Valuation of Ecosystem Services in the Prek Tnoat Watershed

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Acronyms

BAU	Business as Usual
B	Baseflow [mm]l
ELC	Economic Land Concession
ELC	Economics of Land Degradation
ES	Ecosystem Services
FA	Forest Administration
FAO	Food and Agricultural Organization
FLEGT VPA	Forest Law Enforcement, Governance and Trade Voluntary Partnership Agreement
GEF	Global Environmental Facility
J	Joule
K	Potassium
L	Local Discharge
LDN	Land Degradation Neutrality
LWD	Lutheran World Development Agency
MAFF	Ministry of Agriculture, Forests and Fishery
MoE	Ministry of Environment
N	Nitrogen
NGO	Non-Governmental Organization
NSBAP	National Biodiversity Action Programme
P	Phoshporous
PA	Protected Areas
PES	Payments of Ecosystem Services
PT	Prek Tnoat
PTWS	Prek Tnoat Watershed
QF	Quickflow [mm]
REDD	Reduced Emissions from Deforestation and Degradation
SEM	Sustainable Ecosystem Management
UNCCD	United Nations Convention to Combat Desertification
USD	United States Dollar
USLE	Universal Soil Loess Equation – parameter used as measure for Erosion in t/ha

WHO	World Health Organization

EXECUTIVE SUMMARY

1. Prek Tnoat Watershed has undergone severe changes within the past decades. While the Watershed has mainly been covered by forests until the 90es, large scale deforestation and transformation into agricultural land started since then. Later, large parts of the forests were allocated to land concessionaires, mainly in the former broadleaved forests, 5 of them even in the sustainable management zones of PAs. These interventions have had severe impacts into the environmental regime of the watershed. Above all was the change of seasonal flows, pollution and sedimentation, which depleted with ongoing deforestation linearly the productivity of former agricultural production and fishery.
2. The models used to assess these changes were the seasonal flow model of INVEST, the Carbon model and the nutrient and sediment retention and delivery models. The input data were climate data from Wordclim 3.0, which averages climate data over 30 years, DEM and flow data from Hydrosheds, soil data from soilgrid250. Land cover data used were from ESA-CCI, Mekong Servir and from JICA. While these are hard data, the model inputs had also to be based on certain assumptions and standard data. Taking into account, that the latter one would not allow high certainty of results, it is nevertheless possible to draw certain conclusions possible future trends with regard to environmental services but not on absolute values.
3. Total values from provisioning services measured as net returns were for all sectors - agriculture, fishery and livestock – not higher than 280 and 360 USD/ha, aggregated for dry and wet season. Estimated ELC incomes were ranging between 600 up to 2000 USD and more, therefore about 2 to 5 times higher than the ones from smallholders.
4. The outcomes from the scenarios on seasonal water flow changes showed, that the Upper Prek Tnoat became increasingly wetter, accompanied by higher flood risks and destruction of irrigation infrastructure, while conversely the downstream areas became drier, which in particular affected food production and increased the demand for better and more irrigation infrastructure. It likely, that the ecosystem might reach a tipping point with further deforestation in the upstream areas, which will enhance baseflows in the downstream areas of the watershed and could even affect Pnom Penh after an initial phase of getting drier.
5. The impact of changes of the seasonal flow regime was exacerbated by increasing sedimentation loads and nutrient export particularly in the upstream areas, and high contamination rates through high chemical use in the plantations, which were assumed
6. Pollution impacts are moderate under small-scale agriculture, nevertheless will contaminate levels below standards for drinking water quality, while the impact of pollution could be about 8 times higher under ELCs due to higher inputs.
7. Sedimentation of rivers has negative mechanical impacts on the hydrological regime of river systems and hinders proper dam operation. Enhanced Fish mortality through eutrophication of lakes and changes of the food web of water bodies can also be attributed to the combined impacts of sedimentation and pollution.
8. In total these processes led to foregone losses of agriculture of 30% in 20 years and of 50% of fishery in 20 years for smallholders.
9. Accordingly, also the core zones of PAs adjacent to ELCs are exposed to high flood and pollution risks, and accompanying biodiversity loss about 30%, therefore losing a lot of the value which was intended to be conserved through their protected status. Many of these damages are irreversible.
10. The opportunity costs for foregone incomes from tourism, sustainable forest use, carbon fees and non-monetary values of biodiversity cannot be outweighed by additional incomes from ELCs. Calculating all environmental damages caused by ELCs, these outweigh the profits by ELCs especially in PAs, where the cost benefit ratio is 3:1.

11. While both – ELCs and smallholders are affected by environmental damages, it impacts smallholders much more severely, as they do not have financial buffers to deal with these damages.
12. Besides the negative impacts of ELCs on the total value of environmental services generated in the watershed, their presence has contributed to continuous land use conflicts and discontent regarding the increasing inequity of option values which could be generated in the areas appropriated by ELCs, particularly, since this is not shared in a way that allows future and better development for smallholders, who are kept in poverty traps.
13. PES is an important means to trigger activities which maintain and improve the environmental conditions upstreams, but there is the danger that also PES can become poverty traps, or will not fulfil their goal of behavioural change, if they are kept too low and do not fully cover opportunity costs. IF PES are not aligned with sound land titles, property rights and a pro-poor design, there is a threat that they will not lead out of poverty but are instead appropriated by the richer and more powerful groups.

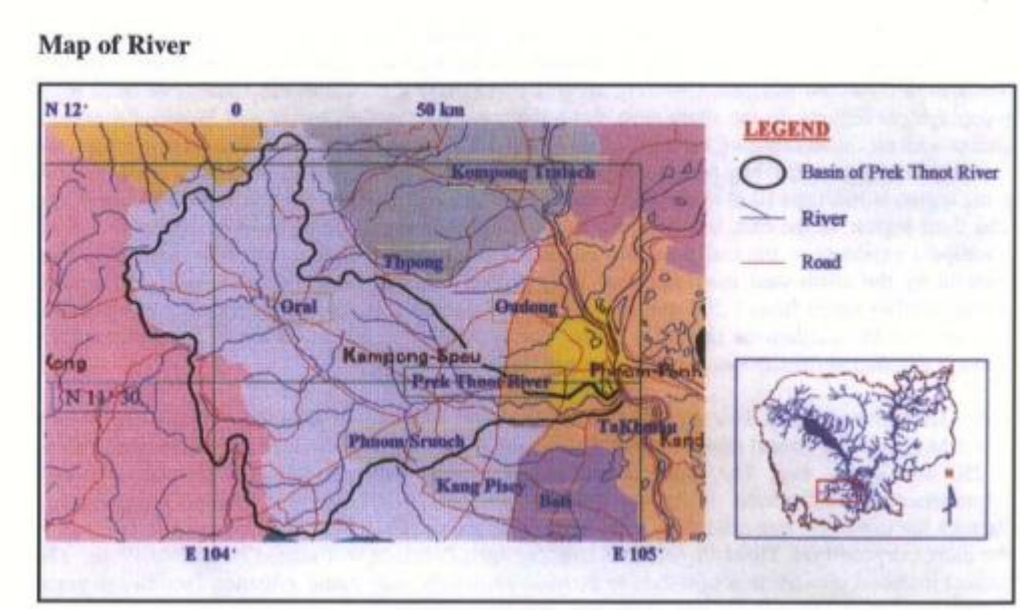
I. INTRODUCTORY PART

1. INTRODUCTION

1.1. CHARACTERISTICS OF THE PREK TNOAT WATERSHED

The Prek Tnoat Watershed is part of the Lower Mekong Basin and covers around 70% of the province Kampong Speu. Its sources emerge in the Western parts of the Cardamom mountain which has an extent of maximally 100 – 200 km with many small sub-watersheds.

Figure 1 Prek Tnoat Watershed (JICA)



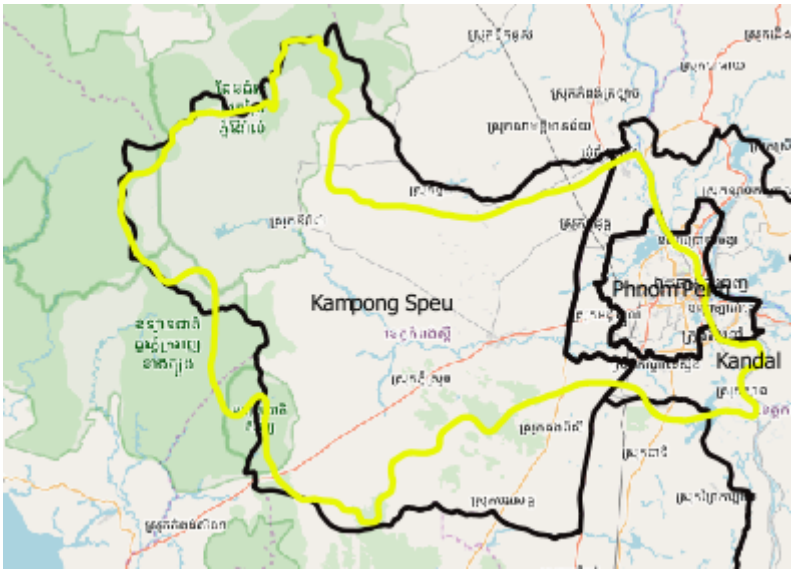
Source: (JICA 2008)

This part has been widely covered by forests, which have mainly been used for harvesting of forest products by communities. However, gradually more and more land was commissioned to ELCs, which currently cover an extent of 44,000 ha (MAFF 2018). The transition zone of the basin as well as the flood plain have an almost flat terrain, therefore draining very slowly into the Mekong while continuously widening its bed towards the Mekong Delta. These areas belong to the major paddy cultivation areas in Cambodia with increasing population density towards Pnom Penh. Currently crop production is low and unstable, with some farmers in the basin not even able to cover their own consumption of rice (JICA 2008) .

The climate is humid, characterized by strong rains, with highly erosive forces. The climate is governed by a regular monsoon regime from May to October, in which the Mekong discharge rises from its lowest value at the end of March, just above 1,000 cubic meters per second, until its maximum around September – October of 12,000 cubic meters per second (MRC, 2009) or even 45,000 cubic meters per second at Phnom Penh (De Bruijn, 2005). However, this situation is highly variable (Imhoff 2016), with many years of disastrous floods, such as 2000, 2011 and 2013, while within the Prek Tnoat Watershed there were 9 minor floods recorded by MRC (MRC 2014).

Kampong Speu is considered as a hotspot of environmental degradation in the NAP for the UNCCD, and is facing more and more natural disasters and hazards, particularly floods. Kampong Speu is also one of the poorest provinces, and a province, where drinking water quality is among the lowest in Cambodia (CSES 2016).

Figure 2: Prek Tnoat Watershed (UNDP) over Province Boundaries



Prek Tnoat Watershed as defined in some studies ends with the boundaries of Kampong Speu, at the Western banks of the Mekong Delta, which is congruent with the Plateau-Mountain part with an extent of 622,932 ha. , The watershed boundaries used by UNDP end at the Eastern bank of the Mekong Delta and include besides most part of Kampong Speu also parts of the Plain zone, especially parts of Kandal, and Pnom Penh zone. This boundary of the enclosess an area of 666,389 ha, and here the total population is 538,907, with 102,633 households. Out of these ones the population in the remaining forest areas is 60,583, with 11,690 households. The population in the agricultural one is 479,224, with 90,943 households. The boundary of the Upper Watershed is hydrologically not clearly defined, but is in the following considered as being congruent with the forest communities. Although the focus of the study is on the Upper Prek Tnoat Watershed, the hydrological impacts reach further downstream into the floodplain, which has therefore also to be considered, if the values of the watershed are to be considered.

1.2. WHY VALUING ECOSYSTEM SERVICES

Land functions, which provide materials such as food, wood, water, fibre etc. and usually well regarded by economy. All these provisioning services rely on regulating and sustaining services, without which land productivity will collapse, such as water filtration, nutrient retention, climate and flood regulation, and taking care of the overall resilience of the ecosystem through biodiversity. These services are usually taken for granted without and until recently, there was no awareness in the global community, that they could end. Therefore, land users could exploit them without feeling that this could create costs – the so-called externalities. According to the findings of the Millennium Ecosystem Assessment (2004), the world has focussed on enhancing provisioning services on the costs of regulating and sustaining services (meaning protection of soils, biodiversity, water etc.). Table 1 lists the major types of ecosystem services.

The deterioration of especially regulating services has reduced the resilience of ecosystems and externalized costs into the future, so that it will become more and more difficult in future to maintain the same productivity in future, up to a possible total collapse of ecosystems. The reduced delivery of ecosystem services has negative impacts on all aspects of human well-being, such as health, security, general happiness etc, apart from negative

impacts on all aspects of human well-being. In the worst case, the impairment of ecosystem services can lead to a complete collapse of an ecosystem.

Table 1: Major Ecosystem Services in the Prek Tnoat Watershed

Type of Ecosystem Services	Examples	Entity which produces them
Cultural Service	Creation of spiritual Values, such as sacred groves, trees at pagodas, places for meditation and recreation Recreation values such as natural places for refreshment and recovery, tourism Inspiration for arts, such as songs, paintings, sculptures, literature	Human mind
Provisioning Services	Food, Fibre, Wood, Water, Biodiversity, Oxygen, Temperature ranges, in which life is possible and convenient	Agriculture, Forests, natural vegetation, Macro-, Meso- and Microfauna
Regulating Services	Filtering, purification, nutrient retention and delivery, erosion control, sediment retention, pest and disease control, climate regulation	Soils, vegetation, especially forests, pristine ecosystems,
Sustaining Services	Soil formation, formation of genetic material, overall resilience	Geological material, microorganisms, natural vegetation

This concern has called for a financial regime, which puts a price also on these formally costless “externalities”, with the intention, that increasing exploitation is also felt financially, to induce behavioural change, that will ensure, that ecosystems are better protected, and early enough, before they collapse. The valuing of these externalities can be virtual to influence policies in a way, that the increasing scarcity of ecosystem services is acknowledged and accounted for, or translated into real prices, which users have to pay to the providers of regulating ecosystem services. However, the economic price is frequently not the one which influences, or should influence policy decisions or payments for conservation, as it is frequently the non-monetary benefits, especially health and human life and survival, which have a higher value, but which is not monetized. Therefore, even where monetary values are assigned to ecosystem services, the non-monetary benefits should also be taken into account in the valuation process. Another problem is, that the land user groups who destroy ecosystem services, are not necessarily the same ones, who are actually affected by the damage, due to the different dependence of users to ecosystem services and their vulnerabilities to their absence. This applies for instance for large-scale landholders, as the economy of scale allows, to produce unsustainably, as reduced productivity might have lesser impact on a large landholder than on a smallholder.

1.3. PREVIOUS STUDIES ON ECOSYSTEM SERVICES IN CAMBODIA

Various studies have been conducted on the economic value of ecosystem services in Cambodia which have been reviewed during a Workshop in Pnom Penh in 2011 (see Annex I). Later also other important studies were added, mainly the one by Brander (2015), Rattanak (2014) and and Hun Sien (2014). All these studies have focussed on provisioning services mainly of forests and of protected areas with a focus on new services, which had conventionally not been accounted for until recently, such as carbon values or, biodiversity values through non-timber forest production and ecotourism. Studies which analyse the interaction of ecosystem services on larger

ecosystem levels are rather rare. The only one, which includes currently Cambodia is the ELD Asia report, which analysis the impact of forest cover on agricultural productivity through nutrient delivery. No other study has included regulating services, whose destruction will lead to a deep transformation of the whole ecosystem. The methods used in those were mainly based on detailed field research or, if consultancy reports, due to the possibility to acquire fast results, on benefit transfer methods aggregated to the land cover classes identified for Cambodia or selected areas.

While the current study, due to a lack of detailed input values in many cases, has also to rely on benefit transfer methods, it integrates also the results of local statistics to highlight the relations between different land users and the values they capture within the ecosystem. For this purpose, the study needs also in particular to take the specific geographical focus on the watershed, as for the identification of potential buyers and sellers of ecosystem services it needs to identify their locations. It is therefore necessary to analyse the local conditions as precisely as possible, as the different land users in the watershed have different sensitivities to costs and prices according to their economic power, which can be easily overlooked, if regional data area transferred.

Finally, it should be mentioned, that there are other studies on payments of ecosystem services available from UNDP, which include roadmaps for PES pilot programs in protected areas such as Siem Reap (Echeverria 2016) 2015), and also studies which introduce the basic requirements for PES (Chevance and Nguon 2017). This will therefore not be repeated here.

1.4. METHODOLOGY

There are different ways to value environmental services

- Direct use values – the benefits of using environmental resources as an input to production or as a consumption good, e.g., the use of forests for recreation or for the harvesting of medicinal plants (Gran-Grieg 2008. These are used for biodiversity and carbon values.

Other valuation methods are

- Indirect use values – the support and protection provided to economic activity and property by natural ecosystem functions, e.g., forests are thought to play a role in controlling sedimentation which in turn can affect drinking water quality, or hydropower generation. This approach is applied for the valuation of seasonal water flows, sediment retention and nutrient retention and cycling.
- Option values – these refer to uses of environmental resources which might be possible in the future, particularly as more information becomes available for example about the medicinal uses of certain plant species. They are especially relevant where loss of biodiversity is considered irreversible. It is applied for the biodiversity valuation and also for the calculation of opportunity costs for all other services.
- Non-use values – intangible benefits derived from the mere existence of environmental resources or quality. What distinguishes non-use values from recreational value is that people can hold these values for a site, even if they have no intention, or chance, of visiting it. (Gran-Grieg et al. 2008).

The Total Economic Value of an ecosystem is the sum of the direct use values, indirect use values, option values and non-use values, but double counting has to be avoided. Therefore, if values of overlapping or interrelated activities are determined, or similar activities are valued by different methods, the most relevant value has to be determined, which is used for calculating of the aggregated environmental costs (Gran-Grieg et al. 2008).

The introduction of valuing ecosystem services had a certain purpose: to show that certain activities which create short-term profits, such as industrial agriculture and extraction of natural resources is not as profitable as it on the first glance seems to be. It implies therefore the hypothesis, that more environmentally friendly management would be more profitable than more exploitative practices. As there are usually different prices possible for valuing ecosystem services, in case there are different options for pricing, according to good scientific practices

those prices are used, which would be against the working hypothesis, meaning lowest price levels for environmental services, highest prices for extractive practices.

1.5. INPUT DATA

For the assessment of the value of provisioning services, the study relies deeply on the annual economic survey conducted by the Ministry of Planning of the Kingdom of Cambodia (CSES) since 2009. The data sets which could be publicly downloaded, covered the years 1997 2004, 2009,2010,2013-2016. The methodology of data collection, summary and interpretation had changed over time, therefore, not all the data sets from those years could be used. Therefore, for regression analyses, there were usually no more than 3 years of the full necessary data sets available, to be able to assess future trends. Therefore, the majority of the data extrapolated here is not statistically significant. Aggregation to sub-national level started only from 2009, but only to the Plateau-Mountain region, not to Kampong Speu or Prek Tnoat Watershed itself. Therefore, these data had to be disaggregated again to the Prek Tnoat Watershed according to the proportion of each land use system practiced in the Prek Tnoat Watershed. This proportion was calculated from raster data, both from ESA-CCI products which are used by IPCC and cover timelines back to 1992, and from Mekong Servir products, which cover the years 2012-2016, verified by vector data provided by JICA. A data gap which might hamper accurate disaggregate is the lack of data on household numbers in the watershed, as these are not provided in the data of the village locations. To assess the number of households in Prek Tnoat, the total land area was multiplied with 1,066, as the average land area per household is 0,938. This is probably the weakest figure in the following computations for aggregating the values of the Prek Tnoat Watershed, therefore, for comparison, always the individual data per household or per ha, and the aggregated data for the Plateau-Mountain region are also introduced. Further statistical data were obtained from FAOSTAT, in particular the type and quantity of input uses, and of prices. However, FAOSTAT data are aggregated to national level, therefore the disaggregation to the watershed area might lead to inaccurate results

The CSES statistics do not contain data on ELCs. But MAFF provided data on the area and crops cultivated by ELCs separately, therefore, also in combination with FAOSTAT data and raster data the values generated by ELCs could be assessed. Also commercial timber sales were not covered by the CSES data, these were assessed from the raster data mentioned above, valued according to studies by Halperin (2014) and prices, which were calculated from FAOSTAT production area and economic output areas. Many yield data or prices, however, were also not available by FAOSTAT, therefore the global yield map was consulted, and for the prices partly individual studies.

The land use data themselves were GIS products, which served also as input data for the INVEST model to calculate regulating services. The land use data are discussed in detail in the Annex.

For the conversion of Cambodian Riel into USD the annual conversion rate was used, as listed in Annex 1, which turned out to be quite stable. For the calculation of the net present value a discount rate of 5% as indicated by FAOSTAT as to be applied for Cambodia was used.

2. DRIVERS AND UNDERLYING CAUSES

To prevent or revert the degradation of ecosystem services through certain instruments such as payments of ecosystem services, requires also to address drivers and underlying causes.

2.1. Drivers

In a most recent, but coarse study (10km pixels) Curtis et al. (2018) have shown the different user groups which contributed to deforestation or degradation of forests: the majority of the land area has been deforested by small-scale agriculture, forest use has a second rank, however, led rather to degradation than to conversion of the whole ecosystem. Industrial agricultural commodity production is the third important driver. However, the report on concessions in Cambodia shows, that there have been certain temporal dynamics which changed the

significance of drives to deforestation and forest degradation from smaller landholders to large-scale agricultural clearances over time: From 1997 to 2002, deforestation in Cambodia was associated with smallholder agricultural encroachment along the boundaries between extensive forest and non-forest landscapes. Forest degradation was occurring in nearby portions of these extensive forest landscapes (IFSR 20049).

The report emphasizes, that this form of deforestation appears relatively limited today in comparison to large-scale agro-industrial plantations, which encroached on forest lands since mid-2004. According to the report, by 2013, virtually all forest clearance was associated with ELCs though clearance extends beyond ELC boundaries in some areas. Total forest land in Cambodia was 9,457,000 ha in the year 200, 735,387 ha of land was subject to land deals between 2000 – 2016. With regard to the SDGs on enhanced food security and poverty reduction there are still gaps in all land user groups. Small-scale rice farmers are hardly able to cover their subsistence level throughout the year, mainly due to a lack of financial or technical capacities. Foreign investors who were called to fill the prevailing gaps of financial capacities for investments, did not meet the expectations. Apparently, the contribution of ELCs to poverty reduction and food security, was considered as low by the Asian development bank. “Expectations on poverty reduction food security through foreign investors were apparently not met.” (ADB 2014).

2.2. Underlying Causes

Underlying causes can be identified in the current political and economic frameworks, which up to now do not give sufficient incentives for sustainable land, especially forest management, to the detriment of the income situation of smallholders, and even of the government itself. In particular, the current price regime does not cover the social costs of environmental services, meaning the costs which would occur, if those environmental services would not be there. For instance, it has been frequently mentioned, that carbon prices are much to low to reflect the real social costs of climate change, which at the end could even destroy the planet.

Lack of Capacity

There are currently no capacities for spatial management, therefore usually land areas allocated to buyers cannot be matched with protected areas, which was indicated as a reason, why partially forest in Protected Areas was sold. Even community management committees requested a GPS, to be able to control the area allocated to them as a community forest.

Corruption

Corruption is a special case of distorted price regime. Cambodia is now perceived as the most corrupt country in the Association of South East Asian Nation (ASEAN) (Parameswaran 2016). Corruption distorts economic incentives in a way, destructive environmental actions become more profitable for the few involved into corruption than benefit from the conservation of resources for many.

For instance Transparency International identified more than 50 cases of bribery of public officials, corruption in the procurement process and lax law enforcement, that enabled issues such as land grabbing, illegal logging, and mining, causing extensive damage to the environment and valuable natural resources are economically more profitable for a few than their conservation for many (TI 2017).

Intransparency

The Cambodian legislation provides a solid fundament for legal protection of ecosystem services, and holds any person responsible, who does not observe it. The legislation calls also for full transparency in any cases of impairments to ecosystem services, nevertheless, there is a point of contention in the rule, that forest concessions require the approval of only three government officials: the two Prime Ministers and the Minister of Agriculture. Therefore, the lower levels are frequently not informed, whose request for agricultural land has

been approved and which not. Also during the field visit, even local officials reported that they are frequently not aware, which parts of forests are opened to concessionaires, as these decisions are made only on the upper administrational levels.

Lack of Law Enforcement

Lack of law enforcement is the major driver to most of the degradation of ecosystem services. Although the use of hazardous pesticides has been banned already in 2012, import is still continuing, and according to information collected during the field visits, small-scale farmers are usually too uninformed to discriminate chemicals which are hazardous and which are not, while the use of chemicals by ELCs is widely intransparent. Although it can be confirmed that hazardous pesticide imports were reduced from a value of 570.000 thousand USD in 2007 and even 2414.000 thousand in 2010, still hazardous pesticides were imported to an amount of 3252.554 thousand USD in 2015, and to 27792.194 USD in 2016.

It is clear, that a lack of law enforcement leads more or less to unrestricted forest exploitation. This has apparently to do with an in parallel ongoing demoralization. For instance, both local officials as well as community members, told frankly during the community interviews, that they originally were volunteering in initiatives to conserve forests, when they saw, however, that each other members one by one involved, they also finally involved into wood extraction. It was also reported, that even conservation NGOs after a while involved into wood extraction business.

Better enforcement of law would therefore certainly be the first step to slow down these dynamics (see Chapter Roadmap).

The Economic System itself

However, as it will become clear at the end of this valuation, that also the underlying causes mentioned above are just the consequences of a neoliberal economic system, which has rewarded over decades activities which ignored the value of ecology and human well- and has exacerbated continuously inequity and inequality locally and worldwide.

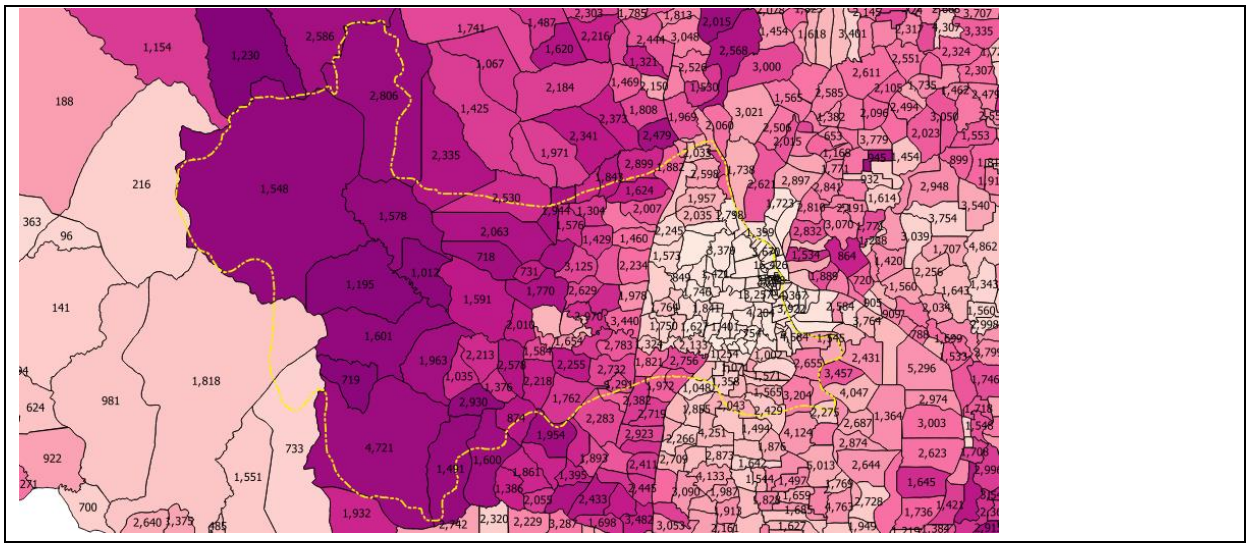
3. CONDITIONS AND TRENDS

The first part of the assignment according to the TOR is the mapping of conditions and trends of ecosystem services and their values. The value of provisioning services is based on the evaluation of products from satellite images as well as on the basis of statistics from CSES surveys. For the mapping of regulating services, a detailed methodology about the mapping of ecosystem services mainly based upon Land Cover maps and the INVEST models have already introduced. The models require various input files, which are annexed in Appendix II, such as physical and chemical soil conditions, a digital elevation model, climate data etc., which are annexed, but one input file is of special significance, as it is most important for the assessment of ecosystem services, which is Land Cover and Land Use. Within this, the most contested issue is the rate of deforestation. Here maps and statistics of different sources and for different timelines exist, which are all compiled, illustrated and discussed in Appendix III to give an overview as comprehensive as possible. Among them are also official governmental data, such as the maps used for the REDD report and the PRAIS report. For the purpose of conducting a meaningful analysis, which also allowed to consider the historical development of land use, mainly two data bases were used, which are the land cover data extracted from the Regional Land Cover Monitoring System (https://rlcms-servir.adpc.net/en/landcover/) which was developed by SERVIR-Mekong. The primitives were calculated from remote sensing indices which were made from yearly Landsat surface reflectance composites. The training data were collected by combining field information with high-resolution satellite imagery. These products date back until 2012, therefore, farer than the maps produced by JICA for the RCG for the REDD mechanisms, which date back only until 2014. The other data set is the ESA-CCI dataset, which has been commonly used by the IPCC, which dates back 1992. The data for the Prek Tnoat watershed were clipped from these raster files for the years 2016, 2012, 2000, and 1992. The maps from these four years were also used as input files for the respective models

3.1. BASIC DATA: DEMOGRAPHIC GROWTH AND LAND USE CHANGE

The estimated population number in total Cambodia increased from 1998 to 2015 from 11,438 thousand to 15,405 thousands, and the number of households increased from 2,162 thousand to 3,308 thousand in the same period, with an over-proportional increase of the urban population, so that the ration between urban to rural population increased from 18.6 to 29.8.

