in	PKNP
			,			

[Source: GDANCP, 2017]



Figure 6: The villages and Community Protected Areas (CPAs) in PKNP [Source: Ministry of Environment, 2018]

In 2016, MoE, with support from UNDP, developed the Phnom Kulen Management Programme (PKMP, 2018-2027). This programme focuses on protecting "the remaining forests, the conservation of cultural heritage sites, the enhancing and sustaining alternative livelihoods, and strengthening institutional capacity and collaboration to effectively manage the Park for future generations" (PKMP 2017). The programme was recently prioritised with an "Action Plan", determining the urgent actions to be undertaken. PKNP is a potential World Heritage site, registered by the Royal Government of Cambodia since 1992 on its tentative list. However, considering the current environmental state, UNESCO considers PKNP could only be registered as a cultural property because of the existing links (historical and geographical) as an extension to the Angkor World Heritage site.

The Phnom Kulen Management Programme consists of four Strategic Programme Areas (SPAs), as follows:

- SPA 1. Strengthen Natural/Cultural Resources Protection and Conservation
- SPA 2. Expand Community Participation and Benefits
- SPA 3. Strengthen Institutional Capacity and Collaboration
- SPA 4. Secure Sustainable Financing for PKNP

Implementation of the PKNP Management Programme and Action Plan means the park is zoned according to the Protected Area Law 2008. Once zoning is completed, two options will contribute to the sustainable production of cashew nuts. The first option is limiting cashew farms to the Sustainable Use Zone and ensuring no new cashew farms are established

in the other three zones, particularly in areas of strategic or sensible water recharge. Law enforcement is an important tool for this option to work. The second option is to provide support to producers at PKNP, ensuring the cashew nut production cycle is economically, socially, and environmentally sustainable. A package of different financial and non-financial incentives supporting the transition to sustainable production and conservation practices will be provided to the community. Interviewees pinpointed the resources they need for this transition to happen: 1) technical trainings on cashew farm management; 2) access to credits to pay for inputs, improve farming, and develop small business enterprises for generating incomes not tied to cashews; and 3) access to timely, reliable and accessible market information. For both options, monitoring and enforcement are essential. The goals of the two options are to ensure the sustainable management of areas where cashew nuts are produced and to gradually divert farmers from converting forest areas into cashew farms by ensuring the immediate livelihood needs are not abruptly impacted.

# 7. Conclusion

At present PKNP plantation development has threatened the forest ecosystem and downstream water supply. Forest depletion has been caused by illegal logging and agricultural expansion and is especially attributed to cashew plantations in the Phnom Kulen Mountain area. Additionally, the Stung Siem Reap Watershed is suffering from diminishing quality and quantity of water resources due to sand excavations from river banks and forest depletion at midstream and upstream from Phnom Kulen. The local people living around Phnom Kulen cannot survive from conventional livelihood activities and as a result have started to expand agricultural lands, which affected the forest and watershed. Heavily forested areas in PKNP, especially the forest on the southern part of the plateau, have been lost to swidden agriculture and cashew nut plantations (Penny et al., 2014).

Several projects from governmental agencies and various NGOs have promoted alternative livelihoods to generate incomes for the local communities. The project objectives are mainly to propose alternatives to the illegal cashew nut cultivation. However, for relatively short-term projects, field observations show results are limited. Behaviour change in villagers requires a long period of time to transition from destructive agricultural practices to environmentally friendly activities. Follow-up activities are necessary. For example, animal farming provides the locals with opportunity for profits and food sources. However, in some cases when food sources are low, animals used for breeding (e.g. broiler breeders) may be used for consumption, thus potentially terminating future sources of profit and food. Therefore, long-term follow-ups are required to achieve minimum success and includes, providing materials, technical assistance, training, and facilitating access to the market for the small producers.

The second major issue is the ability for farmers to compete with their cashew nut production. The net income from cashew nuts is very significant for the livelihood of PKNP villagers. On average, each household farms a minimum of 2 hectares per family. Thus, proposing less profitable options requiring more care and longer period to yield revenues than cashew nut farming is challenging. Only a few villagers see the advantages of investing time and energy in the proposed alternative options. However, most of the CPA members now are happy with

the new livelihood options. The results from the new livelihood options can now be analysed for the cost and benefits between cashew nut plantation and the revenue from the alternative livelihoods the project provided.

The inhabitants of PKNP have lived in the area for generations, making resettlement outside of the park complicated for the Cambodian government. As a result, people will continue to live within the park and the need for sustainable livelihood and ecosystem management is necessary. Development of new environmentally friendly agricultural practices, non-timber forest products and livelihood options is crucial. Long-term projects with regular follow-up of the activities has to be considered in developing alternative livelihood options, as short-term projects have shown limited results. Options for long-term projects, targeting a large population, creating local groups of producers, a Kulen brand label for products, and developing access to the Siem Reap market should be considered. Development of sustainable livelihood opportunities is only effective and successful if joined with law enforcement and a ban on any new cashew nut farms. Additionally, the zoning of the Sustainable and Community zones, as per the Protected Area Law 2008, and as recommended in the Phnom Kulen Management Programme and Action Plan should be implemented. Capacity building activities should also be considered on a long-term perspective with follow up and annual refreshers. They should also engage as much as possible with the local communities, with the aim for the communities to take ownership and see the importance of a preserved natural environment.