Figure 3: Number of Households per Commune



Source: opendevelopmentcambodia.net

Fig. 3 depicts the number of households per commume, which are also tabled in Annex II..

For the statistical assessments of household incomes and household contributions to individual ecosystem services in Chapter 4 and 5, the number of households, which are involved into the production of specific provisioning services, are important, as listed in Table 3.1.. Most households are involved into crop production with declining trends, while the number of households involved into fishery and forestry slightly increased, which might be due to the need for additional incomes under demographic growth and declining land area available per capita. The number of households involved into crop production for Prek Tnoat Watershed, irrigation and aquaculture were not separately estimated, as they were not relevant for the final valuation.

Table 2: Type of Provisioning Services by Number of Households which Generate them

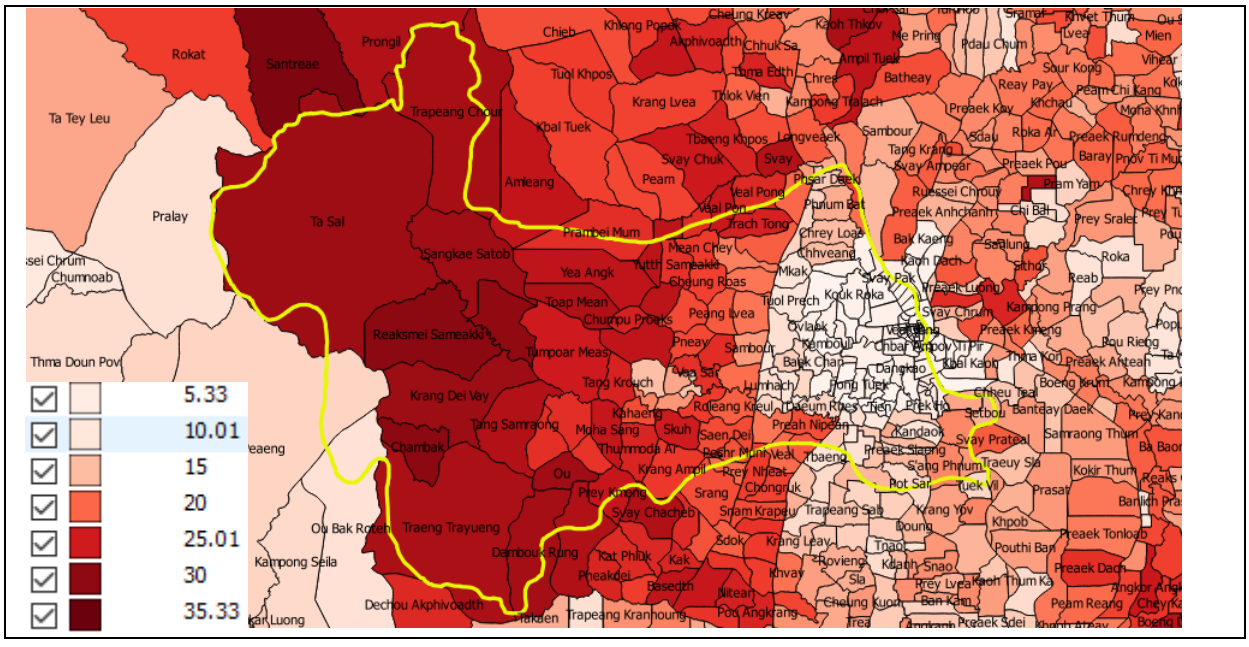
	Livestock			Fishery			Forestry		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
Kampong Speu	46,5124	43,307	49,786	37,3054	39,2832	43,3752	53,3324	59,9478	61,7892
Pnom Penh	1024	288	0192	416	16	256	48	384	0,0544
Plain	37,6996	38,989	39,1118	25,6038	28,6124	25,0512	48,3218	47,892	43,2256

Source: CSES surveys

POVERTY

Accordingly, poverty rate in the area is high, between 25 – 35% in the majority The local population faces even seasonal food and water deficits especially in the dry season (compare Fig. 4).

Figure 4 Poverty Incidence per Commune in Prek Tnoat Watershed



Source: (National Survey 2015)

Table 3: Poverty Rates within the Major Forest Communes

Commune	Poverty Rate
Chambak	30.14
Dambouk Rung	28,65
Krang Devay	28,94
Reaksmey Sameakki	30.15
TaSal	28.93
Traeng Trayoug	28,05
Trapeang Chour	28,47

(Source: National Survey 2015)

Poverty is highest in the Western / Upper part of the watershed, which coincides with forest communities, and in general is higher in the part of Kampong Speu than in Kandal, while poverty rates are lowest in Kampong Speu

Forest Communities are the poorest communities with poverty rates between 28 and slightly above 30, as Table 2.1. highlights, and communities become wealthier the closer they are towards the Mekong Delta. Up to 0.8 percent of households are involved in land conflicts, with highest incidences in the Plain with the highest rate of 0.8 %.

3.2. LAND TENURE AND LAND OWNERSHIP

The evolution of land use as reported in the statistical Census of Cambodia (2013) shows an increase of total arable land from 2.81 Millions of ha in 2013 4.50 Millions of ha. Within that, the proportion of permanent crops covered less than 10% in 2010, but increased to about 80% in 2013.

With this development it is clear, that the available area must have declined. ELD Asia (2017) reports a decline from 1,1 ha in 1990 to 0,5 ha in 2016 (ELD Asia 2014), indicating an increased pressure on land resources, both in forests as well as in agriculture.

The total cultivated area for agriculture increased in total Cambodia from 3,068 thousand ha in 2009 to 3,389 thousand ha in 2016, which is a rate of slightly more than 10%. Total agricultural land in the Plateau/Mountain zone increased to a higher extent than the country's average with a rate of about ca. 15% (compare Table 3.2.).

The corresponding agricultural area in Prek Tnoat was extrapolated from the statistics extracted from the raster files from ESA-CCI and Mekong Servir products with the SAGA tool.

3.2.2. HOUSEHOLDS PRACTICING AGRICULTURE AND AGRICULTURAL LAND PROPERTY DISTRIBUTION

The number of households practicing agriculture all over Cambodia increased to a higher rate than the total land area, from 2,119 thousand to 3,358 thousand ha, which is more than 30%, apparently as a consequence of demographic growth. The increase took place dominantly in the smallest category of land of less than 1 ha, where the number of households almost tripled from 2009 to 2014, while household numbers in the category of above 1 ha to above 1 ha decreased, indicating a sharply increasing land scarcity per capita and a slightly increasing inequity in land property. These data do not include ELCS. Accordingly, the available agricultural land area available per capita decreased from 1,1 ha to 0,5 ha ((ELD report Asia 2017).

Most of the land used by the local rural population is not purchased, but inherited. Few parts of land are rented in or rented out. There are usually not many women which have land properties, their proportion lies between 8 – 10 % (CSES 2014-2016). The survey does not indicate figures about purchased land, although selling of land seems to be an emerging practice for large parcels of 40 ha and many more. The price of land was indicated to be around 3000 USD, which is a little bit smaller than the price indicated by Brander (2015), who reported prices about 3600 USD as an average for total Cambodia. The distinction between purchased land and non-purchased land is important, as the price paid forces the land use into a certain minimum productivity, which should be around 460 USD annually per ha, as in theory the price land land should reflect the discounted stream of returns from its most productive/valuable use. They do not reflect forest values.

While there is no detailed information about the price of concessions, it can be assumed, that at least the price of concessions requires a similar level of agricultural productivity. There is no official information about the number of other private buyers of land who are not ELCs, which are apparently from urban areas and use agricultural land as an investment, but their number is increasing (Field visit 2018).

Land Property of ELCs

ELCs are not recorded in the CSES statistics, but data on land ownership by ELCs were obtained by MAFF. Table gives an overview over the land area occupied by ELCs and the major crops cultivated. The land property of the 20 ELCs listed is about 44,000 ha, therefore, equal to the land area that more than 44,000 smallholders own. According to statistics by opencambodiadevelopment.net, this area is about 20,000 ha larger, which might be due to certain changes which happened during different years. These data are listed in Annex I. Sugarcane covers most of the area occupied by ELCs, most of the other areas are cultivated by industrial wood crops. Also fruits, such as Mango and Cashew play a role, and there is also an industrial Cassava plantation.

Land Titles

Rural communities far from Kampong Speu do normally not have hard land titles, only certificates, while people, while private persons who purchased land from the government or ELCs usually have hard land titles (Field visit 2018). Communities do usually have no land titles for collaborative management, although this would be possible according to the Cambodian legislation (compare Chapter 8).

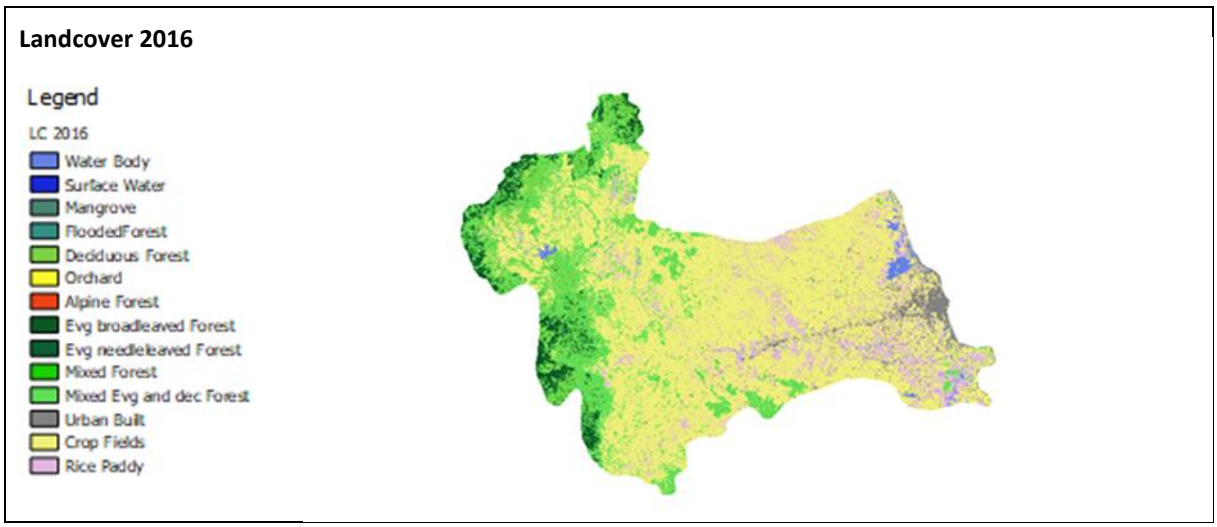
Values for provisioning services from forests and agriculture can directly be derived from the areas of these land cover types, which is why this parameter is discussed here in detail.

II. PROVISIONING SERVICES

4. PROVISIONING SERVICES

4.1. LAND COVER AND LAND USE CHANGE

Figure 5: Land Cover 2016



Land cover change is the most important to trigger for environmental change, and as it is human driven, it is also the most relevant driver which could be addressed for environmental improvement. Values for provisioning services from forests and agriculture can directly be derived from the areas of these land cover types, which is why this parameter is discussed here in detail.

The data show a declining trend of broadleaved forest which can be economically used, while fractions of degrading forest cover increase, and a slightly increasing trend also in agricultural land cover, and of agricultural mosaic land, which indicates, that swidden agriculture might be practiced there.

Fig. 6 and Table 4 display the major land cover changes in the major land cover groups in Prek Tnoat Watershed.

Figure 6 Summary of Land Cover Change in PTWS

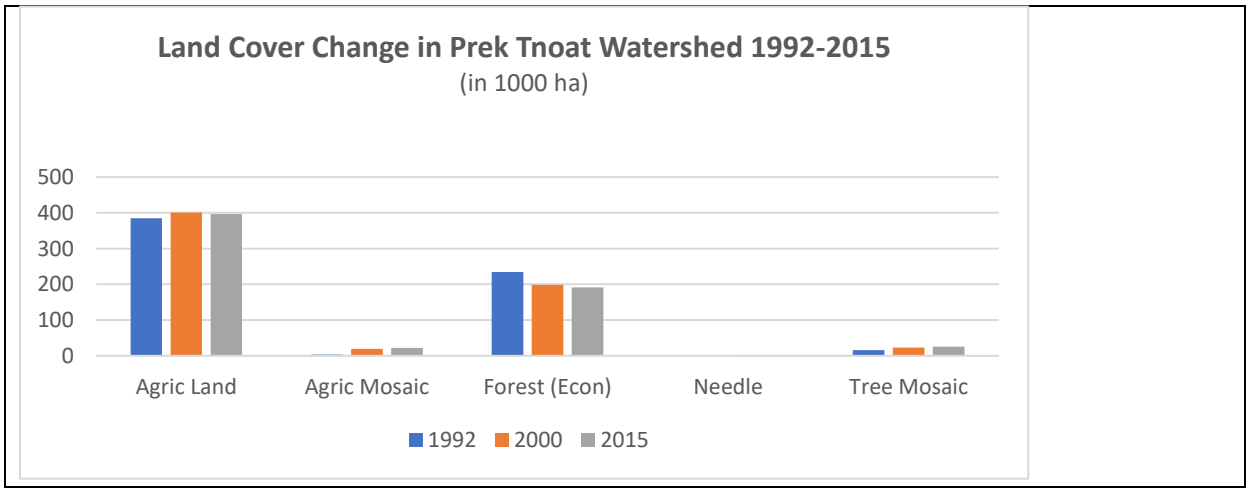


Table 4 Net Land Cover Change between 1992 and 2015

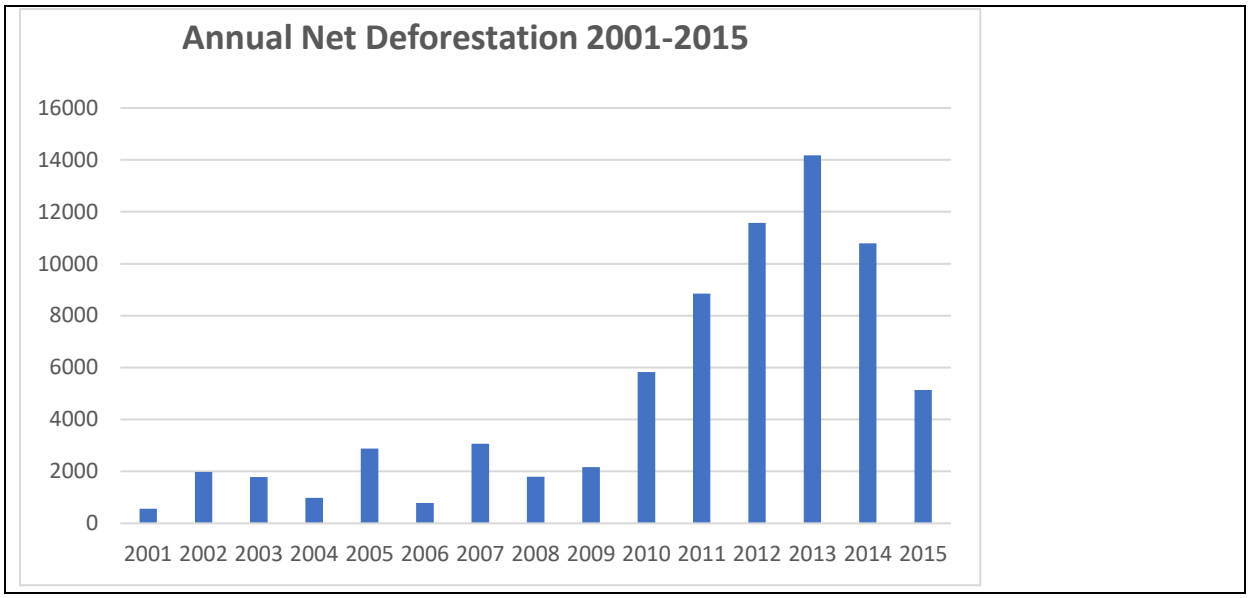
Land Cover (in 1000 ha)					
	Agricultural Land	**Agricultural Mosaic Land**	**Economic Forest Broadleaved, Evergreen and Deciduous**	**Needleleaved Forest**	**Tree Mosaic**
1992	385	3.15	234	1.7	15.46
2000	401	19	199	1.4	23.4
2015	397	22	191	1.4	26
Net Landcover Change in 1000 ha					
2000-1992	16	15.85	-35	-0.3	7.94
2015-2000	-4	3	-8	0	2.6
Net Change	**12**	**18.85**	**-43**	**-0.3**	**10.54**
1992-2015					
LC Net Changes in % between 1992 and 2015	**3.12**	**598.4**	**-18.38**	**-17.6**	**68.2**

Source: Statistical analysis of ESA-CCI and Mekong Servir products

The increasing rate in agricultural mosaic landscapes shows an ongoing encroachment of agricultural land into former forests, respectively, swidden agriculture. The increase in mosaic forests indicates that small-scale degradation happens there, respectively, that abandoned agricultural fields are recovered by forest vegetation.

The data indicate a net decline in economic forest land of absolutely 43,000 ha. while the total deforestation area is higher, as it does not count the area, where forest has regrown in the meantime. This net deforestation rate was calculated by Hansen (2018, Fig 7), which shows, that deforestation rates in the PTWS continuously increased from 2001 to 2015, with highest rates between 2012 and 2014. In total, it were 72,329 ha, actually 22,2 % of the forest cover which has been present in 2000, which had been cut inbetween according to Hansen (2017).

Figure 7 Annual Net Deforestation (Hansen 2017)

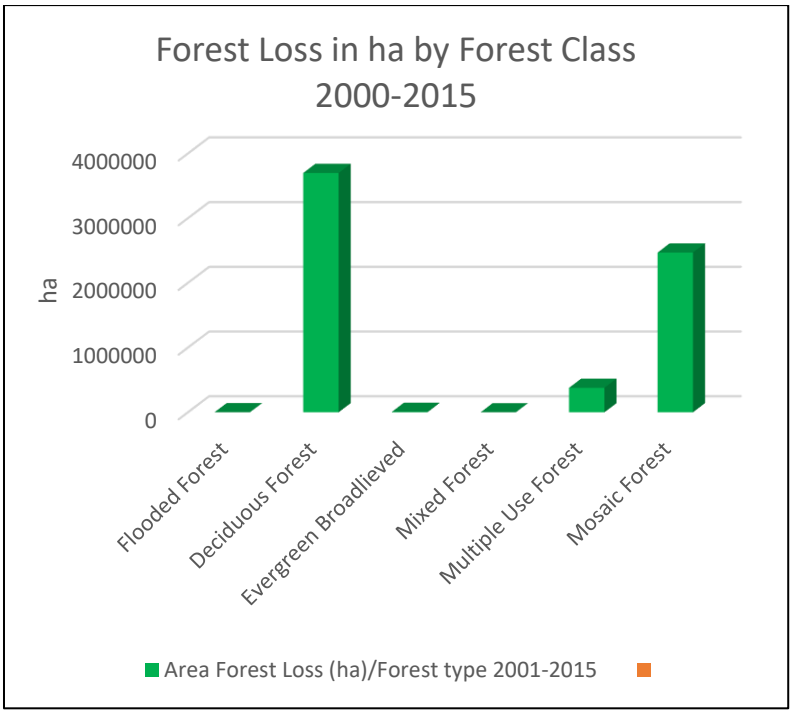


(Source: Calculated from Hansen 2017)

Conversion Timber Values Captured by ELCs

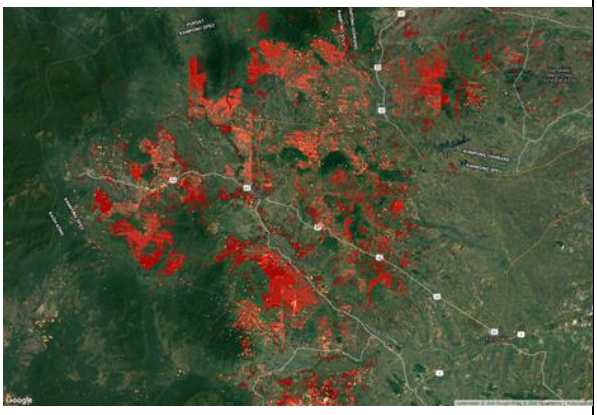
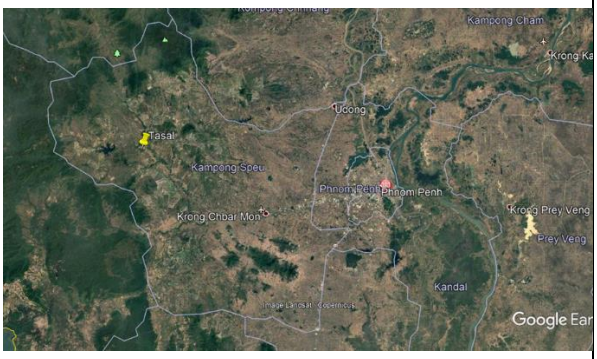
The Hansen data show, that most of the deforestation in the deciduous forest areas of Prek Tnoat were conducted in the areas, where ELCs have been established nowadays. As tracing back the Hansen data to the original forest classes in 1992 shows, it has been mostly forest from the deciduous evergreen class, hardly forest from the more valuable evergreen broad-leaved class. About 20% of the data traced back were crop land already in 1992 according to ESA-CCI data, therefore, there might be an inaccuracy of 20 % in the Hansen data.

Figure 8: Forest loss by Forest Class



To verify the accuracy of the Hansen data, the spatial distribution of deforestation according to Hansen was compared with current and historical Google Earth images, which confirms high congruency (Fig 9).

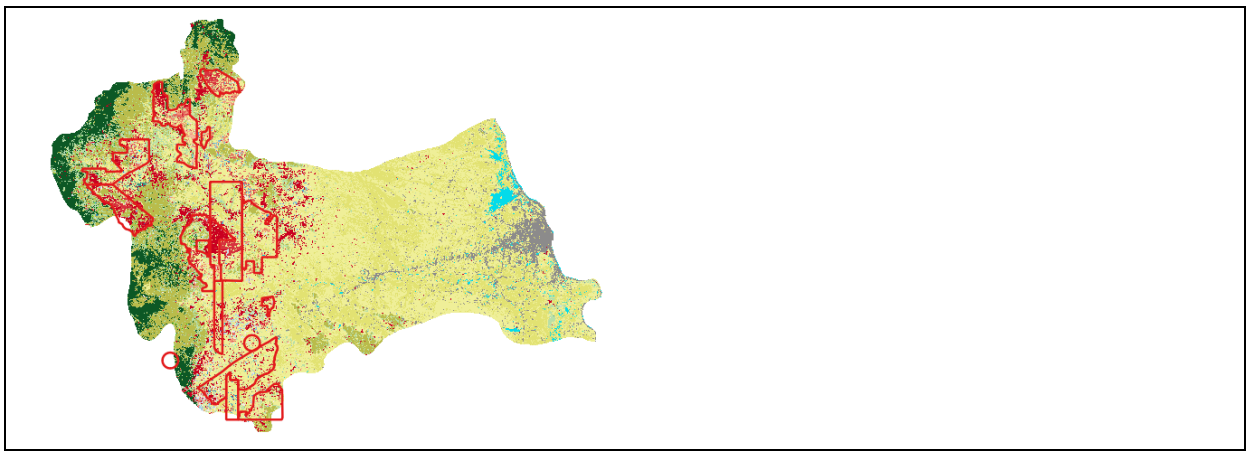
Figure 9: Spatial Representation of Tree cover Loss in Prek Tnoat Watershed 2000 - 2015

Tree Cover Loss acc. to Hansen (2017) over Google Earth Image of Prek Tnoat Watershed	Google Earth Image of Prek Tnoat Watershed only, 2018
	
Kampong Speu Province 2016 (Source: googleearth)	**Kampong Speu Province 1997 (Source: googleearth)**
	

Source: Calculated from Global Tree Loss Data (Hansen 2017)

Comparison with the ELC locations in the Prek Tnoat Watershed illustrate, that around 80% of this deforestation took place in areas, which are concessioned to ELCs, about 20% of them in Phnom Aural Wildlife sanctuary and Kirirom Park (Fig 10).

Figure 10: Deforestation since 2000 over ELCs and PAs



4.2. METHOD FOR THE CALCULATION OF USE VALUES (PROVISIONING SERVICES)

Watersheds are normally not congruent with administrative boundaries, therefore, the CSES surveys, which were conducted according to administrative / landscape boundaries, had to be interpolated according to the water shed.

This required to interpolate data from three zones: the Plateau-Mountain Zone for the part of the watershed which covers Kampong Speu, Pnom Penh and the Flood Plain for parts of Kandal.

The processing of the data included then the following steps:

- Determining the proportion of each zone in the Watershed with GIS geometric tools
- Determining the communes located in the watershed according to the National Survey (compare Annex II)
- Assessing the household numbers of the proportion of each zone
- Determining the income per household unit respective per land area for each land use activity and zone
- Extracting the proportion for each land use activity per zone
- Multiplying the household numbers of each zone with the proportion of each land use activity in each zone and the income per unit.
- Aggregating the incomes per unit over the households in the proportion of each zone to the watershed and aggregating these proportions

4.3. WOOD

Asssessment of Commercial Timber Values

Data on timber values could be extrapolated from a study by Halperin (2014), who related the type of forests in the Central Cardamom Mountains to the timber values. Higher production values correlate the with proportion of undegraded evergreen trees, while deciduous trees produce about 100 m3 lower values, and also timber values are reduced with increasing degradation.

Figure 11: Assessed commercial tree densities and timber values per ha

	Trees/ha	Timber m3/ha
Evergreen Forest Less Degraded	388	525
Evergreen Forest More Degraded	304	352
Deciduous Forest Less Degraded	259	335
Deciduous Forest More Degraded	195	278
Semi-Evergreen Less Degraded	345	321
Semi-Evergreen More Degraded	272	280

(Source: Halperin 2014)

Forests in strongly degraded conditions, as they occur in the removal of saw log sized trees greater than 30 cm dbh, can no more be used, for commercial timber production.

Fig. 12 maps the remaining commercial forest resources for the years 1992, 2000, and 2015. The decline has mainly happened in both important economic classes – broadleaved evergreen and broadleaved deciduous forests, however, as the major area was covered originally by broadleaved evergreen forests, the decline was greater here.

Figure 12 Wood Densities of the Commercially Valuable Forest Resources in the PTWS

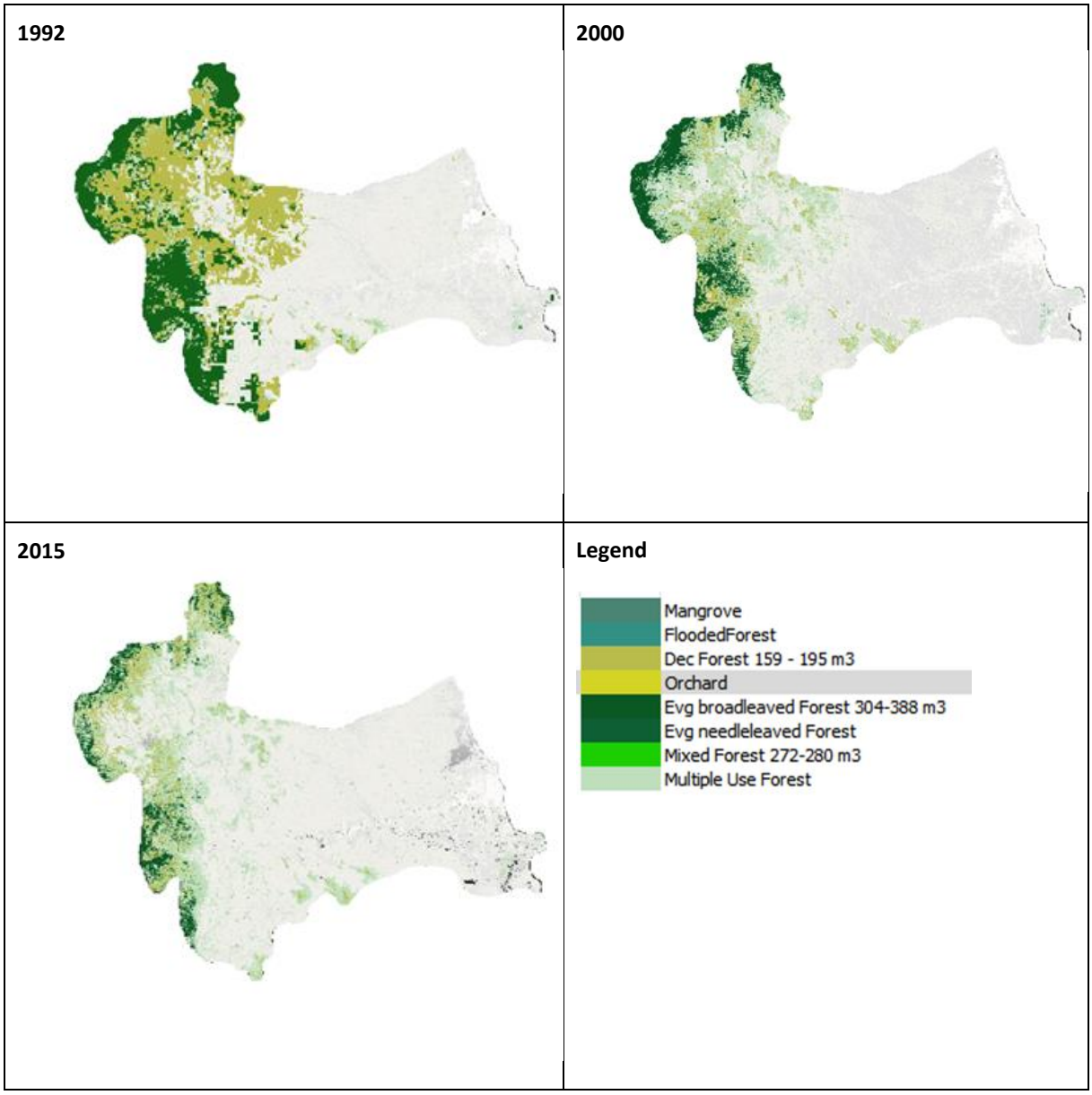


Table 5 shows the total wood mass in the economic forests over the period from 1992 to 2015. Corresponding to the overall change of forest cover, also the decline of commercial wood biomass has been around 10 times higher between 1992 to 2000 than between 2000 and 2015, and happened major in the evergreen forest class, while the deforestation in the deciduous class was higher between 2000 and 2015. The latter one is supported both by Hansen data and the ESA data, while Mekong Servir data do not reach that far back. However, Total Area the Hansen data show a higher deforestation rate of about 18460 ha than the comparison of net forest cover change of ESA-CCI data implies.

Table 5: Total Commercial Wood Biomass in 2000 and its Value

	Area [ha]	Total Wood biomass /ha [m3]		total biomass in 1000 [m3]		Total Value in USD/ha	
	ha	Min	Max	Min	max	Min	max

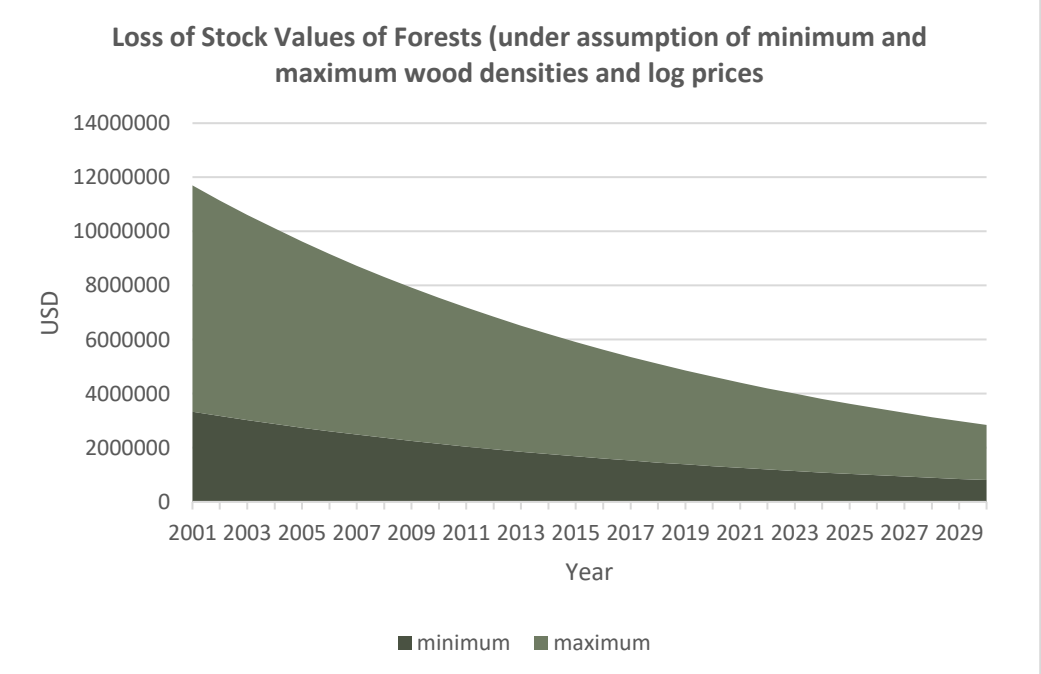
Deciduous broadleaved	114978	159	195	18281	22421	914075	1121035
Evg. Broadleaved	84398	304	388	25657	32746	12828496	32746424
Semi-deciduous and evergreen	23794	272	380	6472	9042	647197	18083440
Total	223170	n.a.	n.a.	50410	64209	**1,439E+10**	**35675803500**

To calculate lower and upper bound values of wood stocks, the lower and upper bound values of Table were used, and for average values the prices of 50, 100, and 500 USD were assumed as lower bound / m3 and of 50, 100, and 500 USD as upper bound prices. The calculated values for exported roundwood varied between 100 USD and 500 USD/m3. The price of 500 USD/m3 is lower than the export price for most valuable roundwood as calculated from FAOSTAT data, which would be 1000 USD/m3, which would be higher than prices of any other comparable assessments. The average m3 price for all commercial forest types is then between 285 and 555 USD/m3. The least valuable forests would be than around 20 000 USD/ha, which is the calculated as the average value of Cardamom forest by Sam and Soussan (2012).

For comparison, earlier of values of wood stock in Phnom Aural have based their assessment of stock values of forests on data of Malaysian meranti, which assumed that some luxury species, commended prices ranging between USD 280 andUS$400 per m3 for four luxury species in minimally processed form. Prices for Malaysian meranti log exports reached US$ 295/m3 in early 2007.

The price of the commercial wood was calculated based on FAOSTAT data from the relation of exported roundwood volumes to the gross output.

Figure 13 Decline of Values of Wood Stocks under BAU Conditions



4.2 FORESTRY VALUES OBTAINED BY SMALL-SCALE USERS

As the Upper Watershed is the part of the Plateau Mountain zone, which still has some forest resources, the average forestry income in the part of the PTWS which belongs to Kampong Speu has highest average incomes from forestry, which are nearly double than the incomes from forestry in the flood plain and triple to double of the incomes from Pnom Penh.

Table 6: Forestry Income by Communities per Household and Total in USD

	2014	2015	2016
Kampong Speu	333,59	296,43	266,55
Pnom Penh	96,07	120,02	153,06
Plain	154,51	89,66	140

Nevertheless, the gross income data collected by UNDP and the gross incomes assessed during the field visits for forest communities are substantially higher, with about 2000 USD annually for some forest communes (compare Annex 1). A study on gross incomes conducted by UNDP in Krang Devay has shown, that gross incomes per month were even around 288 USD/month, while costs were varying so much, that no reliable net incomes could be calculated (Kong 2018). This high difference might lie in the fact that average data were collected, and forestry incomes at the Eastern border of Kampong Speu were averaged with forestry incomes in the mountain areas. Indeed, multiplying the total number of households in the forest areas (22,690) by 2000 USD will lead to the similar figure of 23,380 thousand USD as the aggregated incomes calculated from CSES surveys, which is round 26,000 USD for instance for 2014. ,

For assessing the total incomes from forestry, two approaches were applied: one multiplied the higher incomes of the forestry communities with the household numbers of forestry communities, the other one multiplied the average incomes from the CSES studies with the number of households in Kampong Speu, which gained incomes from forestry and hunting.

Rotational charcoal production in the sustainable community forest project in Krang Devay supported by APFNET, was planning with incomes from charcoal production only in the value of 150 USD:

Im Kampong Speu Table 4.4. shows, that wood products contribute to the bulk of the income in the Mountain area/Plateau, with declining trends, while the income from non-wood products increases. Indeed, the value of non-wood products assumed almost the same value as the value of sawn logs, and covered the proportion of contribution to incomes in the group of all forestry products.

Table 7: Gross Incomes per ha from Different Forest Products in Kampong Speu

	Firewood	Charcoal	Logs	Total wood Products	Non-wood	Total
2014	13.8	50.8	18.1	32.0	7.5	39.5
2015	14.3	1.4	10.7	26.4	10.4	36.8
2016	15.3	2.5	11.8	29.6	10.8	40.4

Comparison with other Studies

The assessed incomes from non-timber forest production and overall incomes from forests by smallholders lie in the range of other studies, as Table 8 and 9 show.

Table 8: Results from other Studies in Cambodia

Province	USD/ha	Source
Ratanakiri, Chum Distric	139	Sara et al 2000
Kampong Thom, Pusat, Mondulkiri and Kratie	312	Kasper and Neth 2006
Ream N, Preah Sihanouk	274,5	De Lopez et al 2001
Ratanakiri	200	Bann, 2003
Phnom Kok CF, voensai district, Ratanakiri	78,9	Sapanarith et al, 2008
Preah Vihear, Kampong Thom, Mondulkiri % Stung Treng	302	Prom 2009
Phom Aural and Phnom Samkos WS	50	Grieg et al.,2008
Sources which include also Timber		
Central Cardamom (includes timber)	1,099	Soussan 2010
Koh Kong province (includes timber)	1050	Bann 1997

On an average this is 299,74 USD per ha and year, ranging between 50 to 1050 USD, which included also the income from timber product harvesting.

4.3. FORESTRY VALUES WHICH CAN BE CREATED UNDER SUSTAINABLE EXTRACTION RATES.

The rule-of thumb sustainable extraction rate for timber is 15 – 20 m3/ha, which would create values in the best cases of 10 – 80 USD/ha, if small logs are low priced, only of 3 – 4 USD in multiple use forests. Another rule of thumb is, that extraction rates should not exceed recruitment rates. Recruitment rates are 5% for Cambodian broadleaved forest, which would mean for instance for deciduous broadleaved forest a woody biomass of 15 m3/ha which could be harvested annually, which still could achieve values of 1500 to 3000 USD/ha for commercially valuable wood. Accordingly, Soussan & Sam (2012) rate the total forestry value under a sustainable harvesting scenario in Cambodia is 10.41 m3/ha, and the total timber service value with sustainable harvesting would range from USD 200–450/ha/year, depending on forest type and quality. If the entire area was sustainably harvested, this would have an aggregate income of nearly USD 440 million annually. Indeed, in the remaining high valuable forests similar values can be confirmed.

4.4. INDUSTRIAL TIMBER

Timber Production in ELCs in the PTWS plays only a minor role with only 13,33% of all crops produced. The largest area - two third – is covered by Teak, the most valuable of all tree crops, besides rubber, which is grown for latex, but normally not for timber. The prices for the tree crops are taken from Malaysia, and Teak is also the highest value crop, with a yield between 4 and 12 m3 pe ha, and maximal prices up to 400 m3/m3. The table below uses average yields and average prices for Teak.

Figure 14: Timber Production by ELCs

Species	Unit	Annual Yield	Unit Price [USD]	ha	
Eucalyptus	m3/ha	6	100	246	147600
Acacia	m3/ha	5	100	425	212500
Moringa	m3/ha	3	200	373	223800
Teak	m3/ha	8	448	4732	16959488
Rubber	t/ha	1,03	1450	241	359933,5
Total Value of Timber crops				6017	17903322

ELC areas in the REDD Report for Cambodia (2017)are also recorded as forests, and according to the Environmental Code (2017, compare Chapter 10), plantations are also supposed to grow mostly native trees. Indeed, trees like Rubber and others are native. Growing native trees does not necessarily qualify as native forests, which have multi-storey canopies and a high diversity. Furthermore, most native trees grow slowly, usually annual production stays behind the national discount rate, which makes them unproductive for most ELCs. Apart from the fact, that the ELCs in the PTWS grow 86.5% non-wood crops, any kind of trees produced on former primary forest land is not applicable for REDD programs. Therefore, the carbon value of these trees cannot be taken into account for REDD.

Fig.15 shows some ELC areas in Kampong Speu extracted from google earth in November 2018 for comparison with forests.

Figure 15: ELCs in Prek Tnoat Watershed

5. AGRICULTURE, LIVESTOCK AND FISHERY

5.1. AGRICULTURAL PRODUCTIVITY

The method used for the value of agriculture, livestock and fishery is using direct pricing / respectively, assessing the values of these ecosystem services on the basis of area outputs and household incomes. It would have been preferable to assess the development of biophysical productivity first, but it was not possible to access timelines for yield data.

The data on agricultural production are also scarce, Table 10 lists the area under agricultural production as assessed with geometric tools, assigning to these areas the net returns per ha, as calculated from CSES reports 2014 and 2015, aggregated for dry and wet season per year. The net returns per ha have slightly declined.

Table 9: Annual Net Income from Agriculture per ha and Total PTWS

	Pnom Penh Plain		Kampong Speu
Total ha under Agricultural Production			
2014	27779,53	63811,32	328545,20
2015	27684,05	42743,75	336628,02
Net Return per ha [USD]			
2014	*1626,93526*	*336,378482*	*253,059829*
2015	452,034882	349,738376	259,827394

5.2. LIVESTOCK PRODUCTION

Table 11. shows the absolute number of livestock heads in the Plateau Mountain zone.

As the original figures in the CSES report record animal heads – poultry equal to cattle - the figures were converted into tropical livestock unit according to the conversion rate: . Tropical Livestock Units are livestock numbers converted to a common unit (in 2005). The conversion factors applied are:

Cattle: 0.7, sheep: 0.1, goats: 0.1, pigs: 0.2, chicken: = 0.01 [1]

Table 10: Livestock Population, Kampong Speu only

Year/Species numbers	Cattle	Buffalo	Pig	Poultry		
2009	758	109	279	3,125		
2013	645	43	254	3,191		
2014	497	78	183	3,367		
Livestock numbers converted into LTUs [in thousands]					**Total umber LTUs**	**Total % Decline**
2009	530.6	87.2	55.8	31.25	704.85	

[1] www.lrrd.org, accessed September 11 2018

2013	451.5	34.4	50.8	31.25	567.95	-19.3
2014	347.9	62.4	36.6	33.67	480.57	-32.3

The converted figures reflect a sharp decline of livestock population in the Plateau-Mountain zone. Due to the information gathered during the field visits, the reason lies in the decline of feeding bases due to increasing inaccessibility of land because of construction or fencing off by plantations.

As the tropical livestock unit indicates the relation between livestock density and necessary fodder basis. As Fig. 5.5. shows, the necessary fodder base has apparently declined, forcing livestock population to be reduced about more than 30% between 2009 to 2014 in the Plateau Mountain area.

Households coped with the situation of a reduced fodder basis apparently by rapid destocking in 2015, as the incomes from meat production through livestock sales grew rapidly in this year, which might have been a response to the exploding costs in 2014 (compare Table 6.2.) The other coping strategy was the production of increased numbers of poultry, which is easy to adopt in small-scale households. But the increase of poultry in value is negligible compared with the decline of the value of cattle and buffalo population.

On an average income from livestock production declined therefore in Kampong Speu from 170,29 to around 160 USD, but almost doubled in the flood plain from 135 USD in 2014 to almost 300 USD in 2015, with a slight decline to 258,2 in 2016. In Pnom Penh income from livestock production also declined.

Table 11: Annual Net Income from livestock per HH and Total Watershed in USD

2014	2015	2016			
Annual Net Income Per Household (USD)					
170,29	94,66	159,87			
189,94	115,7	No data			
134,489	299,46	258,2			

5.3. FISHERY

Fish is the main resource for Cambodian protein supply, which is estimated to worth 2 billion USD annually. It is however changing as the population is growing and the demand for water is increasing with a lack of effective safeguards. In 2015, 751,546 tons of fish were caught in total Cambodia, representing an increase of 6,236 tons compared to 2014. While the government's research for development planning expects this to increase to 910,000 tonnes by 2018, there are also simultaneous reports of falling fish numbers due to considerable pressure from environmental changes and population growth. One study cites predictions of a 40-60 percent decline in inland fishery yields for both Vietnam and Cambodia "in the foreseeable future. In Tonle Sap fish production decreased about 50% according to a study by the Mekong River Commission.

Table 12: Average Income from Fishery per HH and Total Watershed

Part of WS per Zone/Province	2014	2015	2016
Kmapong Speu	154,83	146,42	90,74
Pnom Penh	474	1078,19	1364
Plain	196,54	209,36	129

In the PTWS, income from fishery declined from 154,83 USD in 2014 to only 90,74 USD in 2016 in the Upper Part of the watershed in Kampong Speu. The figure from the CSES is higher than the income indicated during the field visit, which was assessed to be 53 USD only.

In comparison to Kampong Speu, fishery incomes in the Plain, where downstream water accumulates, are about 30 – 50 USD higher than in Kampong Speu, with similar rates of decline and also increasing costs. Communities described it in the way that "Before fish fed the people, now people feed the fish". Pnom Penh has about 10 times higher incomes from fishery than the rural zones, which might be due to the fact, that there are only few households conducting fishery, where specialization and intensification might have taken place. Data errors due to the low sample number might be another reason.

4.5. CARBON

Carbon sequestration is normally considered as a regulating service, as it is the basis for climate change mitigation. However, in this case only the carbon production itself is accounted for, therefore it is included into the chapter on provisioning services. The climate regulation functions by forests, which would a question for the Chapter on Regulating Services, which is following in Part III. Indeed, according to local information it was confirmed, that climate regulating functions in the Upper Prek Tnoat Watershed had been impacted through a significant decline of precipitation, however, the data base which is available from satellite images for Prek Tnoat Watershed over 30 years is too coarse, to allow an analysis of these important services.

With regard to the value of carbon sequestration, several studies and reports have been releasedfor Cambodia on national level, above all the REDD report (2017), the study by Brander (2015) and by Sun Hean (2014). Cambodia is on international level one of the most progressed countries in receiving the status of REDD readiness.

For Prek Tnoat Watershed, the forest classification was conducted based on the same data sets as for wood densities. The assessment of total carbon values was based on the carbon densities assigned to the different vegetation classes in Cardamom forest by Sun Hean (2014). Carbon densities for litter and sub-ground biomass was based on standard values given by the Natural Capital Project in Stanford, the carbon values for soils were taken from data which had been aggregated from Soilgrid250.[2] The greatest amount of carbon per ha is stored in evergreen broadleaved forest, followed by deciduous and semi-deciduous forest.

Table 14 summarizes the total carbon value of the ecosystem which are applicable for carbon credits in Prek Tnoat Watershed

Table 13: Total Carbon (Physical and Monetary) in Watershed

	Total C/ha (kg)	Total C per total area (kg)	Total C in vegetation (kg)	Total C in Soil (kg)	Total C in Litter and Subground Biomass	Carbon Value [USD] Price 20 USD/t	Carbon Value [USD] Price 30 USD/t
Mangrove Forest	*234*	112413.3	53324.2	53324.2	5764.9	2248,3	1599,7
Deciduous Forest	*48*	12514821.5	10216180.8	936483.2	2213505.9	250296,4	375444,6

[2] www.soigrid250.org

Evergreen Broadleaved Forest	*340*	12057256.2	6773341.0	3936339.5	1347575.7	241145,1	203200,2
Evergreen Coniferous Forest	*340*	46010.4	25847.0	15021.0	5142.4	920,2	775,4
Mixed Forest	*268*	61076.4	36691.4	18459.7	5925.3	1221,5	1100,7

For assessing deforestation rates, the initially mentioned data by Hansen are used, starting with the carbon stock of 2000, as assessed by ESA-CCI. For the sake of saving time, just the average rate per carbon stock calculated from the proportion of each class is considered here, which is an assumed value of **269 t**/ha based on the soil data by soilgrid250 and the carbon stocks used by Sean (2014). The calculation of annual losses of carbon between 2000 and 2015 were based on Hansen data, assuming the losses in these fifteen years to happen linearly The amount of carbon losses calculated in this way was multiplied with the average carbon sequestration per year, and a carbon price at a rate of 10, 20 and 30 USD and further projected until 2030.

The potential social costs of emissions are not accounted for, as these should be reflected in the carbon price. It has been discussed already long ago, that the price of carbon of 30 USD/t does not reflect the true social costs of avoided climate change (Natural Capital Project 2008), and even a future price up to 100 USD/t carbon is under discussion (Müller, bmz 2018). That this will lead to higher calculated forgone losses of carbon sequestration is evident.

Calculation of the Net Present Value of Sequestration

Methodologically, the net present value of carbon sequestration is calculated with the formula of the INVEST model for carbon prices of 10,20, and 30 USD and a discount rate of 5%.

The net present value of sequestration in the model is calculated to the formula

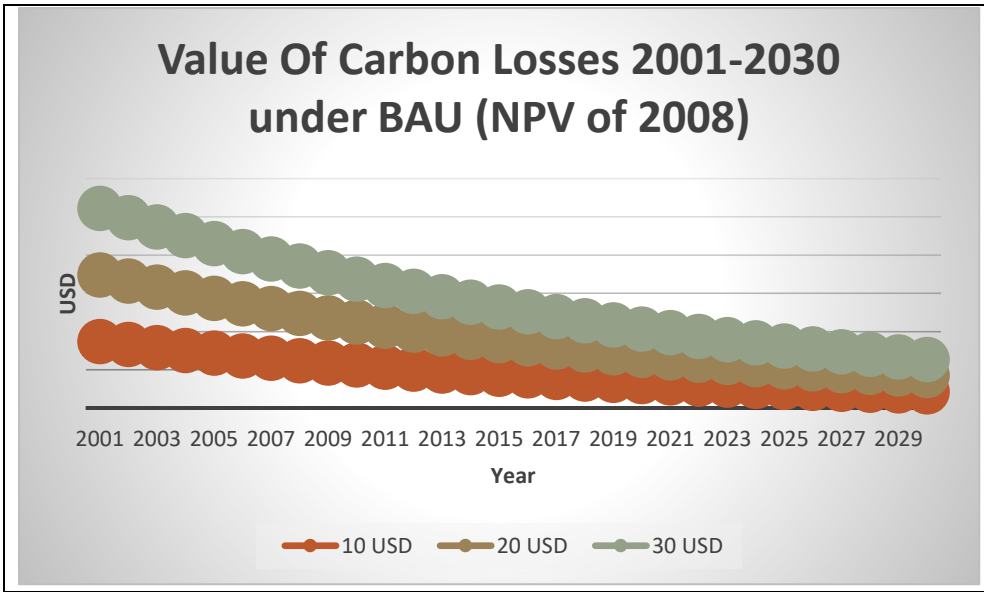
$$V_x = \sum_{t=0}^{T} \frac{p_t(C_{t,x} - C_{t-1,x})}{(1+d)^t},$$

where

- T is the number of years between the current date and the end of the sequestration period
- Pt is the price per ton of carbon at time t
- Ct,x is the carbon stock on pixel x at time t
- D is the discount rate of 5%

Figure 15 shows the annual losses which occurred on an average between 2001 and 2030.

Figure 16 Value of Carbon Losses 2001 – 2030 BAU Scenario


Value Of Carbon Losses 2001-2030 under BAU (NPV of 2008)
USD
2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021 2023 2025 2027 2029
Year
10 USD
20 USD
30 USD

III. REGULATING SERVICES

Structure of the Chapters on Regulating Services

Each Chapter starts with a short description of the underlying model used for 3 scenarios: 1992, 2012, and one scenario for 2060 under BAU conditions, which is assumed to have no forest at all. Then the impacts of changes of each ecosystem service are described, and finally valuated

The regulating services considered are

- Seasonal flows, flood and hydrological drought regulation
- Nutrient delivery and retention
- Sediment retention and protection from erosion
- Biodiversity

The economic consequences which the impairment of ecosystem services can have, are considered in the second part of each chapter on regulating services. These are

- Costs for losses of Agricultural Productivity due to declining nutrient retention as a result of forest loss
- Costs for losses in Fishery due to sedimentation (erosion) and pollution
- Costs for changes in water flow through increased demands for flood risk protection in the rainy season and drought risk protection in the dry season
- Costs for enhanced agricultural inputs or investments into SLM to avoid further agricultural productivity losses
- Costs for foregone losses from NTFP
- Costs for potential losses from ecotourism or of medicinal values due to biodiversity loss
- Costs of carbon losses
- Costs for eutrophication, erosion, and enhanced flood risks in protected areas

The Net Present Value calculation is conducted in analogy to the one used for the calculation of wood stocks and carbon losses in the previous Chapters.

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6.SEASONAL FLOWS

Though not mentioned in the first place, changes in the hydrological regime as a consequence of land cover change are at the heart of environmental change in the Prek Tnoat. Valuing costs and benefits of this change and the related processes of nutrient and sediment export refer genuinely to the deep environmental impacts on all sectors, that land cover change can have. Although provisioning services are easiest to value on the market, they will cease to be available and therefore valuable, if the critical supporting and regulating services upon which they rely, would be lost. It is therefore the focus on the value of regulating services, which will transform actions into deeply ecological and environmental activities, as it transforms forms thinking away from just looking for alternative sources of funding towards establishing catalysts for effective land use planning and allocations that are in public interest of environmental health and equity.

6.1. HYDROLOGY AND LANDUSE

Hydrologically, the Prek Tnoat reaches into the mainstream of the Mekong, where it divides into a complex and increasingly controlled and artificial system of branches and canals, where flow behaviour is tidal and influenced by salt water intrusion. Every year, 35 to 50 per cent of this reach is flooded during the rainy season.[3] Little

[3] MRC 2005: Overview over the Hydrology of the Mekong Basin

hydrological research and monitoring has been done on the Prek Tnoat itself, though AFPnet has summarized the importance of considering changes of the Prek Tnoat water regime as a consequence of deforestation as follows: "*Prek Thnot is one of the watersheds that have the high risk of impairment of its watershed function. The loss of forest cover can greatly diminish the protective role of the watershed and increase the vulnerability of the downstream communities. The ongoing deforestation in the uplands increasingly subjects the downstream communities like Phnom Penh to flooding*." The Mekong River Commission and JICA have established several gauging stations in the PT watershed, but mainly based at the Prek Dam. Several hydrological models have also been applied, but not one which pertains to the full watershed. Also a run-off model for the Prek Tnoat watershed has not yet been established.

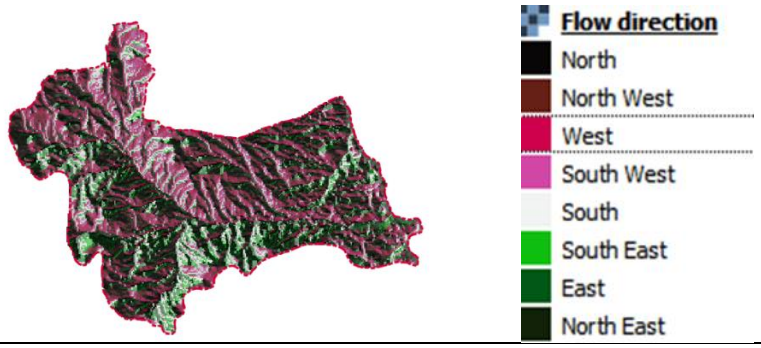
The INVEST model of seasonal flows, which has been run to map the water services in the watershed and which has been used for the valuation of water services, gives only a coarse overview over major changes of the water regime, and cannot do full justice to the hydrological complexity of the watershed.

6.2. INPUT DATA

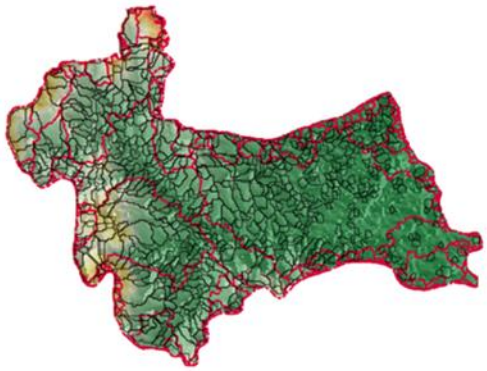
Fig. 6.1a.shows the sub-catchments as availed to the consultant by UNDP over the second-rank subwatersheds identified by the SAGA tool for the applied DEM Fig. 6.1.b shows the digital elevation model. Als there are only few slopes, water flow dynamics remain mainly in the sub-watersheds within the Upper Prek Tnoat watershed. Below the Prek Tnoat river, water movements are mainly directed to South East, while above the Prek Tnoat, water flows mainly to the North West.

Figure 17 Flow Directions and DEM

a) Flow Directions



b) DEM



Further input data are spatial climate data averaged over the last 30 years by WorldClim 3.0. The model considers therefore no changes in climatic conditions, which serves the purpose, of extracting the trends and changes triggered by land use change only.

Fig. 6.2.2 shows, how the water flows computed by the INVEST model are related. Quickflow or runoff occurs during or shortly after rain events. In highly seasonal climates as the one of Prek Tnoat watershed, baseflow provides larger values than the quick flow.

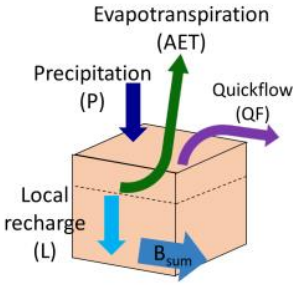
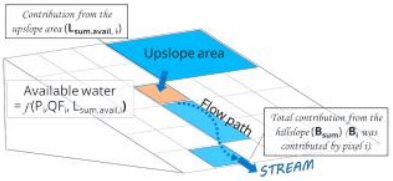


Figure 18 Model of Water Flow Parameters Computed by INVEST Seasonal Water Model

6.3. RESULTS



The model results are robust for the scenario 1992-2015 with regard to question, if conditions become wetter or drier, however, not with regard to the absolute proportion of baseflows and quickflows, which add each other. The model is not robust for the scenario without forests (BAU 2060). In any case the model results illustrate deep and severe changes in the hydrological regime following land use change throughout the watershed between 1992 and 2012. Patterns would further change, if the whole area would be transformed into cropland.