# 8. Potential ecosystem restoration within sustainable cashew farming

Cashew nut plantations are identified as the main driver of land conversion and deforestation at PKNP. Land managers should address this issue within PKNP. Forest cover in the park has decreased significantly over the past decade due to expansion of cashew farms. Therefore, two of the four SPAs in the Management Plan target management of cashew nut farms. For example, under the SPA 1, actions will be taken to manage expansion of cashew farms through law enforcement and survey of farm ownership. Specific activities for SPA 1, as outlined in the PKNP Action Plan, include: survey to identify cashew farm owners, confiscation of land with no owners, and transfer of land to the MoE for forest restoration. The plan will be extremely difficult to implement and would result in a reduction of the total area of cashew farms as most producers do not have titles to their farms. The Action Plan stated customary titles would be recognised. A majority of producers are outsiders who have "illegally" bought their cashew fields. As stated in SPA 1, all cashew farms would only be allowed in the Sustainable Use Zone once the zoning of PKNP is completed. In addition, to supplement SPA 1, under SPA 2, efforts will be made to progressively shift away from and reduce the villagers' dependence on cashew nut plantations by introducing new agro-forest methods to provide more diverse, profitable and environmentally friendly products.

### 9. References

- ADF. (2015). ADF Annual Progress Report for 2015, both for the archaeology and the development component. Archaeology and Development Foundation, Siem Reap, Cambodia https://www.adfkulen.org/uploads/4/4/0/9/44092499/report\_adf\_2015\_website. pdf
- Arulselvi, G. (2011). Analysis of Carbon Sequestration Pattern in Tropical Fruit Trees. International Journal of Computer Applications 30(7), 24–29.
- Ashwell, D. (1993). Zoning and Environmental Management Plan for Angkor. UNESCO, Phnom Penh, Cambodia
- Biodiversity Department. (2020). Baseline Maps and Land Use Management Plan for Payment for Ecosystem Services (PES) in Phnom Kulen National Park and Kbal Chhay Multiple Use Area. *The Department of Biodiversity, General secretariate of the National Council for Sustainable Development, Ministry of Environment,* Cambodia
- Bonheur, N., Khou, E. H. and Phy, K. (2008). Preliminary Study of Kulen National Park for Development of Botanical Garden. *Unpublished report to Ministry of Environment,* Royal Government of Cambodia, Phnom Penh, Cambodia
- Chevance, J. B., Evans, D., Hofer, N., Sakhoeun, S., Chhean, R. *et al.* (2019). Mahendraparvata: an early Angkor- period capital de fi ned through airborne laser scanning at Phnom Kulen. *Antiquity* 371 (93), 1303–1321. https://doi.org/10.15184/aqy.2019.133 1303
- Chhin, S. (2019). Case Studies on Sustainable Livelihoods in Rural Areas in Cambodia: Biodiversity Based Products for Ecosystem Restoration and Biodiversity Conservation in Phnom Kulen National Park, Siem Reap Province. UNEP-International Ecosystem Management Partnership, Beijing, China

Chim, K., Tunnicliffe, J., Shamseldin, A. Chan, K. et al. (2021). Identifying future climate change

and drought detection using CanESM2 in the upper Siem Reap River, Cambodia. *Dynamics of Atmospheres and Oceans, 94*, 101182. https://doi.org/10.1016/j.dynatmoce.2020.101182

- Chim, K., Tunnicliffe, J., Shamseldin, A. Y. Bun, H. *et al.* (2021). Assessment of land use and climate change effects on hydrology in the upper Siem Reap River and Angkor Temple Complex, Cambodia. *Environmental Development*, 39, 100615. https://doi.org/10.1016/ j.envdev.2021.100615
- GDANCP. (2017). Management Programme-Kulen Mountain National Park 2018-2027. General Directorate of Administration for Nature Conservation and Protection, Ministry of Environment, Phnom Penh, Cambodia
- Hayes, B., Mould, A., Khou, E. H., Hartmann, T., Hoa, K., Calame, T., Yon, T. *et al.* (2013).
  A Biodiversity Assessment of Phnom Kulen National Park, with Recommendations for Management. *Angkor Center for Conservation of Biodiversity*, Siem Reap, Cambodia
- Jacques, C. (1972). Étudesd'épigraphiecambodgienne:7.Surl'emplacementduroyaumed'Anindit apura,8.LacarrièredeJayavarmanII, *BEFEO59,p.193-205,205-220.*
- Malhotra, S. K. (2017). Horticultural crops and climate change: A review. *Indian Journal of Agricultural Sciences*, 87(1), 12–22.
- Marajh, L., and He, Y. (2022). Temperature Variation and Climate Resilience Action within a Changing Landscape. *Remote Sensing*, *14*(3), 701. https://doi.org/10.3390/rs14030701
- Ministry of Environment. (2017). Forest cover changes in National Park from 2006 to 2016. *Ministry of Environment,* Cambodia
- Oeurng, C. (2019). Assessment of water availability and sediment in Phnom Kulen National Park of Stung Siem Reap Watershed. *UNDP*, Cambodia
- Penny, D., Chevance, J. B., Tang, D., & De Greef, S. (2014). The environmental impact of Cambodia's ancient city of Mahendraparvata (Phnom Kulen). *PLoS ONE*, 9(1). https://doi. org/10.1371/journal.pone.0084252
- Vieira, D. L. M., Holl, K. D., & Peneireiro, F. M. (2009). Agro-Successional Restoration as a Strategy to Facilitate Tropical Forest Recovery. *Restoration Ecology*, *17*(4), 451–459. https://doi.org/10.1111/j.1526-100X.2009.00570.x

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