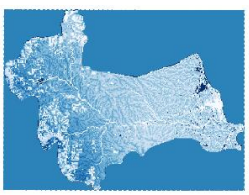
Scenario 1992 – 2012

Fig. 6.3.1. shows, that baseflows increased in the Upper PTWS mainly in the downstream area of the upper PTWS in the South. This area of higher baseflows has expanded further North until now (2012) to the middle of the upper PTWS. On the other hand – and against expectations, these wetter baseflows did not yet reach the lower PTWS, whose average conditions apparently become drier with ongoing deforestation. Interestingly, it is in particular the ELC areas, which are located in the areas, which become wetter between 1992 and 2012 (Fig. 6.3.2.)

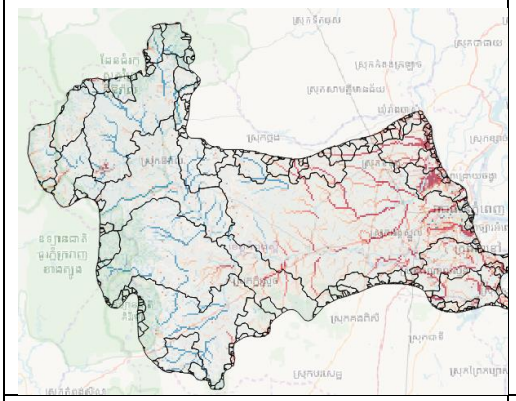
Scenario 2012 - 2060

According to the models, in the scenario without forests, the whole Upper PTWS will become wetter due to higher baseflows, but after cutting all forests, also the downstream areas of the watershed, meaning the transition zone and the flood plain. Apparently, there is tipping point of seasonal waterflows with ongoing deforestation, which affects the lower watershed, where after initially drier conditions, conditions become wetter also in the lower watershed. However, with different input parameters, the results show either a return to earlier conditions of 1992, respectively really enhanced flood risks, which could indeed also affect Pnom Penh, as they are predicted in the quoted proposal by APFNET above.

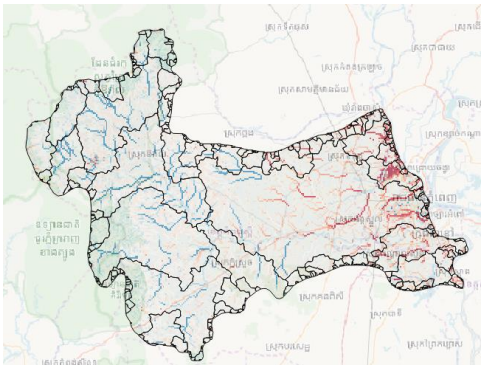
Figure 19 Results from Different Scenarios of Seasonal Water Model

	1992	2016	Without Forest
Baseflow [mm]			
Difference between Different Years			

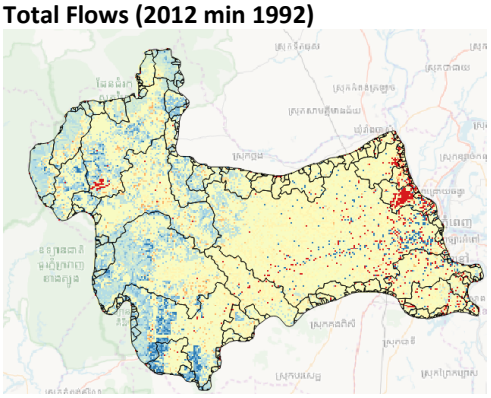
Accumulated Baseflows (2012 minus 1992)



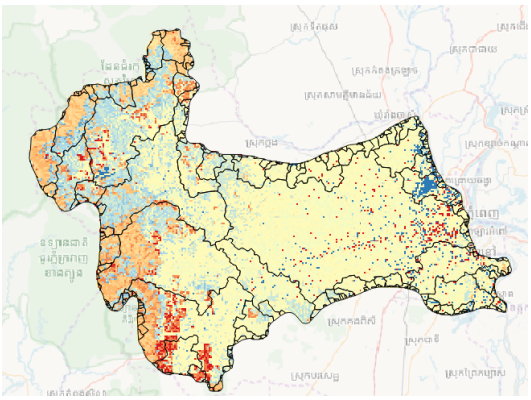
Accumulated Baseflows (BAU 2060 minus 2012)



Total Flows (2012 min 1992)



Total Flows (BAU 20160 min 2012)



These dynamics become clearer, when the area of the Upper PTWS, which had been widely covered by forests in 1992. is considered separately from the Lower PTWS in the East, which had been permanently covered by cropland (Table 6.3.1), which shows the change of average values in the Upper and the Lower Basin

Table 14: Results of Different Parameters from Scenarios Calculated with the Seasonal Flow Model

	B [mm]	Bsum [mm]	QF [mm]
Forest Area 1992 (Upper Watershed)			
1992	360.3	7488.8	91
2012	450.7	8076.1	137
BAU 2060	524.3	10271.0	67
Crop Area 1992 (Lower Watershed)			
1992	415.2	7493.4	**133.06**
2012	343.6	6928.0	**133.06**
BAU 2060	466.3	8625.8	**62**

In total, the water masses retained in the Upper PTWS were in 1992 268,393,270.5 m3, which is equivalent to an annual increase of 1,25% of recharge. This could have been the reason for increased flood pressures and other water related hazards. Apparently the increased discharge remained mainly in the sub-watersheds of the Upper Basin, as the relation in the lower basin was converse: Discharge was reduced about 17%, apparently leading to

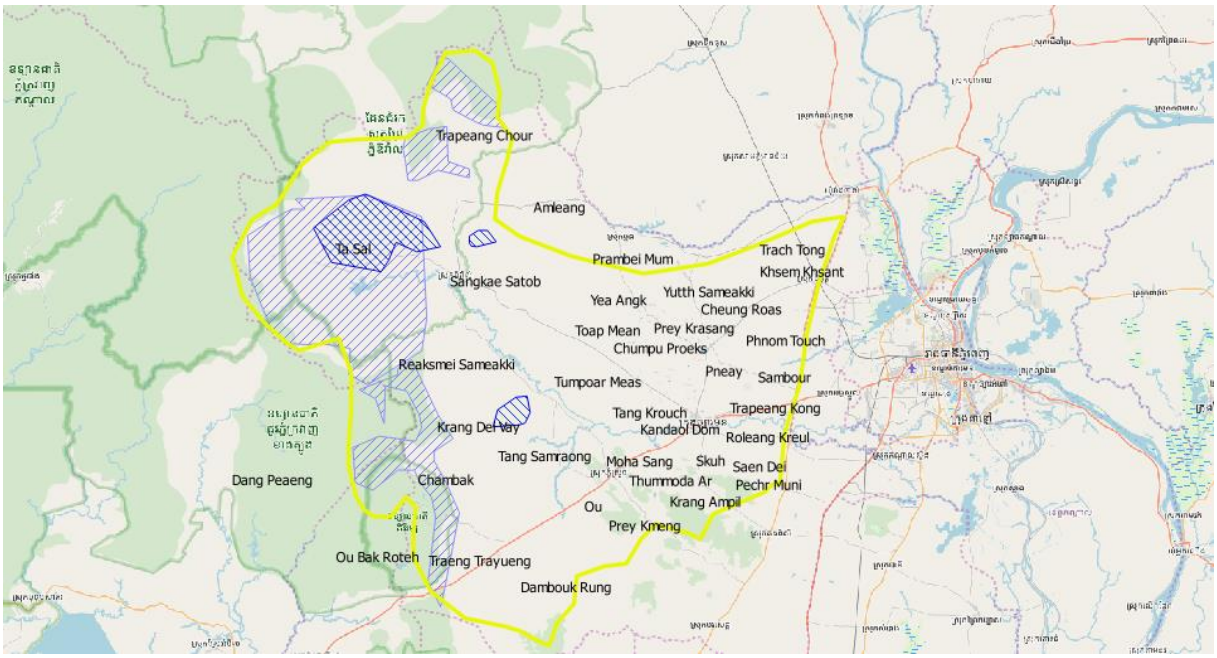
an increased scarcity of water availability for irrigation and other purposes of about 17.5% in 20 years, meaning about almost 1% per year, which is equivalent to an absolute decline of 28,656,2924 m3 between 1992 and 2012.

Locally Enhanced Flood Risks According to Model Results

Wetter conditions do not necessarily have to imply flood risks, where soils and the underlying hydrogeological conditions allow to store additional water. The model run is too simple to predict this. However, if flood risks can be expected, where soils are most shallow and the increase of baseflow is highest, several areas of enhanced flood risks can be identified, as depicted in Fig. 5.

Especially in downslope areas in niches close to forests, water accumulates, therefore, here the probability of flood occurrence is higher. The Mekong River Commission records 9 greater flood incidences between 1990 and 2004, which is, however, a lower frequency than in most other watersheds.

Figure 20 Flood Risk Areas



Comparison with Other Data from the Lower Mekong Basin

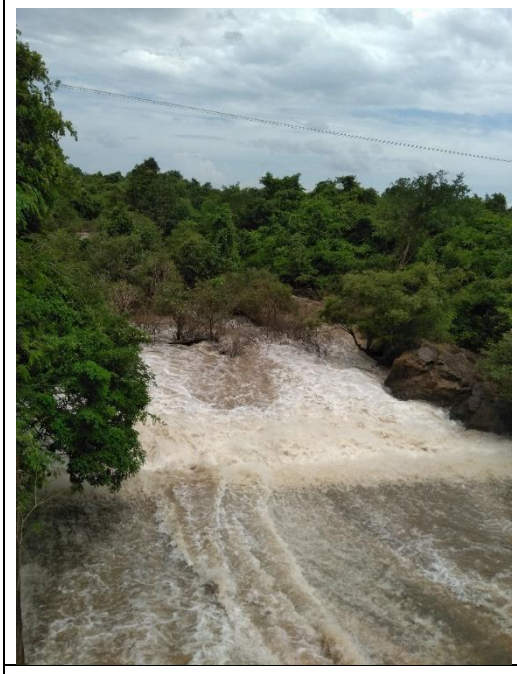
The Prek Tnoat is not considered as an important tributary to the Mekong in most studies. Nevertheless, changes in the flow regime apparently seem to affect the seasonal flooding everywhere in the Lower Mekong Basin. In a comparison of the number of drought with flood years between 1960 and 2005 by the MRC, drought years were in the majority, which underlines, that drier hydrological conditions in the lower Mekong basin are likely to happen.

Local Experience

The dynamics described were well reflected by observations during the field study and records by interviewed farmers and policy makers.

Communities in upstream areas reported, that water storage capacities decline with deforestation, therefore they experienced fast losses of rainwater, on the one hand also enhanced stream flows in downstream areas, so that fast water flows did not even reach irrigation channels in the dry season, which led also to river bank erosionl Heavy inundations were observed in Trapeang Chour, also in Chambak (compare Fig. 6.4.).

Figure 21 Local Consequences of Increased Baseflows in Chambak and Trapeang Chour



Photos: Kong/Hartmann, Chambak and Trapeang Chour

Other data

Several studies have highlighted the impacts of land use changes to groundwater discharge in river basins

- In Brazil has shown, reforestation and best management practices can add 106 m3/a of additional baseflow discharge in the dry season.
- In Indonesia in small catchments reforestation programs would increase the percentage of base fl ow discharge up to 24%, generating an equivalent amount of savings in water collection costs in small communities. (Rattanayak 2004)

Conclusion

The findings are opposite to expectations, which usually is that lower watersheds become flooded after deforestation and baseflows reduce directly within the deforested areas. The findings could be explained by the fact, that the drainage capacities towards the Mekong is very low due to the flat terrain, therefore, most water discharged in the upstream area remains and evaporates already there. Some similar dynamics are the change of water flow directions between the Tonle Sap Lake and the Mekong River. The model could not be calibrated, therefore, as mentioned, these are only scenarios, and it would be recommendable to run a well calibrated comprehensive and complex hydrological ecological model by an experienced research for further elaboration of the hydrodynamics in the watershed, which are so important for the future of the basin.

6.4. ECONOMIC IMPACTS

Who and What is affected

For the design of PES, it is important to distinguish properly, who is affected by environmental changes and who caused them. In summary:

- In the upstream areas, forest communities and emerging small-scale farmers are impacted by increasing disasters and flooding.
- Infrastructure, especially dams, ponds and irrigation channels are affected
- Farmers and Fishers in the downstream areas face income losses due to reduced baseflows.
- As ELCs have widely contributed to the deforestation in the Western watershed, they are themselves affected by reduced water flows, however, have created even drier conditions in the downstream areas in the West and flood risks in the Southern downstream part of the watershed.
- Opposite to expectations in the proposal by APFNET, there are no threats by enhanced floods in the Mekong Delta according to the model results.

Valuation of Watershed Retention Functions

Assessing the changes of water retention directly from production losses and increased disasters, would be difficult, as total land use patterns changed over time. Instead, a smart valuation technique for water retention services developed in Iran was used (Mashayeheki et al, 2010)[4], which assessed the water retention value of forests as the costs of water storage by dams as of 0,5 USD / m3. This method and this price are also used here now for Cambodia, although calculated prices for water from hydropower dams in Cambodia are calculated as 10 times higher (4,5 to 5,5 USD/m3), but these are related than to the value of electricity generated.

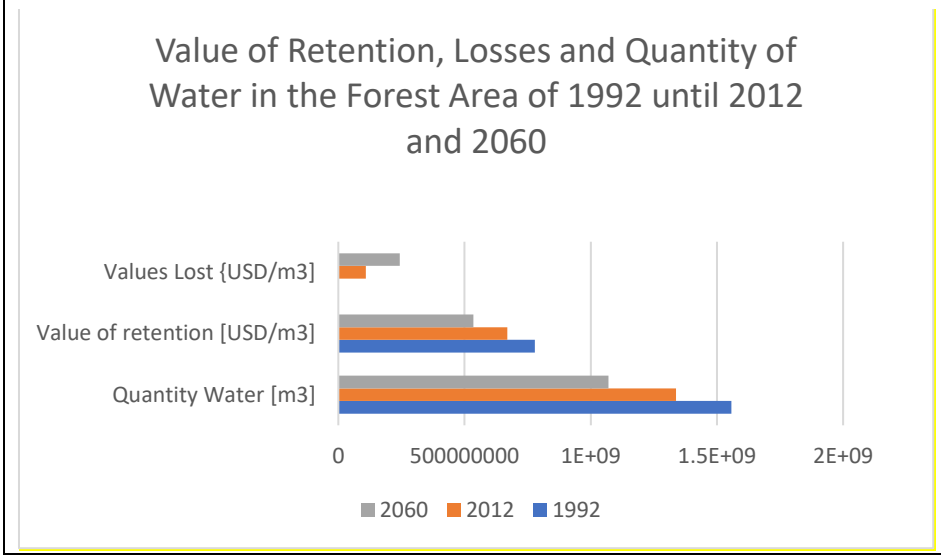
As Table and Fig. 6.5.1 highlight, water values in the dimension of the forest area of 1992 was 0.778 Billion USD; which was reduced to 0.669 billion in 2012, and when all land would be converted into agriculture, the value would be about half a billion.

Table 15: Water Losses in Different Scenarios in Physical and Monetary Terms

	Quantity Water [m3]	Value of retention [USD/m3]	Values Lost {USD/m3]
1992	1556751733	778,375,866.5	
2012	1338223488	669,111,743.9	109,264,123
BAU 2060	1069830217	534,915,108.7	243460758

[4] **Zahra Mashayekhi • Mostafa Panahi • Mahmoud Karami Shahram Khalighi • Arash Malekian:**: 293–300, DOI 10.1007/s11676-010-0074-3, Economic valuation of water storage function of forest ecosystems (case study: Zagros Forests, Iran) **Jou**rnal of Forestry Research (2010) 21(3)

Figure 22: Value of Water Retention and Water Losses, Physical and Monetary



Assessment of Agricultural Production Losses due to Reduced Baseflows

To assess potential losses of agricultural production, some field data on riced yields were collected during the field visit, and a sensitivity analysis of rice yields due to different levels of water availability were conducted with the model AQUACROP. The yield data recorded during the field analysis varied between 2 to maximally 3 tons, but were highest in Trapeang Chour, where soils are deepest.

The results showed indeed that rice production was highly sensitive to varying soil depth with yield decline of of 1 – 1,5 tons if groundwater tables were decreasing, especially in shallow soils.

Rice production is therefore very sensitive to reduced water availability and reducing flood pulses. This can partly be compensated through higher inputs of chemicals, which increased about 30% between 2013 and 2016 .

On the other hand, while rice is very resistant to inundation, it cannot sustain to be submerged for more than 10 days on an average. This means, that full production losses can be assumed in those areas with high flood risks in the Upper PTWS.

In economic terms this means, that – based on the above findings - with a very conservative assumption of of 1,5% foregone losses or enhanced production costs due to reduced flooding, total agricultural yield losses would have been around would have a total value of foregone incomes from agriculture **of 344,785,405** USD for the larger Prek Tnoat Watershed between 1992 and 2012, and of annually **17,239,270** USD annual, assuming a linear increase of damages and costs and at 2014 prices. The assumption of 1,5 % yield loss would also be justified by reduction of agricultural yields between 2014 and 2015 of 3,7% and the continuously increasing costs of agricultural inputs which are recorded by CSES from 2009 onward (Compare Chapter 5).

Additional Irrigation Costs

A practical way to look on the economic impacts of changes of seasonal water flows are additional irrigation costs, which emerge, either where baseflows are reduced, or – the opposite – where irrigation structure is destroyed due to increased baseflows in the Upper PTWS or where small irrigation channels are no more filled due to higher water velocities (Field visit 2018).

Assessing conversely the costs of additional irrigation demand based on the financial requirements for irrigation infrastructure as calculated by LWD, which is an organization which provides usually lowest-cost technologies, the costs would be per 1000 person as follows:

Enhanced infrastructure demand requires investments into ponding and irrigation infrastructure and flood management of about USD 2400/ 1000 persons. Additionally, one spillway of the cost of 5000 – 7000 USD is required. This is equivalent to about 10 USD additional irrigation costs per capita. The population within the agricultural areas attributed to the proportion of the Mountain/Plateau-zone (Kampong Speu) and of the Plain (mainly Kandal) is about 954596, therefore, the additional irrigation costs are about 9,545,960 USD. This figure does not take into account the population of Pnom Penh, as the population density is very high there and does not really reflect irrigation demand, as many are not occupied in the agricultural sector, and it does not take into account, that only one quarter of the population uses irrigation technologies, as most probably also the remaining 75% would also be in demand of that, or already are.

This is a very conservative estimation, but still very difficult to be covered by communities with financial capacities of USD 20 000 USD/year, therefore, communities themselves would be unable to establish the necessary water infrastructure (Field Study 2018).

Therefore, the costs for agricultural production losses would be the ones most applicable here for the final valuation of ecosystem services. But it was also considered as important to have an overview of additional irrigation costs, if this could be funded.

The total costs for changes in seasonal flows are listed in Table 6.2.

Fig. 6.2. Total Costs for Changes in Seasonal Flows

Total Costs (Past 20 Years, 2016 Price)			**Annual Costs (2016 Price)**	
	Replacement Costs (USD)	**Losses of Use Values (USD)**	**Replacement Costs (USD)**	**Losses of Use Values (USD)**
Lost Water Retention(Comparable Costs for Water in Dams), is assumed to cover costs for structural measures for flood Protection	479,000,000		23,950,000	
Foregone Income from Agriculture due to implicit productivity losses		344,785,405		17,239,270
Additional Infrastructure Costs for Irrigation	9,545,960		477,298	
Total (per Column)	488,545,960	344785405	24,427,298	17,239,270
Total (Replacement Costs and Costs for Losses of Use Values)		**833,331,365**		**41,666,568**

Total Costs per ha	**1261.879**	**63.094**
Total Costs per HH	**2159.292**	**107.965**

The foregone losses experienced by households are about 30 to 50 percent of their potential income per household or per ha. It has to be emphasised, that these calculations are based partly on foregone losses from agriculture, which are relative and would be higher for high value crops. This would mean, ELCs are losing about 450 USD per ha.

7. SEDIMENT RETENTION, EROSION, NUTRIENT RETENTION AND POLLUTION

Erosion and sedimentation are processes which are ongoing since millions of years, and have created ecosystems, which are not only adapted to, but even depend on these processes. In case sedimentation levels change, fish species might have difficulties to adjust to these new conditions in their feeding and spawning grounds. Increases in sediment concentration can create turbid waters with a smaller euphotic zone. This decreases plant productivity, negatively impacting fish and bird species and causing abrasion of fish gills, thus increasing potential for disease or mortality. In general, the aquatic food web system in watersheds relies on the constant inputs of soil particles and nutrients through sedimentation. On the other hand, turbidity can also cause visual impairment for predatory fish, affecting their feeding habitats.

Also rice production systems in the flood plains constitute their productivity mainly from the regular sediments eroded from the mountainous areas. Therefore, interventions which interfere into this delicate balance, especially reservoirs and hydropower stations, which reduce sedimentation of river systems, have frequently been criticized for their negative impacts on the productivity of fishery and rice cultivation systems.

However conversely, excessive rates of erosion and sedimentation have as well negative impacts on the ecosystem. It is well known, that erosion reduces agricultural productivity and that excessive sedimentation contributes to the pollution and siltation of water bodies, causing many ecological and mechanical problems up to the change of flow patterns of whole river systems. Protection against erosion and sedimentation are therefore important ecosystem services, particularly in the humid tropics, where erosion is highest in the world.

The calculation of values of protection of erosion, sediment retention and lost values due to sedimentation and pollution are evaluated here together, as many of their impacts cannot be distinguished from each other, they frequently have similar causes.

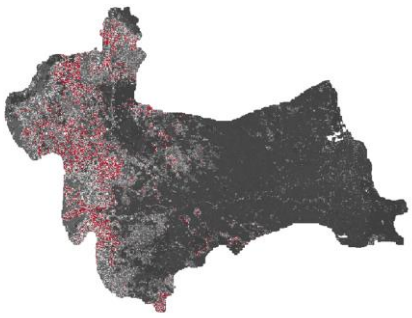
7.1. SEDIMENTATION AND EROSION

7.1.1. METHODOLOGY

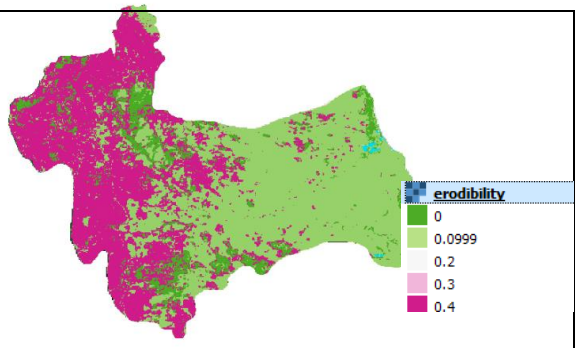
Erosion and Sedimentation have been computed with the SDR model by INVEST. The model has various shortcomings, as it only predicts sediment delivery from sheetflow erosion, thus neglecting other sources and sinks of sediment (e.g. gully erosion, streambank, landslides, stream deposition, etc.), which can affect the valuation approach. As particularly gully erosion plays locally significant role, the model does not do justice to these processes. Therefore, the results have to be considered with care.

Therefore, in addition to the results, also the single parameters which affect erosion, are presented in Fig. In particular rainfall erosivity in Cambodia, which belongs to the world's highest, has a high influence on the locations, where gully erosion might occur.

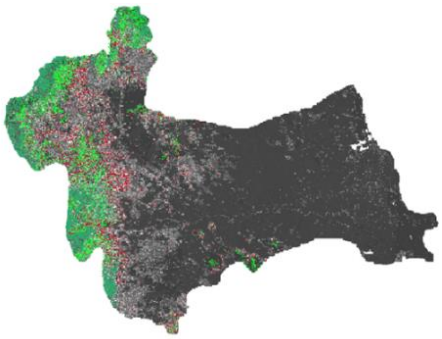
Figure 23: Rainfall Erosion and Forest Cover, Soil Erodibility and Slope



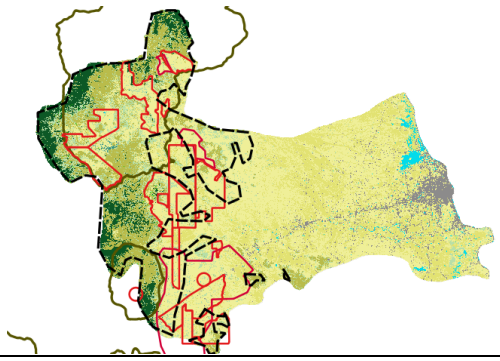
Rainfall Erosivity [kJ*t-1*ha-1*a-1]



Soil Erodibility [t*h-1*a-1)



Forest Cover 2016 over Rainfall Erosivity [kJ*t-1*ha-1*a-1]



ELC areas (red), Forest Line 1992 (black), PAs (grea) over Land Use (2016)

Areas of highest rainfall erosivity exist mainly in the Western part of the watershed (Fig. 7.1.1.1.) Also the most erodible soils coincide with the areas of highest vulnerability to rainfall erosivity. And while these areas until 1992 had still forests vegetation, these areas have been widely uncovered, presenting the current "risk zone" for environmental degradation, which coincides widely with the areas which becomes wetter as illustrated in Chapter 6. Slopes, which are mainly found in the Western zone of the upper watershed, stipulate also erosion. Nevertheless, the soil textures are medium erodible, and forests with their high retention capacities have widely protected soils against erosion despite slopes and high rainfall erosion. Increased rates of ongoing deforestation exposed the slopes to the high energy of rains, which increased erosion rates about four times and also expanded the areas, where erosion took place.

7.1.2 MODEL RESULTS

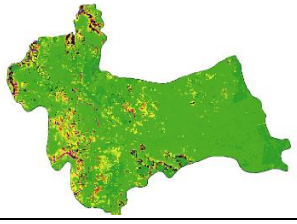
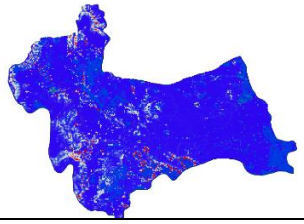
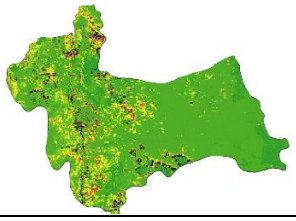
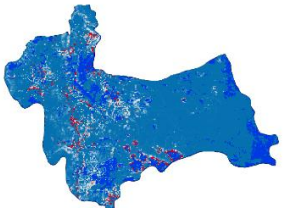
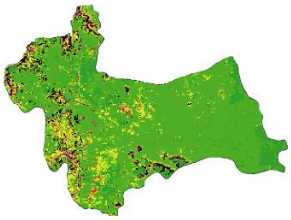
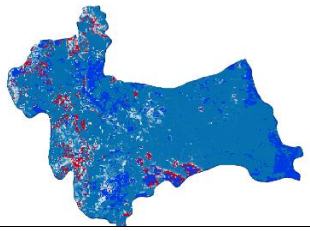
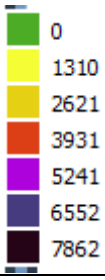
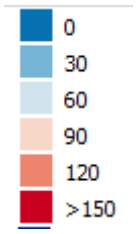
The dynamics of erosion from the relatively high forest cover in the scenario 1992 to 2012, and of the scenario 2012 to BAU 2060 without forest, shows a trend of increasing values of erosion and sedimentation. Table 17 shows that total sediment export and erosion increased about one third between 1992 and 2012, and more than tripled in the scenario without forest cover, compared with the scenario of 2012.

Table 16: Total, Maximum and Average Erosion and Sedimentation

Year	Sediment Export, total area (t)	USLE (t) total area	Sediment export Max (t/ha)	USLE max (t/ha)	Sediment export Avg (t/ha)	USLE Avg (t/ha
1992	2,144.2	113,757.6	5.2388	319.9	16.3	855.8
2012	3,237.1	145,606.2	8.2668	377.97	24.5	1094.2
BAU 2060	10,015.8	452,4997.0	35.182	1611.36	75.9	3404.9

Between 1992 and 2012 maximum erosion rates increased from 319.9062 t/ha in 1992 to 377.87 t/ha in 2012, and would become more than 5 times higher in the scenario without forest cover, which would be 1611.2562 t/ha, Accordingly, maximum values of sediment export increased from 5.2388 t/ha to 8.2668 t/ha in 2012, and would be 35.182 t/ha in the scenario without any forest cover (Table 7.2.1). For comparison with other studies: Converting watersheds to agricultural lands has increased sediment yields to 60 t/ha/year according to Tripathi, (2005). In other areas, the variability of soil erosion was ranging from as low as 16 t/ha/year to as much as 300 t/ha/year (Easton et al., 2010), which are data similar to the ones calculated for Prek Tnot, however, the extremes in Prek Tnot Watershed even exceed these values in highly erodible areas with increasing deforestation.

Figure 24 Erosion and Sedimentation in Different Scenarios

	Erosion	**Sediment Export**
1992		
2012		
Without Forests		
Legend		

As erosion is influenced by many more factors than landcover, the erosion and sedimentation hotspots in the model cannot be related to the deforestation areas in the Northern part of Upper Prek Tnoat Watershed, though in the South they are nearly congruent. However, hotspots of sedimentation coincide well with ELC areas.

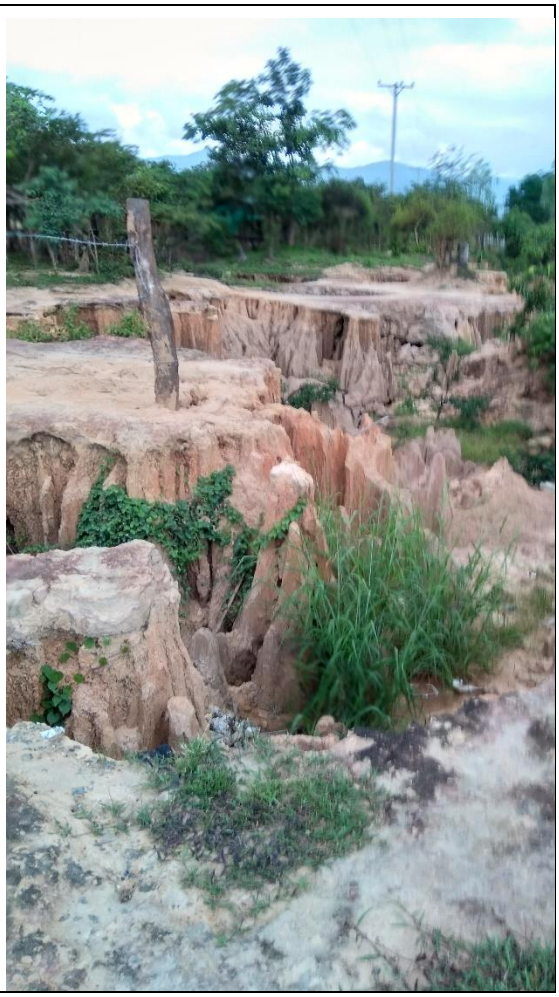
7.1.3 ECONOMIC IMPACTS OF EROSION

The severe impact of erosion could in particular be observed in some hotspots of erosion below Krang Devay, where naturally high erosion rate after deforestation were even exacerbated in erosion channels, where mining happened. According to community statements, this led to a deepening of some gullies of even one metre per year, equivalent to a soil loss of 1 ton per square metre. (Field Visit 2018). With a dimension of about 20*200*4m3, which is equivalent to 16 000 m3 soil, the rehabilitation of the gully depicted in Fig. 10 alone would

cost about 30000 USD. This price is based on a statement by Cambodian authorities, that gully rehabilitation costs between 5000 to 30000 USD; however, without giving details about the associated dimensions.

According to UNCCD, land degradation should be rehabilitated by SLM technologies. A failure to adopt appropriate land use management strategies will result in further rapid resource degradation with negative impacts to downstream communities.

Figure 25: Gully Formation near Krang Devay



The impact of forgone losses from erosion on crop production etc. could not yet be accurately estimated by research, particularly not for Asia, while more studies have been conducted for Africa. Studies for Asia have mainly focussed on prevention costs or avoided costs of erosion, which are for instanced assumed to be 57 USD/ha in the Philippines and about 121 USD for Cambodia, Riem National Park. Assuming that costs for rehabilitation would be 4 times higher than prevention according to ELD reports, the costs of erosion in the identified hotspots of 16,623 ha would then be 484 USD/ha, amounting to 8,045,532 USD:

Prevention Costs

Prevention costs for the remaining sites of the critical zone, which is covered currently mainly by ELCs, should be put under SLM methods or afforestation for protecting it against future erosion. These "compensation costs for topsoil losses" as the ELD Asia report (2017) expresses it, is about 251 USD/ha[5] for Cambodia, totalling to 25,100,000 USD for an area of 100 000 ha. The wood crops grown in the ELCs are in this context an ambiguous issue, which will be discussed in detail in the end of the Report.

7.1.4. ECONOMIC IMPACTS OF SEDIMENTATION

Sedimentation causes costs through mechanical and ecological problems. Fig 26 shows the major hotspots of sedimentation over the water channel network in the basin. The hotspot zone in the most Northern area is located in Trapeang Chour in the Phom Aural National Park, where also severe eutrophication and invasion of the water hyazinth could be observed during the field visit.

[5] ELD Asia Team, Personal Communication September 2018

Figure 26: Sedimentation

a) Hotspots of Sedimentation over Channel Density	Sedimentation near Krang Devay
	

MECHANICAL PROBLEMS CAUSED BY SEDIMENTATION

Dam Operation Problems

Mechanical problems caused by sedimentation reach from siltation of irrigation channels, sedimentation of rivers leads to widening or even changes of riverbeds, up to problems several problems with dams operation. In dams, sediments for instance can block low-level outlets designed to allow for reservoir drawdown and clog spillway tunnels.

Problems of closing the gate at the dam near Krang Devay, which are reported, can probably be directly related to increasing water velocities and simultaneously enhanced sediment loads in the riverbed, and leading to discharge problems related inundation of downstream areas.

It is assumed, that solving the gate operation in Krang Devay alone might involve costs of 50,000 USD.

Desiltation of Riverbeds

Siltation of channels and riverbeds requires regular dredging or other supporting operations (compare Chapter Roadmap). Dredging and desiltation have to be conducted professionally as it can have severe side-effects such as river bank erosion up to the triggering of landslides.

According to the Sovanakhum road engineering (2014), the estimated price of the dredging of the 2,160 meters-long access channel is USD 25,000 in Cambodia, which is roughly bout 10 USD / m.[6]. Assuming in an area of 15013 ha, which is affected by siltation, channels of about 1000 m length are affected by sedimentation, this price would lead to overall dredging costs of about 10,000 USD.

Siltation does not only cause costs, but also profits. These profits are mainly sought for by the sand mining industry, which uses to dredges the sediments from upstream areas as their resource. Side effects are destabilization of riverbanks, erosion channels up to landslides, reports, which is why it is legally prohibited (compare Chapter 10). Therefore, potential profits are also no considered here in the following calculation.

[6] https://cmsdata.iucn.org/downloads/cost_and_benefit_analysis_dredging_channel_in_koh_kapik_eng.pdf

7.1.5. ECOLOGIAL PROBLEMS CAUSED BY SEDIMENTATION

Productivity Losses in Fishery

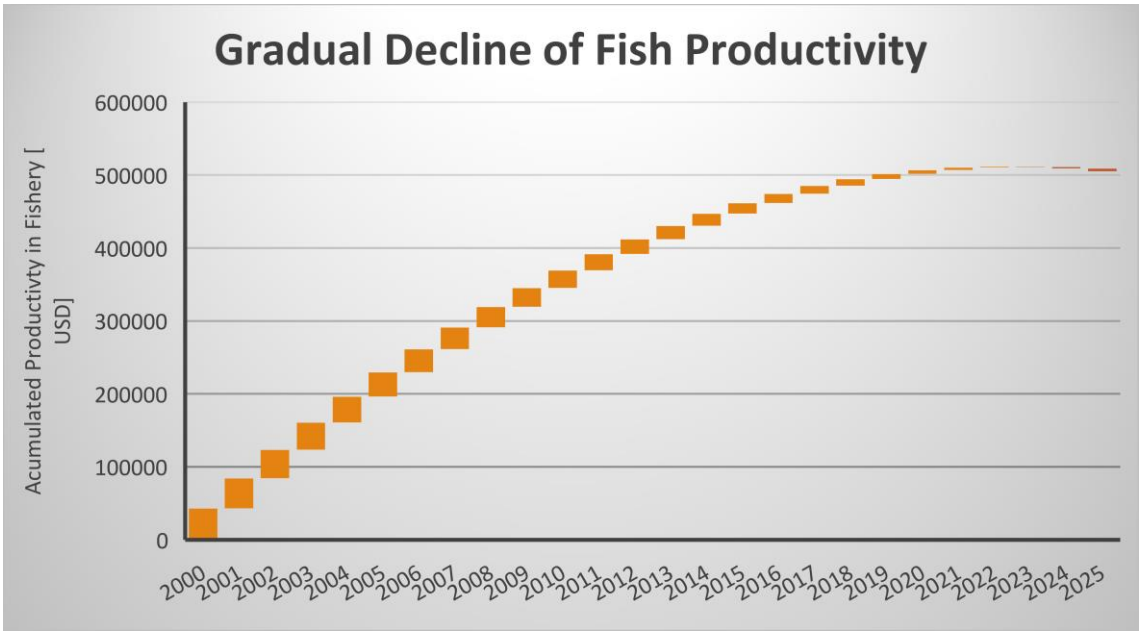
"Before, fish fed the people. Now, people feed the fish." (Krang Devay Community Members)

Incomes and income losses from fishery are difficult to assess, as there are only the two years data introduced in Chapter 5, and no other supplementary data on fish population and its changes. According to MRC studies, in Tonle Sap, fish production declined about 50% due to water pollution, eutrophication, and declining water level depth of rivers (MRC 2010).

There is no other way of assessing losses from fishery than assuming the same rates also for PTWS.. To support this approach further, a regression curve was calculated on income losses from fish production as per data introduced in Chapter 5. The regression curve – though not statistically significant, indicates that indeed fish production reduced about 50% every 12 years after 1992, until all fish would die already in 2025 under a BAU scenario. To be on the conservative side, fish production losses of 50% are assumed not for a timeframe for 12 years, but for 20 years, as in Tonle SAP. Extrapolating data in this way, experienced income losses between 2012 and 1992 were then 470,768 USD and 23,538.4 USD annually

Total future production which would be expected in fishery under a BAU scenario would be 99.821,7, then end, according to the outcomes of the regression analysis. Though this is not statistically secured, it coincided with the perceptions of communities, which might be the most severe warning, as fish is an important species in the ecological web and has other side effects.

Figure 27: Accumulated Productivity in Fishery 2000 – 2040 calculated from Regression on CSES Data



SUMMARY OF COSTS FROM EROSION AND SEDIMENTATION

Table 18 summarizes the costs of erosion and sedimentation. The costs in the fishery sector are in the same way also created by pollution, as introduced in the next chapter, but cannot be cured with the same remedies as drinking water, therefore are listed here. The total costs for dredging are based on the assumption, that the needs for dredging linearly increased with increasing sedimentation, the costs for gate operation are included here.

Table 17: Summary of Costs from Erosion and Sedimentation

	Total Units	Unit price	Costs Annually	Costs 20 years (1992-2012)
Dredging	15 km out of an area affected by sedimentation of 15,013 ha	10 USD / m	1,500,000	15,750,000
Foregone Losses from Fishery			23,538.4	470,768
Total			**1,523,538.4**	**16,220,768**
Costs per ha / All PTWS			**2.307**	
Costs per HH / All PTWS			**3.94772704**	

The dredging costs have to be considered separately from the costs of increased fish mortality, as they in particular also contribute to reducing further losses created by exacerbating disastrous flood conditions.

Other Data

The prices assumed seem to be realistic in comparison with the other studies, as presented in Table 7.1.3.2, as the area is more prone to erosion than for instance in the Siem Reap Park in Cambodia, on the other hand value losses will be less than in the Sumatra National Park, while the costs for prevention are lower than the cots from losses, which is normally the case. The costs for prevention considered here are higher than in the data for Philippines and Laos, as they have also to reflect the risk level of degradation, which is extremely high in the areas considered in Cambodia, while the very low value for Laos is in an area with very low development.

Table 18: Results from Other Studies .

Country	Cost/ha	Type of Cost	Reference
Indonesia, Sumatra, National Park	**900**	Prevention	Van Beukering, P.J.H., H.S.J. Cesar and M.A. Jansen (2003) Economic valuation of the Leuser National Park on Sumatra, Indonesia. Ecological Economics 44(1): 43-62.
Laos	**2,97**	Prevention	Rosales, R.M.P., M.F. Kallesoe, P. Gerrard, P. Muangchanh, S. Phomtavong and S. Khamsomphou (2005) Balancing the returns to catchment management. IUCN Water, Nature and Economics Technical Paper 5, IUCN, ecosystems and livelihoods group Asia, Colombo.
Cambodia, Riem National Park	**122**	Avoided Costs	Emerton, L (ed) (2005) Values and rewards: counting and capturing ecosystem water services for sustainable development. IUCN Water, Nature and Economics Technical Paper No. 1, IUCN — The World Conservation Union, Ecosystems and Livelihoods Group Asia.
Philippines	**268**	Losses from Fishery due to Sedimentation and Eutrophication	Hodgson G. and J. Dixon (1988) Measuring economic losses due to sediment pollution: logging versus tourism and fisheries. Tropical Coastal Area Management 3(1): 5-8

Philippines	**57**	Erosion Prevention	Cruz, W., H.A. Francisco and Z.T. Conway (1988) The on-site and downstream costs of soil erosion in the Magat and Pantabangan watersheds. Journal of Philippine Development 26: 85-11.

7.2. NUTRIENT RETENTION AND DELIVERY

For the process of nutrient retention and delivery, the case of nitrogen is illustrated here as an example, but the dynamics for phosphorous, and one can estimate the nitrogen to phosphorous concentrations in agricultural production system has a relation of 10:1. The processes of nutrient export into water resources stand also for pollution processes of other chemicals, also hazardous substances. Therefore, the processes of nitrogen export and diffusion to water resources happen in similar ways also to other contaminants, especially those ones which do not react with the soil matrix.

7.2.1 NUTRIENT RETENTION

Nutrient retention and delivery are antagonistic processes. On the one hand the land user wishes to accumulate as many nutrients as possible in the top soil to ensure productivity, on the other hand, nutrient leaching into water resources should be minimized, as too high concentrations of nitrate, nitrite, and of pesticides other nutrient components have negative heath impacts, if reaching drinking water. Especially high phosphorous contamination is responsible for eutrophication, as it stimulates rapid production of phytoplankton, algae, invasive water plants such as the water hyazinth and other organisms, which reduce the oxygen status of water resources and at the end causes fish mortality and the disruption of the whole ecology of aquatic systems.

Assessment of Nutrient Retention Potential of the Ecosystem

The retention potential for nutrients of ecosystems is characterized by

a) The nutrient retention capacities of ecosystems
b) The distance to the next wetland, therefore, the extent of the buffer zone between the wetland and the cultivated agroecosystem. ….

The nutrient retention capacities of ecosystems depend on the nutrient retention capacities of soils and of vegetation. Nutrient retention capacities of soils were assessed from CEC values of the soilgrid250 data, which are rather in the low to medium range. Nutrient retention capacities for the vegetation classes were obtained from standard data as indicated in the INVEST models, with highest capacities for evergreen broadleaved forests, followed by deciduous forests and mixed forests, with lowest capacities for agricultural crops. Usually the RAMSAR Convention, to which Cambodia is a part of, demands an extent of buffer zones from wetlands of at least 50m. These distances were also inquired during the field visits. It was reported, that in some cases buffer zones were observed by small-holders, while private owners would not. Forests themselves are considered a buffer zone vegetation.

Nutrient Loads

For assessing nutrient loads as input data, the chemical fertilizer application rates were assessed, and for the newly established ELCs in addition the freshly mineralized nutrients from organic matter, which are released after conversion of forest land.

According to Worldbank, the average fertilizer use in Cambodia is therefore only 25.7 kg/ha (Worldbank data, accessed September 2018), although during field visits communes said they also use up to 50 kg/ha.

For plantations an application rate of 100 kg N-fertilizer was assumed. Additionally, with carbon amounts of about 220 t of carbon per ha, a released amount of 100 kg N/ha and 10 kg P/ha was assumed, leading to a total nutrient load of 200 kg N/Ha and 20 kg P.

Therefore, while the nutrient retention capacities of forests are much higher than the ones of cropland, the opposite applies for nutrient loads. Retention capacity of tree plantations, such as of mango and teak plantations, lies between the one of cropland and forest land, but nutrient loads applied in plantations have to be much higher than of other agroecosystems, to ensure high productivity.

Accordingly, the total nutrient pressure on ecosystems is lowest in forest ecosystems and highest in agricultural land. The pressure to high nutrient inputs is higher in industrial agriculture and for private land buyers, as the current land prices drive commercial farmers into an intensive production system which has to achieve yields, that justifies the land prices. High yield production demands also high inputs. On the other hand, smallholders who inherited the land are on the one hand not under the pressure to use high input levels, on the other hand, they productivity is so low, that they usually do not have the investment capacities to afford high inputs, which is partly a poverty trap.

Pesticides

No data are available on the pesticide use in agriculture, there are just aggregated data on the costs of chemical fertilizers and pesticides together by the CSES studies, although the application of pesticides implies much higher threats to human health than chemical fertilizers. Therefore, while the data for pollution are only calculated here for nitrogen and phosphorous, the expansion of pollution is occurring in the same areas as for nitrogen, without however knowing the concentrations.

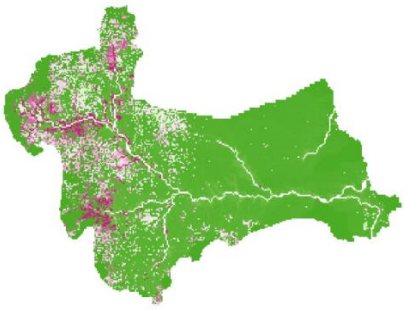
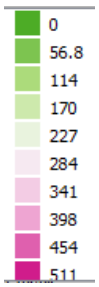
7.2.1.RESULTS

The ecologic modelling was based primarily on the establishment of different scenarios, which were: a) high nutrient loads in agriculture, high extent of buffer zones for 1992 and 2012

- Low nutrient loads in agriculture (25 kg), with different extent of buffe rzones (25 m, 50 m and 300 m) for 1992
- Low nutrient loads in agriculture, with different extent of buffer zones (25 m, 50 m and 300 m) for 2012
- High nutrient loads in plantations for the situation of agricultural land after forest conversion as it is the current situation (200 kg N), medium nutrient loads on smallholder's land in 2012, no buffer zones around plantations.

Figure 28: Pollution Scenarios

1992 with average fertilizer application in agricultural areas	2012 with average fertilizer application in all agricultural areas
	

2012 with average fertilizer application in smallholder farms and assumed high in ELCs 	Legend (kg N/ha) 

The results show the following:

- Independent from the absolute amount of nutrients, highest nutrient export to the water system is around more than double the rate of the nutrients applied, and nutrient transport through the water systems is only of secondary importance. Therefore, the spatial distribution of nutrient concentrations is coincident with the amount of nutrients applied in these locations, and only small proportions are transported farer away through the river system. This means, under forest ecosystems there is usually clean water, but as the water is draining Eastward, the retention or cleaning function of forests has no influence to further reduction of pollution in the East. On the other hand, also high pollution for instance from plantations is not transported far into the Eastern transition zone or the flood plain. No extra model was run for the 50 kg N input assumption, as the results would simply lead to the double amount of the 25 kg version.
- Higher deforestation releases high nutrient loads, therefore in areas which have been deforested, high pollution can be observed, especially, when they are converted into plantations with additional high fertilizer application rates, where the recently upgrowing trees do not have the potential to retain substantial nutrient amounts. Almost everywhere, these areas present a threat to human health, if the water is consumed without further treatment. Even the low rate of fertilizer application of around 25 kg N in agricultural plots of smallholders exceeds the WHO guidelines for maximum nitrate concentrations for drinking water, which is about 50 ppm. With buffer strips the diffusion of contaminants can be reduced, but not fully prevented.

7.2.2. IMPACTS AND COSTS

There are different options for stakeholder to deal with increasing water pollution:

- Travelling farer to collect clean water from remoter areas, which creates travel costs
- Accepting health impacts without addressing pollution. Creates non-monetary impacts or increased medical costs
- Water Treatment, which creates treatment costs.

Enhanced Travel Costs

To ensure the provision of clean drinking water for the population of a country or a watershed requires minimum coverages of forests due to their positive functions on water purification as described above. Agricultural areas are not able to provide drinking water according to WHO standards of 50 mg/l nitrate, equivalent to 11,3 mg N, let alone standards for other chemicals. Usually, the removal of nitrate is so costly or hardly possible, that

therefore special forest or grassland zones are designated as drinking water zones, independent of the technical development status of a country. Especially in areas, where water is not piped over longer distances, such as in the rural areas of Cambodia, the population needs therefore forest reserves to provide themselves with good drinking water qualities.

At least 25% of the people in rural areas of the Prek Tnoat collect water from streams and ponds (CSES reports 2013-2016). With the vanishing of forests, they cover farer distance for the collection of clean drinking water. For instance, people from Chambak reported, that they collect water from Kirirom park now, because it is cleaner there (Field Visit 2018). Alternatively to water collection from streams and ponds, rainwater collection schemes are also applied by about 25% of the population in Prek Tnoat. This, however, has some disadvantages due to their seasonality and vulnerability to damages and contamination.

As clean drinking water is obtained from forests, as the same way as non-timber and timber products, the increased travel costs for drinking water collection are considered as equal as the increased travel costs for obtaining other forest products. This is only done for the part of the watershed, which belongs to Kampong Speu, as this is the only area, which still has clean groundwater under the forest which comply with WHO standards.

These are listed in Table 20 for the Prek Tnoat WS in Kampong Speu only.

Table 19: Travel Costs for Kampong Speu to Next Forest Areas

Costs Forestry in USD	2014	2015	2016
Travel Costs	241,614	954,437.2	1,105,222.8

Health Impacts

Health impacts were not assessed and should be strictly avoided. According the positive message is that according to UNICEF reports, child mortality below 5 years is continuously declining in Cambodia.

Water Purification Costs

Nitrate can be purified from drinking water by applying chlorine, chloramine and ozone, which will oxidize nitrite to less hazardous nitrate. Reverse osmosis methods for anion exchange are mainly conducted in waste water sewage plants.

Water which is sold in containers of 240 l/4 USD is usually treated with chlorine. Therefore, replacement costs through bottled drinking water were based on the assumption, that clean drinking water, which can be purchased in 240 l quantities, costs around 1.7 cent /litre water, that one person needs at least 3 l/ day, which would be about 1095 l a year, amounting to costs of 18,25 USD/person annually. For comparison, Unit Operating Costs for water purification in Canada with anion exchange methods are assumed to range around 0.59 and 2.16 USD/m3 for chlorination. Therefore, the costs assumed as a baseline here are also very conservative.

Assuming that the whole population, in particular in Pnom Penh would be in need to buy bottled water or receive pure water from the tap, would – alone due to pollution from deforestation in the Upstream areas, create annual costs of **37,847,397.5** USD, out of which the bulk is based in Pnom Penh, whose water quality is also affected by the water quality in the Prek Tnoat Watershed.

Losses in Vegetable Production due to Chemical Pollution from Pesticides

Vegetable production on small patches of 0,2 ha is widely encouraged by NGOs and Government as an alternative However, especially vegetable farmers associated to an organic marketing cooperative complained, that they were unable to meet organic standards due to spill-over effects of pesticides from ELCs. This is only mentioned here for completeness of the impacts. The foregone losses from pollution in the vegetable sector cannot

estimated here, as the total area of newly emerging vegetable production is not known, secondly there are other overlapping problems such as high soil acidity which is unfavourable for vegetable production and a lack of demand for vegetables. Nevertheless, they are mentioned here, to highlight the problems that vegetable farmers face due to pollution.

7.2.2. NUTRIENT CYCLING

There are two forms of values from nutrient cycling considered:

- Nutrient cycling by decline of livestock numbers
- Nutrient losses of disruption of nutrient cycling within the larger ecosystem due to forest decline.

Nutrient Losses Through Losses of Manure

For assessing the forgone losses of nutrient cycling through manure, the loss of livestock numbers was multiplied with the average faeces produced per species, year and their nutrient content. The value was then multiplied with the current price for nitrogen, which is 3,33 USD/kg of pure nitrogen (compare Annex).

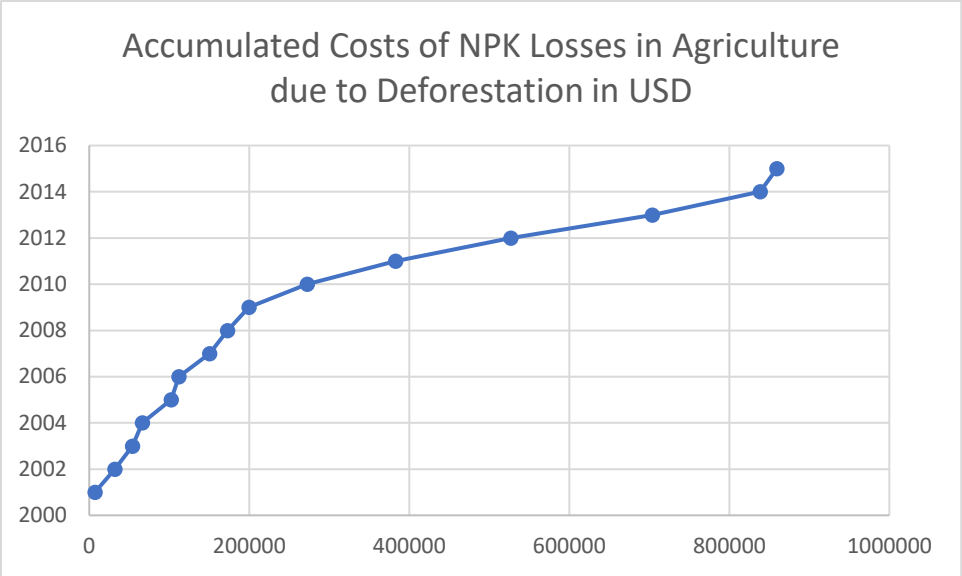
This would lead to values of 20444 thousand USD N annually in manure in the JICA WS, and to around 82000 USD in the UNDP WS in 2019, with 33 % losses in 2014, when highest rates of destocking occurred.

Agricultural Productivity Losses through Impacts on Nutrient Cycling by Erosion

Erosion increases surface runoff as described in the former sections, which is taken into account in the seasonal water model. The other negative impact of soil erosion is topsoil loss, which is related also to nutrient losses. The value of nutrient loss is assessed by using the benefit transfer functioning method from the assessment of nutrient cycling data from the ELD Asia report (2017). In the ELC report it was calculated that a 1 % increase in arable and permanent cropland area would cause NPK loss (kg/ha/year) to increase about 0.156 %n and soil NPK depletion (1000ston/year) to increase by about 0.505 % and vice versa (Source ELD Asia, 2018).

From these functions NPK losses from were calculated based on to the Hansen data. With an annual deforestation of 1,5 % and average fertilizer application of 25 kg NPK/ha and prices of 3,3 USD/kg, this would lead to annual costs of additional fertilizer needs of additional costs of 12,57 USD/ha, which would amount to annual costs of additional fertilizer demands for about 4823 ha of 62067 USD/ha, which would amount to additional replacement costs of about 931,006.791 USD.

Figure 29: Accumulated Costs of Nutrient Losses



7.2.3. RESULTS

Travel costs would increase exponentially if the whole watershed would travel to the Eastern parts of the watershed to get clean water. Theoretical a combination of these activities in the appropriate areas coud reduce total costs, but the very parameter, which covers the water demands for clean water for all persons in the Watershed are the replacement costs, as it will not be a realistic option for everybody for travel to a PA zone for drinking water collection. The cost assessment is related to the area affected and does not take into account the concentrations of water which will have to be purified, which will be higher with increasing concentrations. Also no efforts are undertaken to relate the pollution data to deforestation only, as besides deforestation, which contributes to a release of estimated 100 kg N/ha in the first years after forest conversion, there are other factors which play dominant roles.

Table 20: Overall Costs Caused by Pollution [USD]

	Replacement Costs	Protection Costs for Surface Waters	Opportunity Opportunity Costs	Replacement Costs	Protection Costs for Surface Waters	Opportunity Costs: Travel and Transport Costs .	
Annual costs for chlorinized water	**37,847,397.5**						
Increased transport costs for Upper Watershed only			1,105,228				
Buffer strips (50 USD/ha)		1,000,000					

Total Costs	21,738,300					
Per ha / Total PTWS	32,9174					
Per HH / Total PTWS	56,327346					

Data for Comparison

As there are no other data for water purification values of ecoystems for Cambodia.. The values of water purification in the ESVD data basis vary between 3 USD in Lao to 311 USD/ha in South Africa. The total value of nutrient cycling in Xishuangbanna Corridors of China was estimated for Broadleaved forests about US 1,102 ha per year (Rattanak 2014). The data calculated here are the lower side, which might be due to an underrating of the water purification price. Rattanak (2014) cites data from China. In Xishuangbanna the estimated purification values of broadleaved, respectively coniferious forests were US$1,123 per ha and year. If water purification costs are related to broadleaved forest areas only, these would also be the data applicable here.

Conclusion

The ecology and hydrology in the Prek Tnoat watershed is very complex, and the coarse models applied here do not claim to explain all these complexities. Especially the sediment retention model is highly sensitive to the different input parameters. Accordingly, the economic valuation arising from these models can also be no more than coarse. In particular, it will be difficult, to separate the impacts of sedimentation and nutrient export, whose costs are therefore considered together in some cases.

Nevertheless, apparently the observed changes have an impact on fishery, agriculture and human health, costs of irrigation, and on necessary mitigation measures which are necessary to maintain the system

8. BIODIVERSITY

8.1. ECOLOGICAL VALUATION

There are different hotspots of biodiversity which include

- protected areas managed by the MoE
- protected forests and other site-based conservation areas that are managed by the MAFF
- community managed forests.

Within the watershed, the area of PAs totals 132,772 ha. All PAs reaching into the Prek Tnoat watershed belong to the Cardamom landscape, out of which they just present a small corridor of 100 – 200 km extent in the East, with larger areas in the North. They are the following ones:

- **Central Cardamoms Protected Forest:** It was established in 2002 with an area of 401,313 ha. The protected forest connects Phnom Samkos and Phnom Aural wildlife sanctuariy, which reaches into the Prek Tnoat watershed. The area contains large three of the most threatened ecosystems in the region: lowland evergreen forest, riparian forests, and wetlands. It is home to the Asian Elephant, Indochinese Tiger, Pileated Gibbon, Siamese Crocodile, and other globally threatened wildlife, and while not all of these ones are still found in the Prek Tnoat watershed, this part is still necessary to protect the quality of the habitat at its edges.
- **Southern Cardamoms Protected Forest**: Established in 2004 with an area of 144,275 hectares (Royal Government of Cambodia [RGC], 2004). Vegetation types in this area are a combination of dry evergreen forest, melaleuca woodland, and grassland. The protected forest connects the Botum-Sakor National

Park to the Talam village community, Dong Peng Multiple Use Area, and Kirirom National Park, which reaches to a small part into Prek Tnoat Watershed. It provides habitat for globally endangered wildlife such as the Asian Elephant, Indochinese Tiger, Pileated Gibbon, and other birds. This area still plays a critical role for the Asian Elephant providing a corridor to move from the Botum Sakor all the way to the Kirirom and possibly Bokor National Parks (Sun Hean 2014).

- **Kirirom National Park was** established in 1993 with an area of 35,000 hectares, largely covered by semi-evergreen forest, with drier deciduous forest at lower elevations and an extensive area of pine forest on a central plateau (Japan International Cooperation Agency [JICA], 2003). The park provides habitat for the Asian Elephant, Indochinese Tiger, Malayan Sub Bear, Pileated Gibbon, Indochinese Lutung, Pig-tailed Macaque, Stump-tailed Macaque and other globally threaded birds. A new species of Harrison's Tube-nosed Bat was also discovered in this park. In the park the Kirirom I and III hydropower dam is located and it also offers ecotourism facilities (Sun Hean 2014)

Community forests

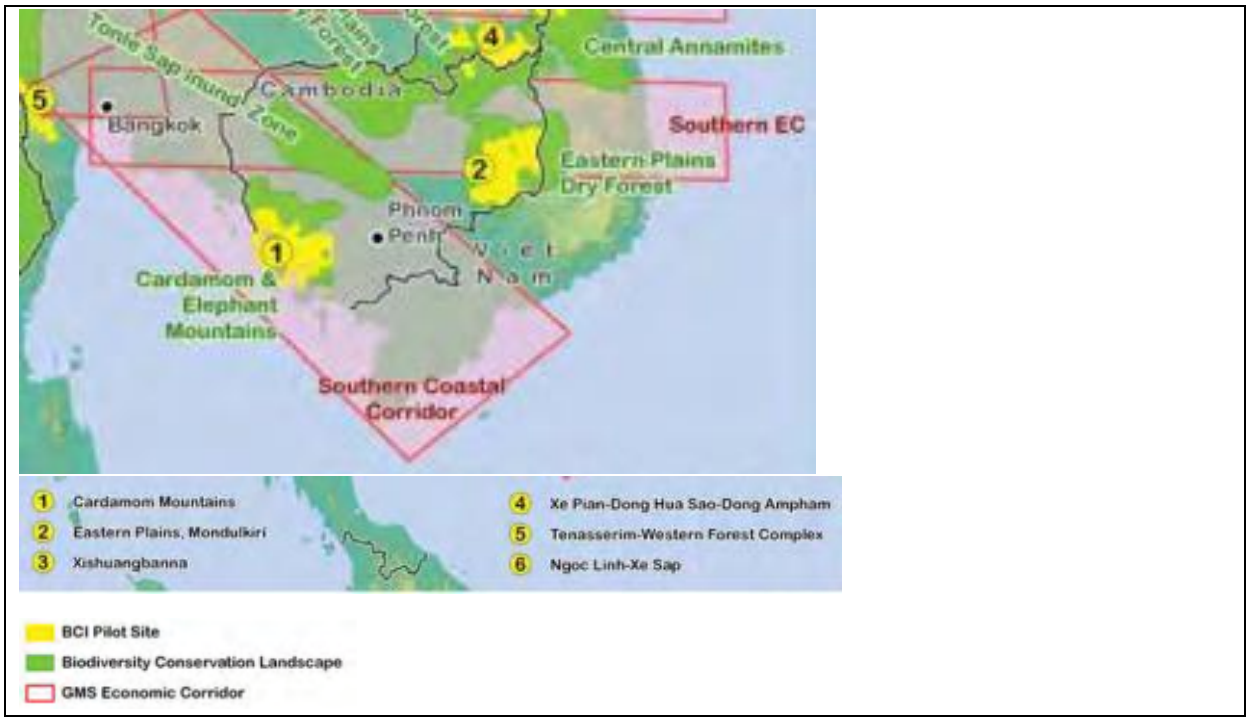
Community Forests are located in the sustainable use zones of the PAs, and usually secondary forests with many bamboo stands, as already described in Chapter 4. They are managed in different ways

- Chambak Forest: Within the Upper Prek Tnoat Watershed it is mainly Chambak forest, which is managed as a community forest project for ecotourism. It is a secondary evergreen forest with evergreen and deciduous broadleaved and coniferous species and bamboo stands near water sites
- Krang Devay is a community forest managed collaboratively for the sustainable use of its resources. It is funded by the APFnet and together the communities established a rotational sustainable use plan, which includes rotational charcoal production and collection of non-timber forest products, which allows communities to earn a sufficient income from forest use.
- Tasal community applied for the status of a community forest, but depleted the forest before it was approved. Apparently the community faced also high pressure on forest resources due to the establishment of an ELC in the forests of Tasal commune.
- Currently Trapeang Chour is on the verge of applying for community forest status. Trapeang Chour has still a small proportion of valuable primary forest sites of broadleaved evergreen species. The forests contain partly commercially very valuable non-timber forest species, such as orchids or mushrooms, snails and sweet bamboo, which achieve high prices (Consultancy Visit 2018). The downstream areas of the forest however are widely inundated.

Connectivity and Corridor Projects

The species rich areas which remain, are highly fragmented, which disables the movement between different habitats. Therefore the BCI has called for a corridor project which connects the Northern with the Southern protected areas and and for reconnecting Bokor to Kirirom National Parks (compare Fig. 31) Planting of some core areas with native species is one of the rehabilitation strategies. A reforestation program is going on by Wildlife Alliance in the Western Cardamom landscape to establish these corridors, this is not reaching the Prek Tnoat watershed. (Sun Hean 2014).

Figure 30: Biodiversity Corridors and PAs in lower Mekong Basin



Source: BCI 2010

Biodiversity and Spiritual Values

Highest community commitment – in terms of value of labour and material inputs – are currently given to the small parks or forests around pagodas. Stakeholders are investing time and seedlings to afforest areas around pagodas for spiritual purposes, and at the same time contributing to biodiversity conservation and carbon sequestration. Assuming, that there are pagodas in every 5th community with a forest area of 2 - 3 ha, this is just is an area of 90-100 ha. This sounds small, but these areas have the potential to act as in situ conservation areas for biodiversity. Therefore, the NBSAP 2002 mentioned Buddhist Wat communities as potential drivers to promote community management, as "Conserving biodiversity and sustainably using biological resources are fundamental to reduce poverty and improve the quality of life of all Cambodians. These goals are an echo to the teachings and beliefs of Buddhism on the obligation for man to maintain balanced relations with the other elements of creation". (NBSAP 2002). Buddhist Wat communities are also mentioned as drivers to promote community management.

8.2. ECONOMIC VALUATION

For the valuation of biodiversity, contingency valuation is used to assess the existing and potential values of biodiversity. The Habitat Risk Assessment Methodology is used for assessing the foregone losses by damages to the habitat due to allocation of parts of PAs to ELCs.

8.2.1 CONTINGENCY VALUATION

For the contingency valuation the local gross income from tourism and the travel costs are used, based on the experience of the Chambak community forest ecotourism project. The income from ecotourism is a feasible tool for valuing biodiversity in general, because biodiversity is the basis for the benefits from natural attractions.

Figure 31: Chambak Tourism

Fig. 8.2.1. Poster in Chambak Ecotourism Resort, which shows flags of countries, where international tourists originate from	Fig. 8.2.2. UNDP visitors with their Host in front of a Homestay Hotel
	

The gross income from tourism according to the Annual report of 2017 was 57,000 USD, and with a household number of 719 (whole community, not only the ones involved into tourism, which are 520 households according to field visit data), this is equivalent to a gross income of almost 168 USD, therefore, similar to the income from forest products, which can be additionally gained. These incomes are much higher than the ones calculated for other areas in Cardamom forest of hardly more than 1 USD by Hean (2014).

This gross income is less than the expenses, which tourists really paid to see Chambak forest.

According to the Annual report by Mlup Baitong, 16000-17000 tourists visted Chambak forest. Assuming that foreigners had an expenditure of 1000 USD per flight, and nationals of 100 USD to reach, and assuming that a share of 10% can be attributed to the visit to Chambak (among other targets in Cambodia), the total travel expenses are 995,000 USD. The total value that is therefore given for Chambak forests is then 1,052,000 USD, which is more than 3,000 USD per ha and more than 1000 USD per household and year. However, this amount is not realized by communities but by foreign travel agencies.

Box 8.1. Key Data Chambak Forest

- Forest size ; 340 ha
- 15000-16000 visitors per year from 60 countries, half of them from overseas.
- High season September – March
- Low Season: April-June
- Around 15 000 – 16 000 visitors
- Accomodation concept: Homestay with a rotation plan, 20 tourists per house
- 1 house receives 20 visitors
- One visitor pays 4 USD ..
- 1500 Riel per visitor are paid as benefits to community
- Entrance fee forest. 1 USD
- Community receives symbolic fees from Vittel water company

Potential Future Income for Ecotourism in Trapeang Chor

There is a currently ongoing effort also in Trapeang Chor to apply for an ecotourism project with support by Mlup Baiting. It can be assumed, that incomes from Trapeang Chor can be even higher, as the forest still contains more broad-leaved evergreen species with a multistorey canopy and interesting medical species, such as mushrooms. An additional attraction are the inundated areas below the forests, with quite romantic places and fishing boats. All this might therefore keep tourists a few days longer in Trapeang Chour than in Chambak. The attraction is nevertheless quite ambiguous, as the flooded area and growing water hyacinths indicate rather an ongoing collapse of the ecosystem, as is discussed in the following section.

Future Prospects

In general, it does not seem to be difficult to triple or even quadruple the income from ecotourism in Chambak and Tranpeang Chour, if accompanied by a certain interesting program such as fishing, botanical excursions, bird watching, horse riding, local dancing and spiritual courses etc., which would require the respective capacity building of the communities in tourism. To avoid competition between different ecotourism projects, a specialization on specific attractions is recommendable.

The positive side of ecotourism is also, that it provides many and new income opportunities for women. For many women it was the first opportunity to generate substantial income.

8.2.2. COSTS OF HABITAT LOSS AND HABITAT DEGRADATION

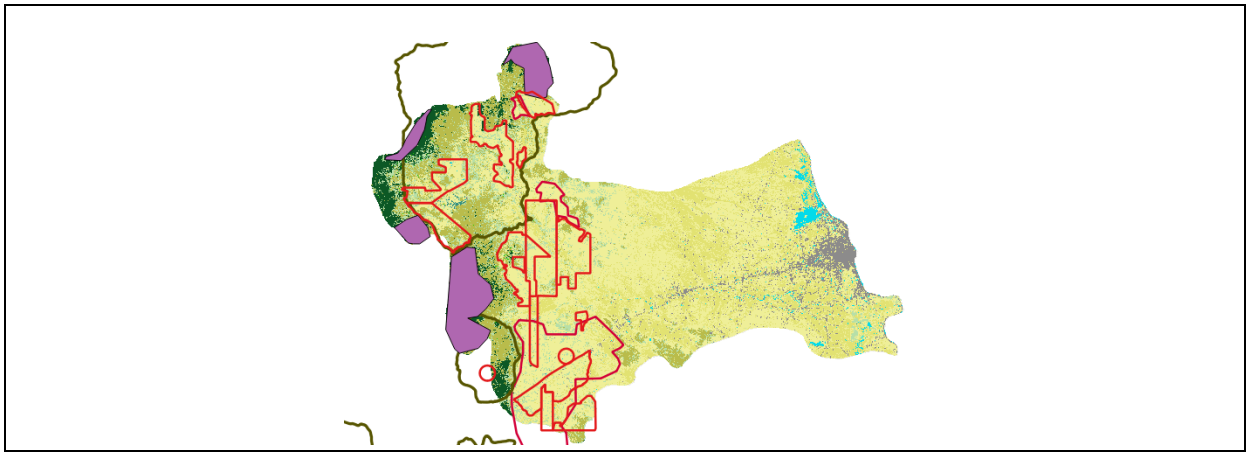
The area occupied by the 4 ELCs in the Protected Areas in Phnom Aural is 10,490 ha. One ELCs located in Kirirom National Park has an area of 2,829.1 ha. Table 30 lists the ELCs present in those areas.

Table 21: List of PAs in Wildlife Reserves and Pas Table 8.2.2.1 ELCs in PAs

Developer	Area (ha)
HLH Agriculture Cambodia Co. Ltd.	2,578.53
Great Field (Cambodia) International Ltd.	2,578.53
Yellow Field (Cambodia) International Ltd.	2,578.53
Cambodia Haining Group Co. Ltd.	2,578.53
Kampong Speu Sugar Co. Ltd.	2,578.53
Jian King (Cambodia) International Investment Co. Ltd.	2,829.15
Total	13,175

Source: opendevelopmentcambodia.net

Figure 32: ELCs over PAs and Wildlife Reserves



According to governmental statements, concessions to investors/developers are only granted in the sustainable use zones of PAS. “In general, these areas are of low qualities for biodiversity and wildlife conservation. It can be put in other words that the biodiversity and wildlife are not seriously affected by these concessions. In contrast, it contributes to protection and replenishment of biodiversity as it works as the flood protector in the country”. This means, that no further opportunity costs for biodiversity conservation are assumed by the government, but instead synergies. It is further stated, that these concessions protect the core zones against local communities, “who formerly used them for their livelihood” (FLEGT 2014). Ironically, there are reports, that especially the allocation of concessions in Phnom Aural has given access to illegal logging by ELCs themselves[7].

Moreover, industrial agriculture and tropical forests are “uneasy neighbours” due to their different nitrogen cycling regimes. Forest soils are usually poor, and nutrients are mainly cycling in the above-ground biosphere. On the other hand, intensive agricultural systems have to rely on high nutrient contents in soils. Therefore, the rate of chemical fertilizer application is accordingly high in industrial systems. As the models have shown, high nutrient exports and sediments from ELCs reach also into the PAs of Phnom Aural (Compare Fig. 9.4). The conversion of forests inside and outside of the PAs has also changed the flow regime there, as highlighted in Chapter 6. Frequent inundations are submerging large areas of the protected forests and inevitably change the composition of their vegetation, while on the other hand in other seasons the water flowing from forests into the PAs will cause droughts. Instead of creating a buffer around the core zones of PAs, as apparently once had been mentioned as a reason for allocating concessions around core zones, PAs have contributed to irreversible damages within those core zones.

8.2.3. CHANGES IN SPECIES RICHNESS

Forest plantations in the PAs are not able to support the rich faunal and floral richness which has existed there before, nor the scenic qualities, therefore, they do not have any replacement value.

For the protected areas the Walm page[8] records almost similarly around 900 different faunal species, which are listed in Annex II for the Northern protected area under MoE. Birds cover 463 species alone, mammals, 121 mammals, non-marine turtles, amphibians, a high population of insects, while fish species are actually the smallest number, among them Pangasius and Chinese noodlefish. This number is about 30% smaller than in other areas of Cambodia. Annex II lists also species of greatest concern for the Cardamom areas. In comparison, for the part of the Cardamom mountains about 1200 species are listed on an average, while the deforested or degraded areas outside the PAs in the Prek Tnoat watershed contain about 600 species. This is a non-monetary value, which cannot be monetized, as it is invaluable.

8.2.4. FINAL EVALUATION OF COSTS AND BENEFITS OF BIODIVERSITY

The total area ELCs in Upper Prek Tnoat Watershed is about 44,000 ha according to MAFF data 2018. Within PAs the coverage of ELCs is 13,175 ha, according to cambodiadevelment.org data. If the area would have used for ecotourism, visitors would pay about 1,010 USD per ha, out of which 10 USD / ha would benefit local communities. Furthermore, there are foregone losses for communities between 40 USD/ ha from non-timber forest production, as has been calculated Chapter 4, leading to opportunity costs of 1050 USD/ha annually. Additionally, there are foregone carbon credits of 280 USD and biodiversity values accounted for by Brander (2015) of 650 USD/ha. In total the forgone losses per ha ELCs in a PA are then in total 1980 USD/ha, which is about equivalent of profits made from rubber farms. On the other hand, the first benefit sharing regime from the side of ELCs starting in the communities gives a share of 25 USD per ha ELC size to communities and as well as fertilizer bags of higher concentration of NPK to the original price of 30 USD/bag than the ones which are commonly available on the market. This might be an additional benefit to each farmers of about 10 USD. There

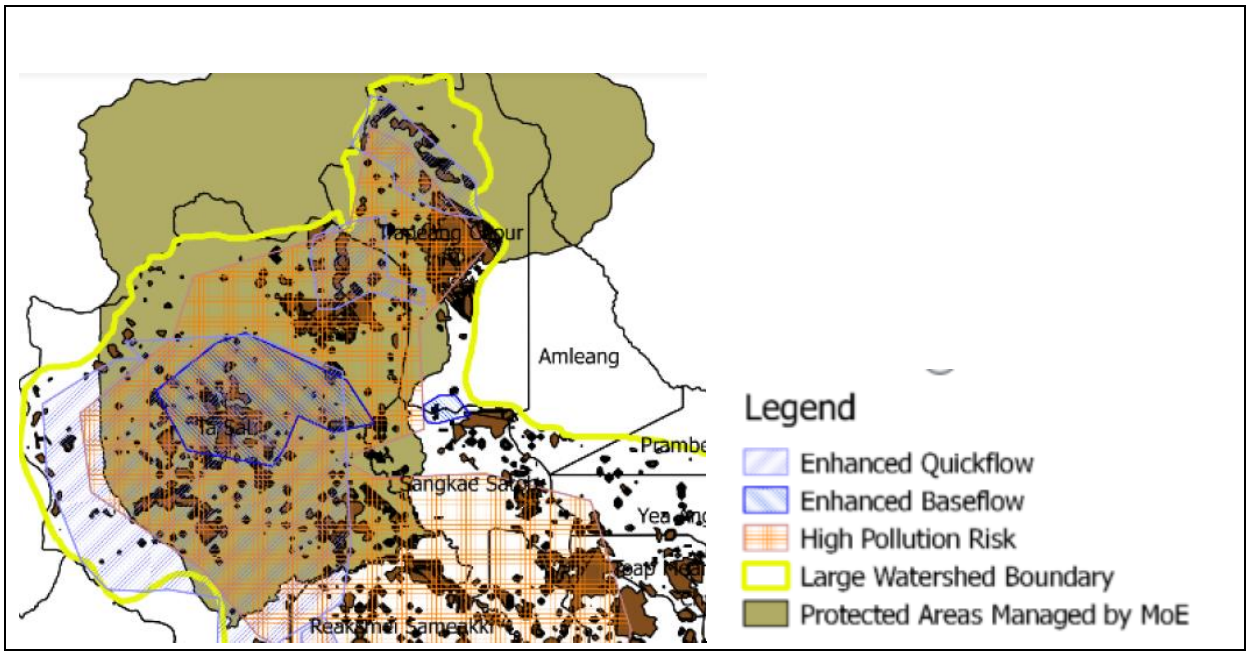
https://www.cambodiadaily.com/news/sugar-plantation-caught-illegal-wood-118908/

[8] www.walm.org

are also temporal incomes provided to community members which generate seasonally 100 – 200 USD. Last not least, Phnom Penh Sugar has published on its website that it also distributes umbrellas and raincoats among communities and has established a water purification plant within the ELC premises.

Comparing costs and benefits of ELC farms with the use of PAs, ELCs are only more profitable, when they cultivate high value crops, with the difference, that those profits benefit neither the country and the community, the income from the mentioned activities by communities do, though not all can immediately be converted into cash, which might create problems for a government to decide on environmentally responsible allocations of entitlements and resources, while at the same time achieving the necessary liquidity for development.

Figure 33 Environmental Pressures on Phnom Aural Wildlife Sanctuary



Additionally, to the losses of provisioning services there are also costs for damages to the environment. Above all, the mentioned inundations, sedimentation and pollution, which affect parts of the PAs, which is about 3 times as large as the ELC areas themselves.

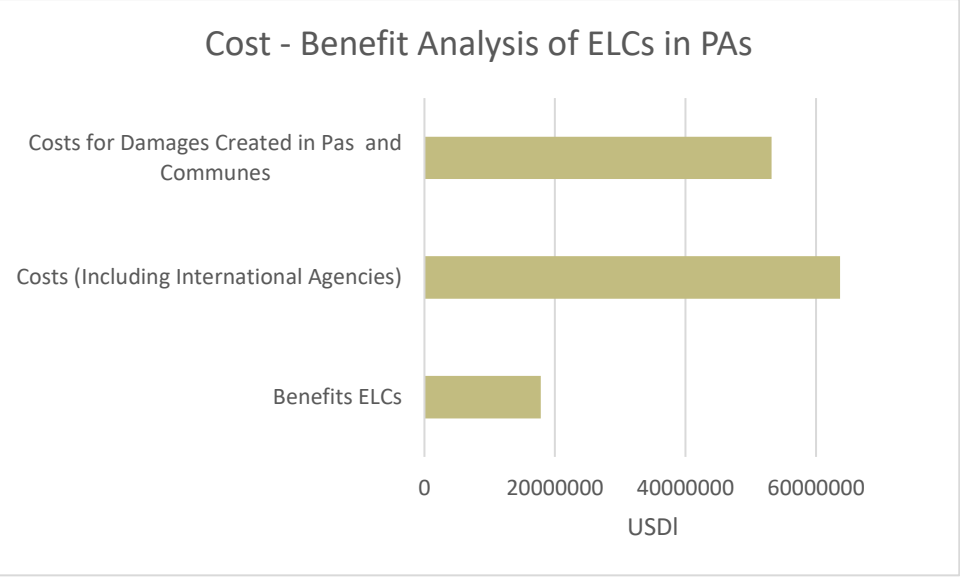
Table 22: Final Valuation of Biodiversity Losses due to ELC

	Costs per Unit [USD]	Units	Total Annual Costs
Foregone Losses International Agencies	1000	10,490	10,490,000
Foregone Losses Ecotourism Communities	168	10,490	1,762,320
Foregone losses from forest products for communities	40	10,490	419,600
Foregone losses carbon	2690	10,490	28,218,100
Damages floods	63,094	30,470	1,922,474.18
Damages Sedimentation	2,307	30,470	70,294.29
Damages through pollution	32,82	30,470	1,000,025.4

Species loss[9]	650	30,470	19,805,500
Total Costs Caused by ELCs in PAs (including International Agencies) [USD]			63,688,313.9
Total Costs Caused by ElCs in PAs (excluding International Agencies) [USD]			53,198,313.9
Total Benefits earned by ELCs in PAs			17,833,000

The total area of ELCs in Protected areas is 13,175 ha, according to MAFF data, which is a lower value than the assessment of the coverage of ELCs via google earth would indicate. If the area would have used for ecotourism, 168 USD/ha would benefit local communities and 1000 USD international agencies. Furthermore, there are foregone losses for communities between 40 USD/ ha from non-timber forest production, as has been calculated Chapter 4, leading to opportunity costs of 1050 USD/ha annually. Additionally, there are foregone carbon credits of 280 USD and biodiversity values accounted for by Brander (2015) of 650 USD/ha. In total the forgone losses per ha ELCs in a PA are then in total 1980 USD/ha, which is about equivalent of profits made from rubber farms. On the other hand, the first benefit sharing regime from the side of ELCs starting in the communities gives a share of 25 USD per ha ELC size to communities and as well as fertilizer bags of higher concentration of NPK to the original price of 30 USD/bag than the ones which are commonly available on the market. This might be an additional benefit to each farmer of about 10 USD. There are also temporal incomes provided to community members which generate seasonally 100 – 200 USD. Last not least, Pnom Penh Sugar has also distributed raincoats and umbrellas to its workers and has established a water purification plant on its farm, according to reports on their website. However, these benefits have not yet reached the respective PA areas, therefore could not taken into account in the cost benefit analysis, which has a relation of cost to benefits of 3:1, where in this special case the costs lie mostly with the communities (compare Fig 34 .

Figure 34: Cost-Benefit Analysis of ELCs in PAs



9. SYNTHESIS

[9] Price based on assumptions by Brander (2015) from Benefit Transfer. Normally biodiversity values cannot be directly monetized, as it is invaluable.

Fig. 35 gives an overview over the value of all provisioning services in the watershed achieved by smallholders. Clearly the highest value is achieved by agriculture. Fig 36 shows a slight decline of total provisioning services between 2014 to 2016. The proportion of provisioning services by ELCs is shown in Fig. 37 and Table. Certainly, the highest values are achieved by sugar cane, which has also the highest proportion in area. The average income per ha in ELCs is 1,500 USD/ha, the one of smallholders is about 280 – 360 USD:

Carbon values and sustainable extraction of timber can add substantially to the value of environmental services in the watershed.

Figure 35: Summary of the Values of Provisioning Services Generated by Smallholders

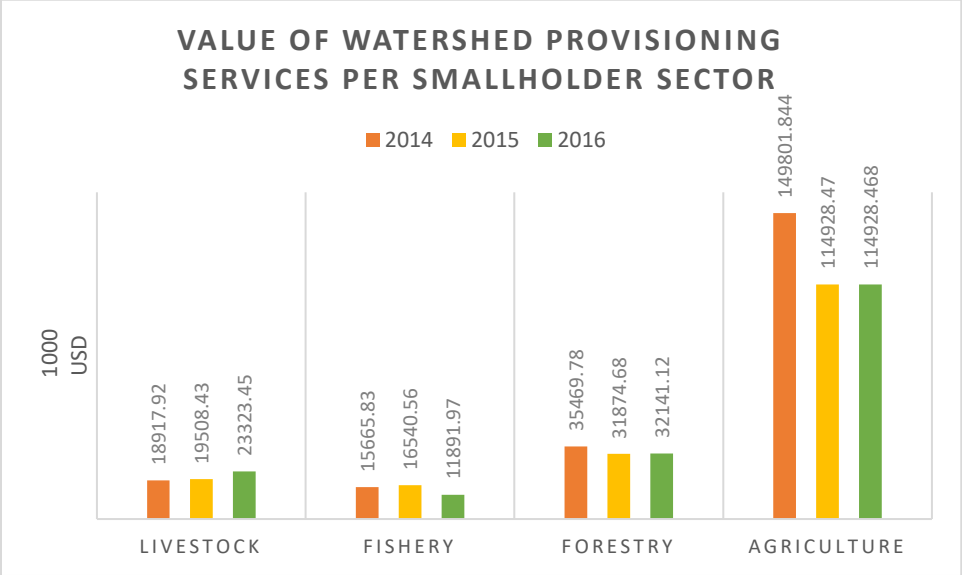


Figure 36: Total Provisioning Services Generated by Smallholders 2014, 2015 and 2016

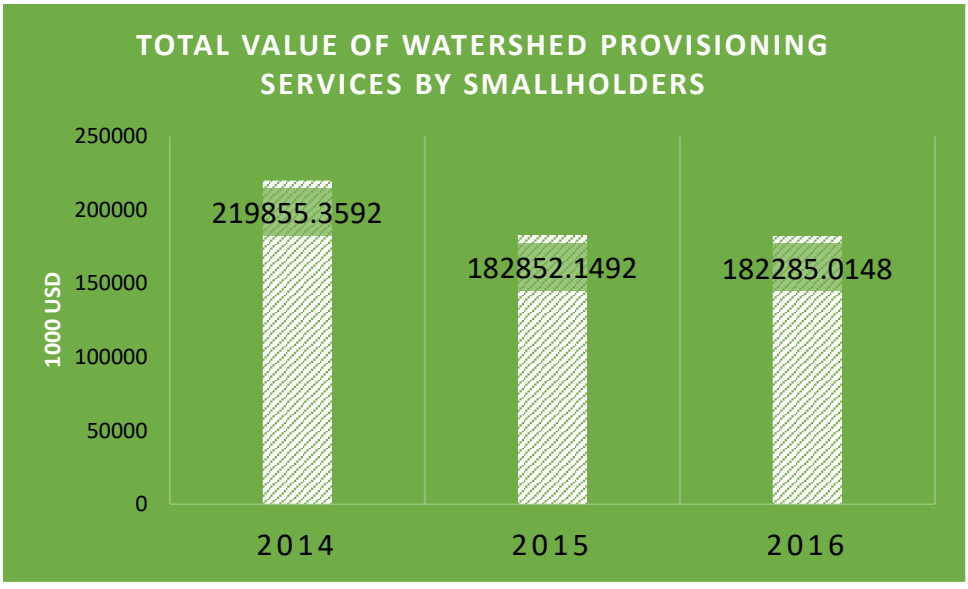


Figure 37 Proportion of Timber Crops in ELCs

Figure 38: Proportion of Crops in ELCs

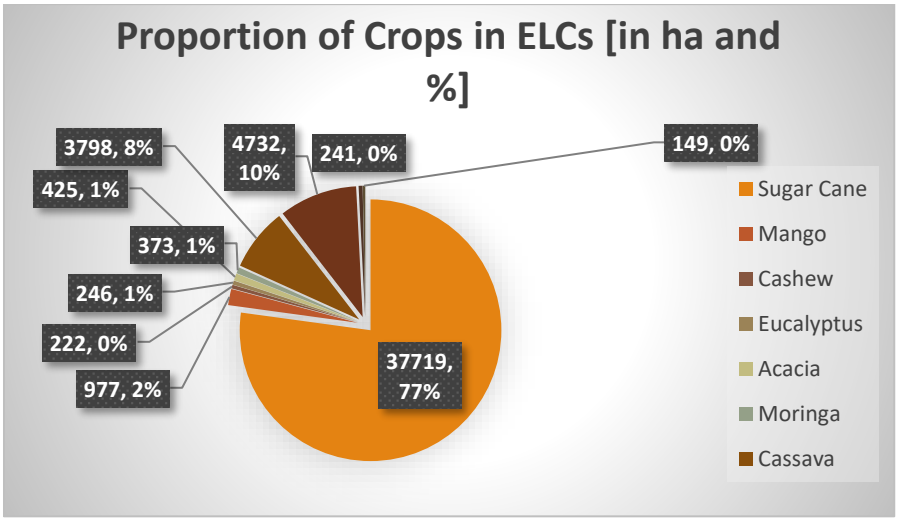


Figure 39: Estimated Incomes by ELCs

	Estimated Income per ha	Estimated Total Income Per Crop [USD]
Sugar Cane	1496	56,420,835
Mango	3031	2,961,826
Cashew	797	176,851
Eucalyptus	600	147,600
Acacia	500	212,500
Moringa	600	223,800
Cassava	469	1,782,037
Teak (avg)	1192	5,640,544
Rubber	1493	3,599,335
	Estimated Income all Crops	**70,587,267**

9.2. TRADE-OFF ANALYSIS

Various other reports have highlighted, that cutting off valuable trees outcompetes economically all other land uses even within long time horizons, particularly if associated by subsequent plantations. The trade-offs involved here are all very poignant:

The current system allows foreign investors do grow high value crops, which require high upfront investments, which smallholders cannot afford. While new opportunities with new markets for environmental services and in tourism open up now for forest communities, it is in particular the downstream crop farmers which are captured in poverty traps. Smallholders with small land areas and low productivity can usually only – or in the Prek Tnoat Watershed not even, cover their subsistence needs due to low productivity. Currently foreign investors invest solely into their own leased land, profits do not spill over into other benefits for the communities, which would particularly lie in the establishment of a sound credit system, to allow them to enhance their productivity and also diversify their production towards higher proportions of high valuable crops.

Even if high virtual prices are put on these non-monetarized services, at the end, they actually do not determine the market, because they are not transformed into cash. Therefore, where these non-monetarized values are at risk, it needs strong political frameworks to protect them, and though this protection will create costs which might deviate from the neoclassical economic principle of maximizing profits, this principle will have to be abandoned.

Frequently non-monetary values are traded against monetary values, because immediate cash needs might be considered as more urgent than the satisfaction of non-monetary needs. Pollution is the most typical example: pollution is usually caused through intensive agriculture through high chemical inputs. As long as there is no governmental health system in place, which pays for enhanced health problems arising from that, higher profits in agriculture particularly of more powerful groups can easily be traded off against greater health problems of socially weaker groups.

Still the major remaining trade-off, for which opportunity cost considerations are insufficient, is the trade-off between monetary and non-monetary values, as non-monetarized ecosystem services are the ones have the highest values, such as health, human life, genetic diversity etc. As they have no price, especially not in cash, there is no immediate financial feed-back, if they are affected. As in particular the ones who destroy ecosystem services are not necessarily identical with the ones who feel the impacts, human lives, human health, biodiversity and the survival of the planet are endangered, when regulations of environmental services take only place on markets and are not also controlled through rights, rules and legislation.

Another example is the trade-off between the ones who have land titles, the ones who have no land titles but use the land and the ones who have the means to purchase the land. Without land titles for the poor, the neoliberal economic approach will lead to a loss of land for all land users, whose profit will be below the benchmark of users of high technology and rural land will cease to provide space for the poor.

Therefore, decision making should not be based on the question, which type of land use achieves the highest benefits, but rather be guided by the question: which land use patterns keep ecosystems diverse and alive, and which would be the economic and political framework, to achieve this in the most profitable and equitable way, which can also not be achieved solely by considering monetary values of ecosystem services, even of the regulating ones.

9.3 SEM SCENARIO WITH COST-BENEFIT COMPARISON VERSUS BAU SCENARIO

A sustainable land cover and land use scenario is actually the scenario of 1992, where highly erosive locations in the Upper Prek Tnoat Watershed are still covered by forests and stream flows are not yet negatively affected. Due to irreversible changes which have happened and the occupation of land by various ELCs whose contracts cannot be terminated fast, the SEM scenario suggested in the following is an intermediate solution, which tries to mitigate environmental damages and major challenges, which are

Ecological Challenges

- Very high deforestation rate, therefore also high erosion rate. Hotspot of land degradation
- Reduced biodiversity in the remaining forests
- Increased climatic dryness due to deforestation and extreme changes in the hydrological regime
- High ecological and economic vulnerability to climate change conditions of the population and the ecosystem
- Relatively low economic role of fishery
- Rather few rivers and waterbodies, although still high in international comparison, with increasing exacerbation of both dry and wet conditions, leading to higher seasonal hydrological drought and flood risks.
- Increasing climatic dryness
- Overuse of groundwater

- In certain areas high arsenic concentrations

Socio-Economic and Institutional Challenges

- Increased pressure on land
- Decline of land area per capita
- Reduced current and future incomes in comparison to the past
- Exacerbation of the above-mentioned pressures through the occupation of about 12 – 14% of the land by ELCs
- Intransparency and lack of law enforcement
- As a consequence, high level of land conflicts.

A SEM scenario, which could address these challenges must have the following elements:

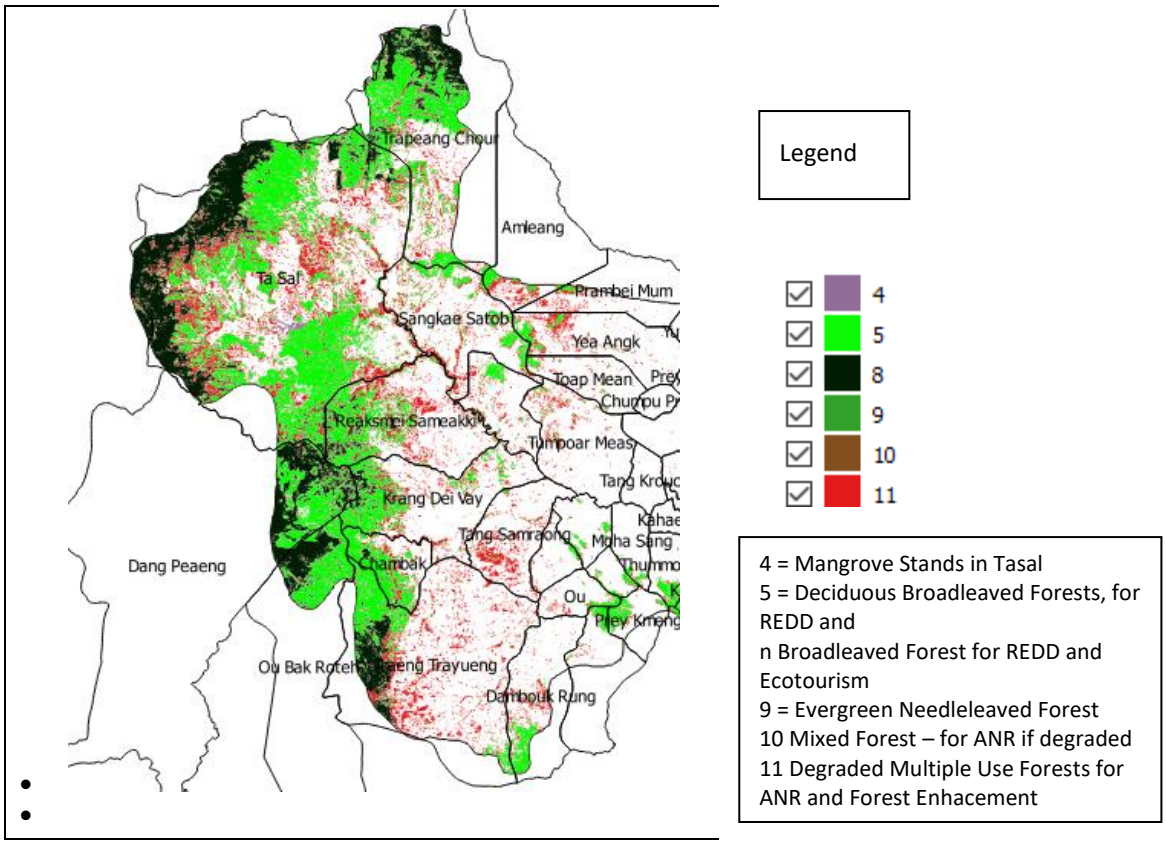
- Absolute protection of all forests feasible for REDD projects from timber harvesting
- Sustainable Extraction in multiple use forests
- SLM measures, ANR and forest enhancement in all areas which have been degraded due to deforestation after 1992
- SLM measures in agricultural areas
- Erosion, sedimentation flood, drought control, adaptation, and mitigation in hotspot areas which are mostly at risk
- Buffer zones along wetlands
- Improved hydrological management

All these measures and more have to be incorporated into a detailed land use and integrated water management plan in collaboration between Government and location stakeholders.

In the following, various maps are depicted which illustrated, where and through which measures the above challenges can be addressed.

Fig. 40 shows the location of mixed and evergreen forests, which should be absolutely protected for REDD schemes or ecotourism, as well as the location for ANR measures or afforestation.

Figure 40: Location for Future Sustainable Forest Management Zones per Use Type

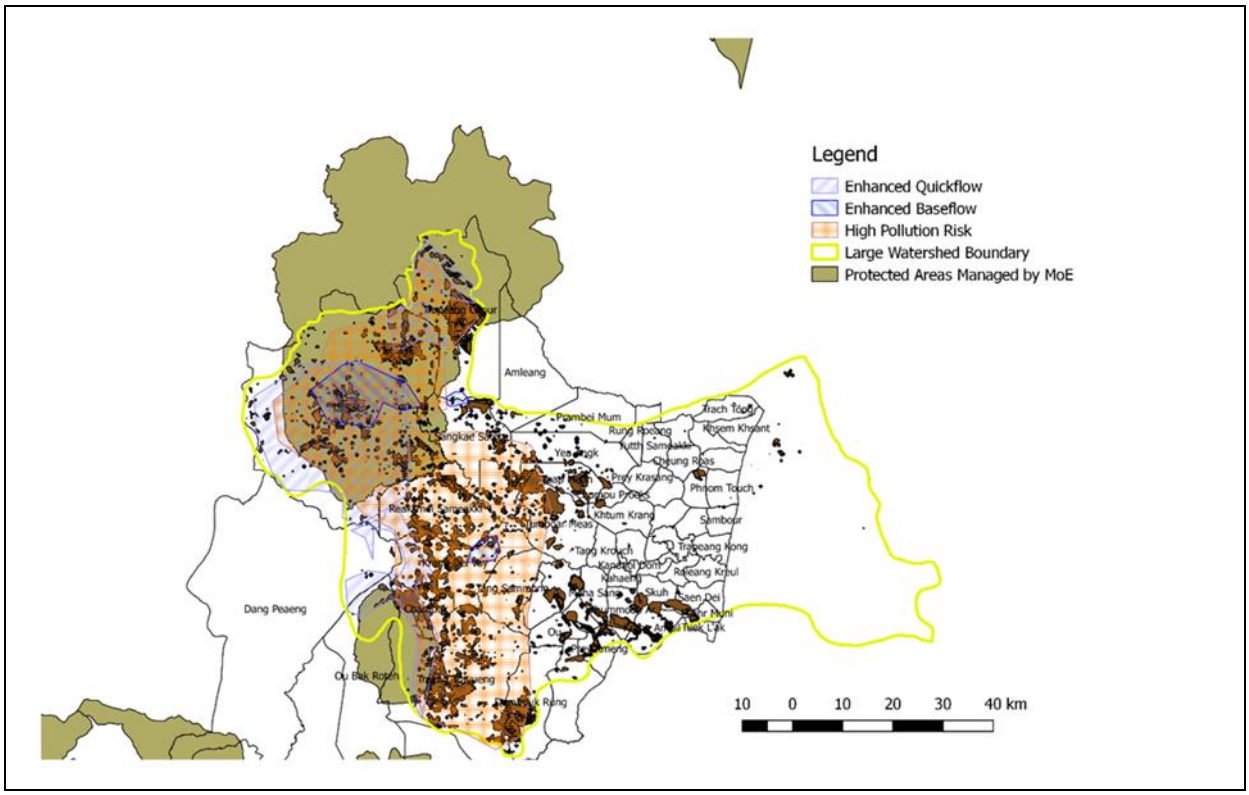


It should be investigated, if the Mangrove Forests in Tasal are particularly valuable ecosystems, which should be put under protection.

All areas left in white are put either under ANR or SLM measures, as they are highly vulnerable to erosion.

Furthermore, erosion, sedimentation and flood risks in the SEM scenario addressed as shown in Fig. 41.

Figure 41: Areas where Erosion, Sedimentation and Flood Risks are Addressed



Cost and Benefit Analysis for the SEM Scenario in comparison with BAU Scenario

Table 23 summarizes the environmental costs which have been created annually versus the costs for rehabilitation.

The major measures to prevent and mitigate ongoing environmental damages are avoided deforestation in current forest land, SLM or afforestation in the areas which have been deforested between 1992 and now, and rehabilitation of strongly degraded land with risks of gully formation. The total costs are 37,345,532 USD**.** In contrast, the total environmental costs are 84,778,996. They are higher than the ELC profits and have more than twice the value of the rehabilitation costs. Therefore, already in one year of investment, the cost-benefit ratio is 1:2.

Table 23: Costs of Environmental Damage and Rehabilitation

	Area (ha)	Average Price [USD/ha]	Total Cost
Annual Cost of Environmental Damage			
Erosion and Sedimentation			21,783,300
Pollution			37,847,397
Hydrological Change			41,666,658
Biodiversity Loss			19,805,500
Total			**121,102,855**
Initial Costs for Potential Rehabilitation Measures			

Costs for Avoided Deforestation	100,000 ha	42	4,200,000
SLM or afforestation	100,000 ha	251 USD/ha	25,100,000
Rehabilitation	16,632 ha	484	8,045,532
Total			**37,345,532**

The roadmap in Chapter 11 highlights the necessary steps to be taken to reach there. Chapter 10 illustrates the legal regulation which could support these undertakings.

10. LEGAL ISSUES

Any kind of environmental activities and payments derived from them are subject to legislation. Therefore, in the following an overview is given over the most relevant issues with regard to the regulation of ecosystem services and the design of PES in the Prek Tnoat Watershed. These relate to

- Regulations regarding payments for environmental harm
- Public Information and Participation
- Watershed and Pollution
- Forestry, Protected Areas and Ecotourism
- Land use and land law

10.1 GENERAL ISSUES AND REGULATIONS ON ENVIRONMENTAL HARM AND ENVIRONMENTAL LOSS

The top legislation, which regulates the management of natural resources and therefore the protection of the environment is the Cambodian National Constitution, which states that "land, mineral resources, mountains, sea, underwater, continental shelf, coastline, airspace, islands, rivers, canals, streams, lakes, forests, natural resources…" are state property", whereas the state is obliged to protect "the environment and balance of abundant natural resources and establish a precise plan of management of land, water, air, wind, geology, ecological system, mines, energy, petrol and gas, rocks and sand, gems, forests and forestry products, wildlife, fish, and aquatic resources" (Kingdom of Cambodia, 1993b).

The newly established Environmental Code is the most relevant instrument to regulate environmental issues. It declares a clear commitment to environmental protection and the SDGS and emphasizes the importance of environment for human well-being

The Code prohibits any activities which are likely to cause environmental harm unless all reasonable and practicable measures to prevent or minimize that harm are undertaken. In case environmental harm does happen, the Polluter Pays Principle applies, which demands that any costs for the prevention, avoidance, mitigation or reparation of environmental harm should be covered by the one who caused it. Moreover, the User Pays Principle demands, that the "user should pay "for the direct and indirect cost for use of or the impacts from the use" of natural resources.

The Principle of Net Loss ensures that no actions cause net losses of the "Kingdom of Cambodia's stock of living natural resources and associated flows of goods and services." As a last resort, losses of living natural resources and associated goods and services in one location may be offset by action that achieves ecologically equivalent gains in another location. The net loss prevention is also currently implemented by the UNCCD Land Degradation Neutrality program, which Cambodia is a party to.

The Environmental Code emphasizes also the principles of intergenerational equity and the principle of sustainable use, that provides the fulfilment of all environmental needs of future generations.

10.2 PUBLIC INFORMATION AND PARTICIPATION

The above principles can only be applied, when they are operated in a public and transparent way, which is formulated by the "Principle of Public Participation". The Principle of Public Participation provides, that those who may be affected by a decision, shall be entitled to provide informed, timely, and meaningful input prior to the decision being made, to be able to influence in a transparent, inclusive, and accountable manner the decision-making process. This has to be guaranteed through the "necessary access to regarding environment and natural resources, which includes "proposed policies, plans and projects, risk and impact assessments and

mitigation measures, resettlement plans, and information on hazardous substances and wastes. Information on environmental protection and natural resource management shall be made widely available and publicly accessible in a manner that maximizes the opportunity for public participation in planning and decisions affecting the environment and society." This is in line with the Principle of Evidence-Based Decision and the Principle of Prior Informed Consent – that people are prior informed about environmental decisions and their consent is sought.

The Environmental Code regulates also questions of fairness and equity, especially the principles of Gender equality, which promotes equality and empowerment of women in all aspects of environmental conservation, protection, and management, recognizing the diversity of different groups. In the same way, equitable participation of vulnerable, marginalized and at -risk people in environmental protection and natural resources management has to be ensured.

10.3 LAND LAW

The Land Law regulates four major categories of tenureship, which apply for agricultural land as well as for forest land:

- State land, divided into State public land, which has a public interest value, containing things like lakes or mountains, ports or airports, roads or public parks, schools, hospitals, protected areas, historical sites, or official properties of the Royal Family. State public land cannot be sold or granted as economic land concessions (ELCs), but can be leased up to 15 years, therefore, can be transformed into community forests.
- State private land does not have public interest value. It can be sold or leased, including long-term leases and land concessions for agro-industrial businesses, but any such transfer must follow legal procedure.
- Collective property in two sub-categories:
    - Monastery property,land and structures existing within the premises of Buddhist monasteries.
    - Indigenous property,lands where ethnic minority communities have established their residences and where they carry out traditional agriculture.[10]

Land Titles and Registration

As initially shown, most of the land is inherited by customary law, without a proper legal status. Therefore, from 2002 onward, a systematic classification and registration of all land parcels was established to remove uncertainty over land ownership that caused conflicts and tenure insecurity. A Cadastral Commission was set up to resolve disputes arising during the course of land registration. Up to the end of 2015, the government has handed over 4.15 million private land titles. Unsurveyed and untitled land remains the property of the State, facilitating the granting of concessions on that land.

ELCs

The Land Law provides for the issuing of large scale land concessions to domestic and foreign investors through transferable land titles. ELCs can be granted for a maximum of 99 years (although 70 years is most typical) and should not exceed a size of 10,00 ha.

10.4 FORESTS

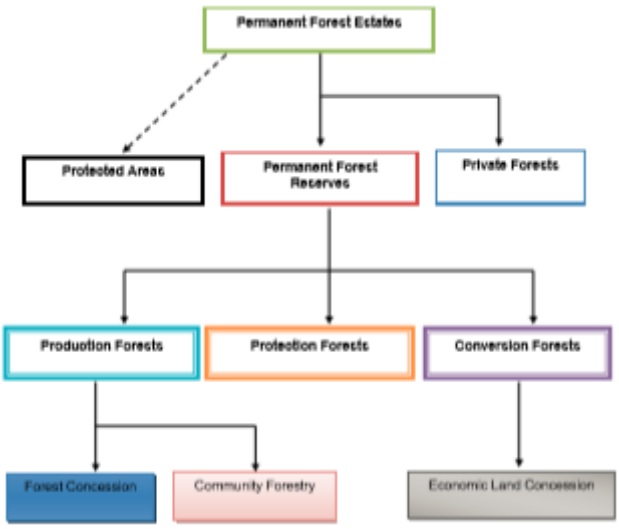
The Royal Government of Cambodia officially regards the ecologically, socially and economically viable conservation and sustainable management of forest resources to be an important pillar of public welfare that directly contributes to environmental protection, poverty reduction and socio-economic development. All kinds

[10] www.opendevelopmentcambodia.net

of wildlife species in Cambodia are state property and components of forest resources. Three categories of wildlife are classified: Endangered species, rare species and common species.

Fig. 10.4 gives an overview over forest tenureship in Cambodia.

Fig. 10.4 Forest tenureship in Cambodia



Source: Yeang et al 2010

There are four different land categories, which also applies for forst land :

- Public land administered by governments,
- Public land designated for use by local and indigenous communities,
- Private land owned by communities and indigenous communities and
- Private land owned by individuals or firms.

De facto, all public land is owned by the government, but local and indigenous communities are granted right to use forest resources because they are considered as common pool resources.

Community Forestry

Community forests are forests owned by the state but have been allocated to communities under a 15-year agreement. These forests are managed by the local communities but with the technical support from the FA. The managements of these forests is also financially supported several international NGOs. The primary goal of community forests is to protect and rehabilitate forests and to enhance sustainable use of forest resources of the communities and to improve their livelihoods.

There are eleven steps required by communities to complete the process of receiving the status of a community forest, including the development of a management committee and by laws, the demarcation of community forest boundaries, and the establishment of a management plan approved by the Forestry Administration.

Sustainably Managed Forests

Sustainably Managed Forests are “any areas designated as such by the relevant government entities in forested areas located outside of Biodiversity Conservation Corridors, Protected Areas, and any other protected areas

established at the provincial, district, or commune level, or any other state public lands with ecosystem or conservation values, and indigenous peoples' or other customarily conserved lands."

They should be used to preserve social, economic, and environmental benefits, conserve, enhance, and restore biological diversity and ecosystem values; improve local livelihoods and cultural heritage; and promote sustainable development**.**

According to the Environmental Code, royalties have to be paid for harvesting timber and non-timber forest products for commercial people. A portion of these royalties is to be redistributed to local communities, which are not charged of using the forests to meet their subsistence needs.

- **Sustainable Production Forests** are state public lands consisting of degraded forest, afforestation lands, reforestation lands, and forest suitable for tree plantation. Commercial activity in Sustainable Production Forests is subject to permit.
- **Restoration Forests** are state public lands with important ecosystem and biodiversity values, including degraded forest lands, that are suitable for maintenance, restoration, and conservation.
- **Stock Forests** are state public lands consisting of forested areas held in reserve for future sustainable production or conservation.
- **Tree Plantations** have to follow special rules and standards, that are compatible with landscape environmental, social, economic, and resource goals and should include the cultivation or re-cultivation of native species.

Law Enforcement

Improved forest law enforcement and governance it planned to be enhanced through legal and administrative reform and improved monitoring and reporting of forest crimes

10.5 WATER

It was a policy, which for the first time gave watersheds a high priority in protection, the NBSAP 2002 under the CBD. It sees watershed protection as a key challenge, by "Creating environmental security for integrated biodiversity water resources, management and development), including the formulation and adoption of a coherent policy for the water sector as a whole, which also refers to water resources use and development planning control of floods and watershed management. This includes the prevention of "the damage that may occur as a result of flood, drought, watershed, degradation, erosion and sedimentation to protect aquatic and fish resources and other biodiversity, rehabilitation of bank protection work, dikes, provision of water storage facilities, prohibition or licensing of the filling of reservoir and of the obstruction of flow /drainage and prohibition sand mining on the bed and banks of water bodies."

As one of the international agencies which supports Cambodia in the implementation of the CBD, it was IUCN, which has also listed the Prek Tnoat watershed as one of the 7 watersheds in the country in 2009, which most urgently would need protection due to steep slopes, endangered biodiversity etc.

In January of 2004, the RGC adopted the country's first National Water Resources Policy, which calls for short, medium and long-term river basin plans[11]. Management efforts are to be focused on priority river basins that are "under threat" due to degradation or pressure from competing water uses. This is re-emphasized by the

[11] http://info.mrcmekong.org/assets/midocs/0003429-inland-waters-comparative-analysis-of-policy-and-legislation-related-to-watershed-management-in-cambodia-lao-pdr-and-vietnam.pdf

Environmental Code, which also regulates upstream-downstream user relations. For instance, the user of downstream land d is entitled to collect and use rain-water and the water flowing over his/his property from the upstream but shall not hinder the natural flow of the water by constructing road, large or small dykes or other structures for storing water, unless there is appropriate authorization. Moreover, water should not be prevented from flowing to neighboring land users to meet their irrigation and other needs. Land users shall be compensated for any damages to their land in case for disposal of sewage water and drainage water.

The Sub-Decree on Water Pollution Control requires permits for wastewater discharges, which have to meet meeting effluent standards prior to discharge.

10.6 BIODIVERSITY

Biodiversity protection is regulated through the legislation for Protected Areas, which was first drafted in the Protected Area law on 2008 and later on continued in the Environmental Code. For all designated as Protected Areas prior to the Environmental Code in 2017 applies the law of 2008.

It divides PA zones into three management zones which are

- Core zone – access only for research.
- Conservation zone – open for small-scale community uses of NTFPs.
- Sustainable use zone – community sustainable use of resources including NTFPs, fuelwood collection, timber cutting, fisheries, ecotourism and agroforestry (outside of community protected area).

Due recognition is to be given to the livelihoods and customary rights of indigenous people and people whose livelihoods are based on forest use. The Ministry of Environment is responsible to oversee and provide Community Forests, Community Protected Areas, Community Fisheries, and other local and customarily acknowledged areas, as well as for patrolling, monitoring, investigation and enforcement. Ministry officials have the right to control export and import of flora and fauna, seeds, and samples from or into the Biodiversity Conservation Corridors and nationally-designated Protected Areas;

Forest Concessions and ELCs

The sustainable use zone can be committed to “investments and management areas of high economic values for national economic development and management and conservation of the protected area itself”, thus “contributing to the local communities, and indigenous, and new agricultural skills to the community people who live in and nearby the project areas as well as convert illegal activities of the community people such as logging in PAs, change income generation activities by working with the investment companies and change from traditional farming to specialized one and enable them to select high-yield but low risk rice seeds which are resilient to climate change facing the world.” The concessionaire has the exclusive right to the logs from the concession, which is usually named conversion timber.

No new commercial activities are allowed in the currently existing protected areas and biodiversity corridors.

Collaborative Management

Protected areas, which are managed collaboratively, can receive the status of Community Protected Areas or Community Forests upon application. Decentralization and de-concentration are encouraged to happen at the commune level. Therefore, each commune council is requested to develop its own commune annual development project proposal to submit to the government and donors for support.

Tourism

The Ministry of Environment is the responsible government entity for the final approval of all proposed and current tourism projects in Biodiversity Conservation Corridors, nationally designated Protected Areas, and any other protected areas established at the provincial, district, or commune level. The implementation of commercial ecotourism requires an agreement with the relevant government entities or the collaborative management committee.

10.7 PESTICIDES

Cambodia's agriculture policy has emphasized eco-friendly production system, organic farming and IPM practice for sustainable agricultural development and food safety. Considering all these issues, the Pesticide Registration and Management Department has also emphasized the registration of bio-pesticide pesticides, which gradually reduce highly hazardous pesticides. The Plan and policies of Cambodia also encouraged eco-friendly measures of agricultural production, IPM practice and organic farming which directly or indirectly support the concept of pesticide risk reduction in food safety. The preparation of pesticide policy and bio pesticide promotion directives is under way which encourages for the production, registration and use of bio-pesticides pesticides and bio-agent.

10.8 FUNDING OF ENVIRONMENTAL ACTIVITIES

Funding of Collaborative Environmental Activities

The funding regulations in the Environmental Code pertain also to options for PES schemes, therefore, they are introduced here in detail. The Code foresees, that the "Collaborative Management Committee may receive funds from the Environmental and Social Fund and other public and private sources and may generate income by means of taxes, rental leases, and usage, recreational, or access fees. The Collaborative Management Committee may also solicit and receive donations, endowments, and grants in the form of contributions, sustainable financing, and payment mechanisms for natural resource and ecosystem services, including the entitlement for communities to be compensated for the provision, maintenance, stewardship, restoration, or enhancement of flows of natural resource goods and services originating from the Collaborative Management Protection Zone, including those originating from ecosystems, through payment mechanisms."

Payments for Ecosystem Services

The Environmental Code has also a section on regulations on payments for ecosystem services. It emphasizes that the scheme has to be a result-based mechanism, which disburses funds only, if results have been achieved for providing natural resource services originating from parts of ecosystems under their control, stewardship, or management. It emphasizes that "the design and operation of such mechanisms shall take into account best available data and statistics concerning both the status and assessed values of natural resource services. Payments for natural resource services shall be allocated and distributed on an equitable basis taking into account the rights of local communities."

As one scheme to store and generate payments is the Environmental and Social Fund. This should be recruited from fees charged for EIAs for each new project to the amount of 1% of the total project costs. The purpose of expenditures from the Trust Fund must be in line with the

a) Conservation, protection, restoration and enhancement of the environment nd natural resources;
b) Protection of cultural heritage or biodiversity;
c) Promoting sustainable management of natural resources and natural resource goods and services;
d) Promoting research or environmental education;

e) Capacity development or institutional strengthening;
f) Social responsibility in support of a community directly affected by development

An environmental trust fund is only valid if registered at the Ministry of Economy and Finance. The assets may be constituted from the National Budget; official development aid; grants from international organizations; payments for natural resource goods and services; natural resources stewardship services; and/or direct donations from private sector actors, charitable individuals and non-governmental organizations. All interest arising from the Environmental Trust shall be paid into and form part of the Environmental Trust Fund.

10.9 SUPPORTING POLICIES

A supporting policy is the rectangular strategy, which had 5 periods of legislature up to noq.

Rectangular strategy Fourth Period

The Rectangular Strategy in its 4th Legislature (2008-2013), was set out to fight corruption, enhance public financial management, improve good governance, reduce poverty as well as promote the welfare of all citizens (International Labour Organisation 2008). Keeping in line with this strategy, in 2010, the AntiCorruption Law was passed and came into force in 2011 (Cambodia Investment 2010), and was considered as being in line with international standards. It provides for measures of education, prevention and law enforcement to curb corruption. Corrupt acts are covered and criminalised in the Provisional Criminal Code, which criminalises corruption in the form of active and passive bribery, abuse of office for private gains and extortion (GAN Business Anti-Corruption Portal 2015). It also criminalises accepting bribes in the form of donations or promises. There is no limitation on the value of gifts, but they are forbidden if given with a corrupt intent.

Rectangular Strategy Fifth Period

The fifth period addresses good governance, fighting of corruption, legal and judicial reforms, public administration reform, and sustainable management of natural resources. Under the promotion of the agriculture sector strategic rectangle; the first side is about improved productivity, diversification and commercialization, the second is about promotion of livestock farming and aquaculture, the third is about land reform and clearance of mines, and the fourth is about sustainable management of natural resources.

National Policy and Strategic Plan on Green Growth 2013-2030

This plan was approved on 01 March 2013 by the RGC, aiming at developing the economy with consideration for environment and natural resources sustainability. The national policy targets a balance between economic development and environmental protection, culture preservation, social stability and sustainable consumption of natural resources to improve people's living conditions and welfare through the effective use of natural resources, environmental sustainability, green jobs, green technologies, green finance, green credit, and green investment.

11. ROADMAP TOWARDS IMPLEMENTATION OF ECOSYSTEM SERVICES IN PREK TNOAT WATERSHED

As the previous analysis has shown, the current economic framework gives rather incentives for unsustainable and extractive ways of land use, as it does not account for the values of certain natural services, which might be depleted by maximizing financial profits by ignoring their environmental impact in particularly on regulating ecosystem services, the natural capital that will be left to future generation, the well-being of people, to whom these services might be no more available first, especially the poorest and land less ones, and by ignoring the impacts of increasing inequality as well.

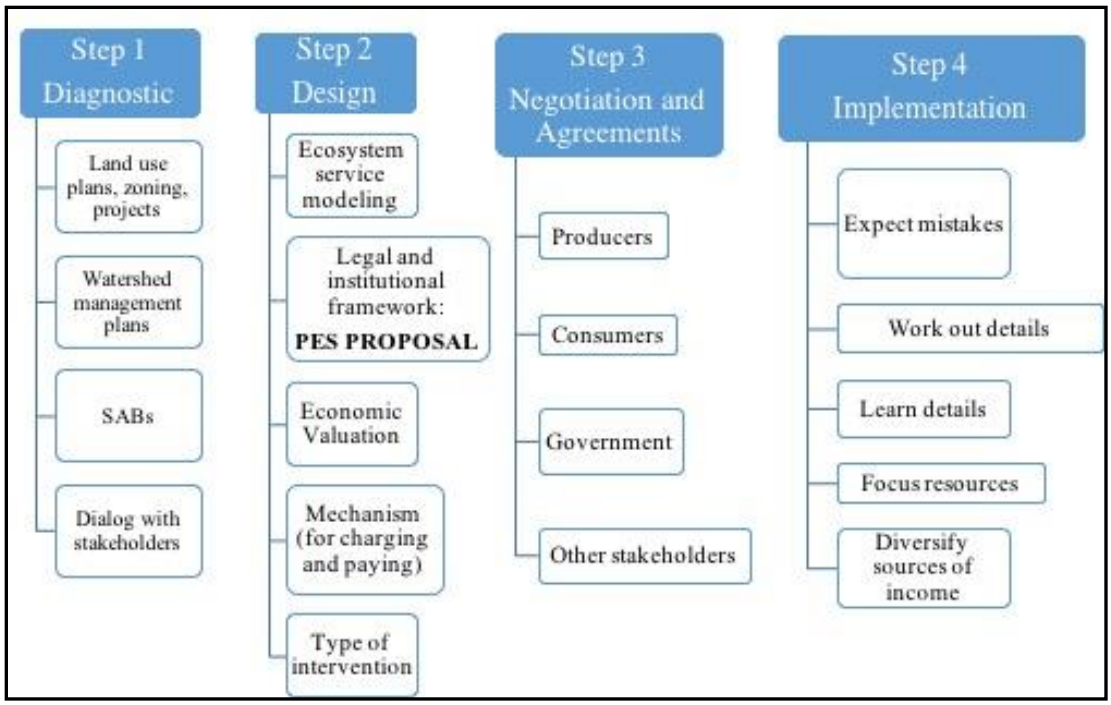
PES are assumed to be an effective financial instrument, which could help to remediate the failures of this system in future**.**

Payments for Ecosystem Services have already been well-defined by a previous study by UNDP, which is therefore cited here: 'Payments for Ecosystem Payments (PES) are transactions between a "buyer" and a "seller". The buyer expects the seller to modify its practices, change behaviour or forego the use of the land altogether to improve the condition of an ecosystem and therefore the services it provides. Broadly speaking there are two types of PES: voluntary and mandatory. Voluntary cases are often the result of private sector companies establishing arrangements with different actors that result in sustained, or increased, provision of an ES. This is related to the "willingness to pay" concept[12]. Mandatory cases, on the other, are the result of specific national or local legislation and regulations, or international agreements that mandate reductions in pollution or other damages, and provide the option of purchasing credits. For example, the Kyoto Protocol framework was a mandatory agreement for signatory countries and, through the European Trading Scheme, created a demand for reducing emissions and carbon sequestration (Echeverria 2016).'

11.1. FRAMEWORK FOR IMPLEMENTATION

Echerrevia (2016) has also designed a framework for PES implementation that consists of four phases, as illustrated in Fig. 1.

Figure 42: Framework for PES Implementation



With regard to this framework, Phase 1 is conducted on governmental level as a preparatory activity to introduce PES schemes. So far, there are land zonings for the protected areas, otherwise land use plans or integrated water management plans are not available for the Prek Tnoat watershed, except some committed development documents by JICA. Nevertheless, further watershed planning could interactively be conducted with environmental modelling in Phase II, which has been roughly started for this report (See chapter 6)

The next steps to be covered by the roadmap would be the identification of a mechanisms for charging and paying for ecosystem services, which is also related to the identification of potential producers and consumers, furthermore the design of the type of the intervention, and the role of the definition of the role of the Government and other stakeholders. Phase 3, the negotiation process and Phase 4, are not part of the following roadmap, but there are suggestions about issues, which would be useful to negotiate and which stakeholders to involve in Phase III and IV. .

11.2. BASIC CONDITIONS FOR IMPLEMENTING PES IN CAMBODIA

The definition for traditional PES is " a voluntary transaction, where a well-defined ecosystem service (ES) (or land-use likely to secure that service) is "bought" by at least one ES buyer from at least one ES provider, if and only if the ES provider secures ES provision (conditionality)."[13] PES are always conditional and the goal is always to improve the ecosystem and the services it provides."

The well-defined ecosystem service would require a regular and reliable monitoring system proper law enforcement to ensure, that the ES provider secures ES provision and the buyer pays for it. This monitoring scheme is not available currently in Cambodia, although foreseen in the Environmental Code. Another ingredient, which guaranteed success in other countries, such as in Costa Rica, are for instance strong institutions. Strong protective environmental laws have led for instance in Costa Rica to success in the implementation of PES schemes, as for instance, any kind of land use change is strongly forbidden. As this cannot be expected in Cambodia, this also calls for a more flexible approach, as Escherrevia (2016) suggests, who recommends the approach suggested by Milne and Chevier (2014I, based on the UNDP's definition

[13] http://www.cifor.org/pes/_ref/about/index.htm

"Payments for ecosystem services (PES) occur, when a beneficiary or user of an ecosystem service makes a direct or indirect payment to the provider of that service. The idea is that whoever preserves or maintains an ecosystem service should be paid for doing so." [14]

11.3. STEPS TOWARDS PES IMPLEMENTATION IN PREK TNOAT WATERSHED

Table 24 lists the different steps to take within the road towards the implementation of PES, which includes environmental, economic and political activities.

Table 24 Steps to prepare the Roadmap for PES schemes in Prek Tnoat Watershed

i.	Assessing the major challenges that ecosystem services face in the watershed
ii.	Identifying the location, where ecosystem services have been impaired and the stakeholders and activities, which contributed to their destruction and the ones affected by it.
iii.	Assessing the financial impact of reduction of environmental services in different locations
iv.	Identification of different scenarios for intervention and potential trade-offs
v.	Development of a Land Use and Land Management Plan to Implement a SEM scenario
vi.	Stakeholder Analysis to identify potential providers for the identified activities on ecosystem services
vii.	Stakeholder Analysis to identifying potential buyers and their willingness and capacity to pay
viii.	Stakeholder Consultations
ix.	Identifying a scheme or framework for a payment of ecosystem services scheme.
x.	Improving enabling conditions for PES
xi.	Identify the roles and responsibilities of members in these funds or payments of ecosystem services schemes.
xii.	Introduce fairness and equity criteria in these schemes
xiii.	Prioritize different interventions according to their efficiency

11.4. DESCRIPTION OF THE INDIVIDUAL STEPS TO BE CONDUCTED ON THE ROAD TOWARDS PES IMPLEMENTATION

11.4.1 PRECONDITIONS FOR THE IMPLEMENTATION OF WATERSHED AND ECOSYSTEM SERVICES: INTEGRATED WATER MANAGEMENT, LAND USE PLANNING AND ESTABLISHMENT OF MONITORING SYSTEMS

As shown above, a detailed land use and integrated water management plan is necessary for the implementation of PES, which should also take care to meet SEM visions. In collaboration with all stakeholders, a potential SEM scenario should be developed, that minimizes negative land use impacts, poverty and inequity. Based on the decisions for a proper SEM, a land use and land management plan should be developed or updated, that matches the SEM scenario. The social planning should be followed a bottom-up approach to ensure that the needs of all stakeholders are considered, the hydrological and ecological planning should follow a top-down approach to ensure that technical measures are well coordinated. For technical planning, a hierarchical top-down approach is recommended, to ensure, that various watershed-activities in the sub-watersheds of minor order do not cause trade-off with technical goals for the overall basin. It is therefore recommendable on governmental level to establish a land use plan first, to which Integrated Water Management Activities are tailored.

[14] http://www.undp.org/content/sdfinance/en/home/solutions/payments-for-ecosystem-services.html
Retrieved on December 17 2017

11.4.2. ACTIVITIES TO BE CONDUCTED

It is useful, if the decision upon activities to be conducted has already the size of areas in mind, which would be treated. These are listed in Table 2**5.**

Table 25: Size of Areas which are Affected by Particular Environmental Risks

Area affected by	Area in ha
Potential Flood Risk (baseflow)	84230
Nutrient export high	29638
Nutrient lower	430664
Flood risk double	196623
Critical Environmental Risk Zone	Ca. 100 000
Sedimentation Hotspot	16000

Activities which apply for PES could either address underlying environmental changes/ drivers, be preventive measures or rehabilitation activities, as the following list of suggested activities implies, which by no means assumes to be complete.

The problem is, that many of the damages done are irreversible, therefore, even reforestation would not bring back primary forests and their biodiversity or restore water flows to former conditions.

The following activities define therefore the roadmap for a SEM scenario, which might achieve intermediate conditions, which are not as favourable as 1992, but also not as detrimental as the current scenario.

Avoided Deforestation

Avoided deforestation refers to forest conservation measures, which are partly already in place in the Cardamom Mountains and could be continued and strengthened, to maintain the high value biodiversity, watershed maintenance, and carbon sequestration ecosystems services that are contingent upon continued integrity of its large forest ecosystems.

This requires safeguarding, patrolling and monitoring, while simultaneously forest product extraction can happen at a sustainable rate.

No forests have been demarcated or mapped up to now, neither Chambak forest nor Trapeang Chour, which is on the verge of applying as an ecotourism project. Lack of spatial management capacities is here the greatest challenge to be overcome. It is suggested, to capture both the lack of spatial capacities and the lack of demarcation in one activity: by hiring a national consultant, experienced in GPS and GIS technology, who teaches local officials in those technologies, using the demarcation and mapping of Chambak forest and Trapeang Chour as an example. Involving also forest management committee members into this activity is very important, so that they have the knowledge to prove the correctness of all demarcations themselves.

Assisted Natural Regeneration and Forest Enhancement

Assisted natural regeneration is a mixture of area protection, afforestation and smart forestry techniques, which circumvent the high labour demand and input costs for reforestation. These could be used either on abandoned agricultural land or highly degraded forest land.

Preferably the example from the Philippines should be applied, compare Annex IV.

Ecosystem Restoration within the Critical Zone

Ecological restoration aims at rehabilitating the functionality of the damaged ecosystem and its relevant physical, chemical, and biological properties. The essence of ecological restoration lies in the establishment of a natural, self-regulating ecosystem that forms an integral part of the entire ecological landscape. In the end this is the SEM scenario.

There are several options to develop sustainable land management strategies that reflect local dynamics of change and can provide a more harmonious relationship between desirable development and long-term sustainability of land resources (Hean 2014). However, as we have seen, there is mainly one cause for the reduction of environmental services, but many impacts, and this is deforestation. Conserving forests upstream is very critical not only because of the upstream services for carbon and biodiversity, but also because the rivers and surface runoffs drain towards Phnom Penh. The other causes are mainly insufficient wetland protection. While it is in many cases not to reverse deforestation, other potential activities which can be undertaken are interventions which substitute certain functions which forests have provided such as better water, soil and nutrient retention, biodiversity etc. Payments for Ecosystem Services are meant for new and additional activities. PES is not meant for already ongoing activities or activities in the past. For instance. an erosion control scheme which is already in place is no more applicable for PES (Hien 2014):

Sustainable Land Management in the High Erosion and Nutrient Export Zone

SLM technologies are needed both to improve the provision and quality of environmental services and as well to adapt to degrading environmental conditions, which could no more be reversed, and finally, to enhance land productivity in a sustainable way in general. It is particularly the first purpose, which is applicable for PES.

- Technologies can be applied to serve the following purposes:
- Enhancement of forest area
- Erosion control
- Sedimentation control
- Runoff- and flood control

Especially in the area which had been deforested between 1992 and now, sustainable land management techniques would ensure the second-best solution, where full afforestation is not possible. Given the existing conflict between watershed conservation and livelihood development of locals, agroforestry activities will be a proper way to balance these two elements. Improving land use planning could address the environmental issues in Prek Thnot watershed. Under proper land use planning, sustainable land uses can also be introduced in critical areas. WOCAT has identified already 40 applicable SLM technologies which are effective in Cambodia, and further technologies could be adopted from the WOCAT catalogue. Collaboration with WOCAT, which is already ongoing, is therefore to be encouraged, and preferably disseminated by farmers'field schools or model farmers.

Table 26: Examples for SLM Technologies Implemented in Cambodia

There are numerous highly efficient and effective SLM technologies to be adopted from the Philippines and also some from Thailand, out of which the most important ones are listed in Table… and for which more detailed descriptions are annexed.

It is highly recommendable to hire a consultant with expertise in SLM practices in the Philippines and good linkages to WOCAT together with a national consultant, to introduce some of these technologies in the Prek Tnoat watershed, as not only the adoption of the technology itself is important, but also its proper location and the adoption of the principle behind each technology to the local context in Cambodia. As the portfolio of potential SLM activities is very high, it is suggested that this consultancy involves deep stakeholder engagement through at least one or two stakeholder meetings, where potential SLM technologies and their locations are prioritized, secondly to decide roles and responsibilities in implementations.

Direct Water Services

a) Addressing immediate problems

All above mentioned services improve already the hydrological conditions. However, flood and drought risks, sedimentation and pollution need also to be directly addressed, as the original conditions can not be fully restored.

Activities which are necessary to counter sedimentation of wetlands and reservoirs are for instance

- Those that divert some of the sediment through or around the reservoir;
- Those that remove or rearrange sediment that has already been deposited; and
- Those that minimize the amount of sediment reaching the reservoir from upstream.

This could include

- On-stream sediment bypassing, which diverts part of the sediment-laden water around the reservoir, typically using a weir that operates during high flows when sediment concentrations are high.
- Off-stream reservoirs, which divert only the clear over a bypass weir. Works only for the sediments which are carried by higher streamflow.
- Dredging
- Flushing: emptying the reservoir by opening bottom outlets and allowing the incoming streamflow to scour sediment.
- Erosion Control and SWC. There are structural or vegetative measures which could be conducted.

Structural or mechanical measures - such as terraces, conveyance channels, check dams and sediment traps decrease overland or channelized flow velocity, increasing surface storage and thereby reducing the sediment load in the runoff. Gully rehabilitation is particularly necessary in the communities of Tasal and around Krang Devay community.

Vegetative erosion control takes advantage of plants' natural ability to limit erosion. Agricultural practices that minimize sediment yield are particularly effective. These are beneficial for the creation of buffer zones around Phom Aural and at the Eastern boundary of ELCs, to protect the downstream areas from further influences of sedimentation, pollution and water flow changes. A vegetation boundary along the forest line from 1992 would also be useful, if not full afforestation to that level is possible.

Erosion is considered as the most effective sediment control, but positive financial impacts on individual farmers fields are not high enough to give an incentive to start erosion control measures, as it is the whole watershed, which benefits. Therefore, it is very necessary that erosion control is encouraged through PES, and also the practice in many countries.

Composting and Manure Production, Restoration and Expansion of Grazing Areas

The recreation or restoration of grazing areas for enhanced manure production are necessary activities to reinforce agricultural productivity and enhanced independence from chemical fertilizers. Accompanying composting programmes would create further benefits.

Wetland Protection (in particular Trapeang Chour)

The construction of a wetland protection zone and restoration of riparian vegetation along wetlands could absorb any residual nitrogen and phosphorus. Buffer zones: Buffer zones of at least 50m are recommended by the RAMSAR convention and are almost nowhere observed in Cambodia. The protection of buffer zones could be integrated into by-laws of communities and PES could be obtained through communal work of buffer zone creation or restoration. Nevertheless, the key to restore the degraded ecosystem of shallow eutrophied lakes lies in controlling the amount of internally released nutrients, it will be necessary to control sewage flows from ELCs.

Groundwater protection

All areas below plantations or farms cannot be used for drinking water generation. Therefore it requires detailed planning of buffer zones for drinking water generation

Biodiversity Protection

Biodiversity Protection is already covered through ecotourism services. However, as the major threat to the PAs within PTWS is arising from PAs, biodiversity protection requires control of chemicals used by ELCs above all and a successive closing down of ELCs in the PAs.

11.4.3. STAKEHOLDER ANALYSIS I: IDENTIFICATION OF PROVIDERS OF ECOSYSTEM SERVICES AND TYPES OF FEES WHICH COULD BE GENERATED

Providers of ecosystem services are those stakeholders who are able to manage ecosystems and ecosystem services, which are prone to depletion or who would be able to rehabilitate them. These are stakeholders in the forest areas, and land users in the agricultural zone which are also able and willing to provide ecosystem services.

As all PES are supervised by the MoE anyway and the MoE is also managing great parts of the forests in the upstream areas, the MoE is the major institution to supervise and manage PES. Besides this, the major stakeholders to be considered as potential providers of forest ecosystem services are the forest communities. Forest communities have also proven to be effective in managing forests, as most forests under the management

of communities were maintained despite the great pressure by ELCs, except Tasal community, which also lost a huge part of its forest to ELCs. The FLEGT report therefore even recommends to put all forest areas under community management.

The following list provides example for fees for services, which providers of ecosystem services might be able to earn:

Community Forestry, Biodiversity Protection and Ecotourism

Fees from Ecotourism and accession fees are the payments which seems to be easiest to be generated for community forests. To enhance current fees, entrance fees should be doubled first, from 1 to 2 USD.

Other fees to be collected are fees for habitat protection, which Cambodia has already a lot of experience in. Partly these could be covered by INGOs such as IUCN, CI, etc.

The preconditions for generating fees from these activities are community land titles, demarcation and mapping of the exact forest boundaries, therefore capacity building in spatial management of local officials and community forest management committee members, as well as capacity building or strengthening in ecotourism. The common partner in this activity is Mlup Baitong.

Fees for Carbon Services

Avoided deforestation, enhancement of forests and afforestation are the major activities for enhancement of carbon services. Proving success of carbon services can be difficult without appropriate measurements. But there is an ex-ante technology to determine the carbon quantities accumulated by different technologies through the Exact-tool, which is listed in detail in Annex V. The application has to be coordinated with the REDD office within the MoE, and precaution for the avoidance of the leakages has also to be implemented in collaboration with the REDD office. Recently deforested areas which are afforested again are not applicable for carbon services under REDD. However, there are other possibilities on the voluntary carbon market for carbon sequestration through climate smart agriculture, agroforestry etc.. The further condition to make REDD schemes work for local stakeholders are clear land titles, in this case it might be community land titles

Fees for SLM

As SLM and afforestation would take place around those areas where ELCs are located, the scheme is not only most difficult to implement, but there are also a lot of hindrances to obtain funds for it. One obstacle is the current intransparency of ELCs not only regarding management practices, but also with reference to their incomes.

The other obstacle is that also no compensation fees for foregone losses from deforestation and conversion timber, which benefitted ELCs are foreseen by law. Nevertheless, with regard to the “polluter pays” principle, it would be mostly ELCs, who should be charged here.

It is suggested to hire an experienced consultant on land and resource conflicts, to conduct here a mediation and ensure voluntary compensation fees by ELCs to the affected communities shown in Fig….

Fees for water services

It should first be tried to collect fees from users and polluters. Polluters can be legally charged. As long as law enforcement is not strong enough to trace and charge polluters, long as polluters cannot be traced, or legal enforcement is not yet strong enough, well-known polluters together with users can be called for a meeting where decisions on voluntary payments for water purification are made. These could be in-kind such as the establishment of a water purification plant, as it has been established by Pnom Penh Sugar in one area, or financially by other polluters, who have not yet taken care adequately for water purification.

From all user fees could be collected through a small fee for water consumption above a critical level. This limit could be for instance water consumption above subsistence level, meaning water consumption about household needs plus the amount of water required to irrigate 1 ha of farmland. As there is no legal regulation for this, it

requires a consent by stakeholders, which are affected by water scarcity, enhanced floods, droughts or pollution. Therefore, the initial activities needed to implement these goals are screening of stakeholders who pollute and screening of stakeholders who consume more than average of water.

Methods to be applied could be – besides or before the installation of technical equipment for monitoring, a rapid appraisal with participatory methods including a stakeholder meeting.

Fees from international organizations: it is suggested to approach IUCN for fees for the protection of the Prek Tnoat watershed, as PTWS has once been prioritized by IUCN as a protected watershed.

Furthermore, it is suggested to prepare at least one proposal for an Ecosystem Based Adapation project under the UNFCCC, to be funded by GEF, preferably, once the hydrological modelling will be finalized.

Which fees for which activities?

Water fees should be equally shared with all upstream stakeholder groups, but preferably with consideration of needs and efforts undertaken. SLM activities and afforestation are frequently more laborious than avoiding deforestation, which also has other income opportunities. Therefore, it is suggested to distribute the bulk of water fees to SLM activities and afforestation.

All of those options have a link between the payer and the ecosystem services of the park (i.e. would be buyers are beneficiaries of the ecosystem services of the PKNP), are logistically simple, the base is broad and seem feasible at this stage. Most are not mutually exclusive and could be used in parallel (Table 27).

Table 27: Activities to be paid from different fees

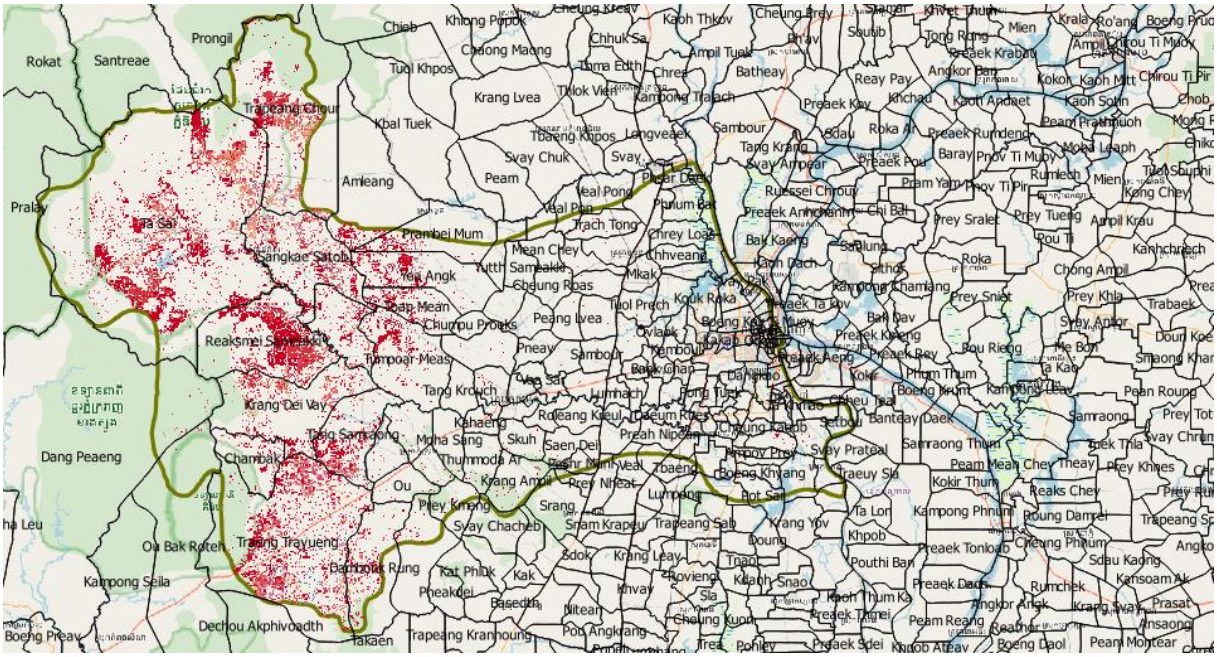
Type of Payment	Type of Service
Ecotourism and access fees	Biodiversity, avoided deforestation
Habitat protection	Biodiversity
Carbon fees	Avoided deforestation, afforestation
Waterfund/Fees for watershed services	All, but preferably SLM activities, fishery, agriculture For commercial companies(stakeholders within sub-watersheds, downstream users pay upstream users within that specific watershed
EIA fees	All
Charges for transgressions	Pollution, flood and drought mitigation, buffer zones hed services
International Transfers from GEF	Specifically, for the issues addressed within the proposed activities/project

11.4.4. STAKEHOLDER ANALYSIS II: IDENTIFICATION OF POTENTIAL BUYERS OF ECOSYSTEM SERVICES

The identification of potential buyers of ecosystem services is normally the most difficult part in the development of PES schemes, as usually many are interested into good environmental conditions, but only few are willing to pay for it. Experience from other countries have shown, that PES schemes have been conducted in many countries with different success. The lessons learned from these countries about the conditions, when success was generated was that the most efficient schemes happened, when providers and buyers had a genuine economic dependence on each other, meaning, that negative financial impacts had been felt by at least one

stakeholder group, and environmental improvement had conversely positive financial or other impacts, that they were even willing to pay for it. In the following the locations, where major environmental damages happened are related to the communities, which have been affected by these damages.

Figure 43: Biodiversity and Carbon Losses



For biodiversity and carbon losses the location of damage and the impact of damages coincide, as both are directly driven and located in the hotspots of deforestation from 2000 – 2014. According to Fig 2.1., the communities mostly affected are Treapeang Chor, Tasal, Sangkae Sabo, Raeksmaj Samaii, Krang Devay, Tang Smrong and Chambak. These are simultaneously the communities where on the other hand still the most valuable commercial forest resources are left.

Ongoing deforestation has uncovered major areas in the centre of the watershed, mainly through conversion of the land by ELCs, which have created a belt, which is called in the following as a “critical risk zone” to erosion, but also to sedimentation and pollution (compare Chapter 9.2).

Deforestation has deeply changed the regional water regime, especially seasonal flood and drought risks. The change affects the total basin far beyond the core areas of deforestation occurred and affects even further downstream areas towards the Mekong river. Here are areas of greatest poverty rates, where the agricultural production system is is slightly affected by drier conditions, which reduce the agricultural production potential.

Nevertheless, as there are many sub-catchments in the mountain areas, the dynamics of the most severe changes happen here, while the impacts in the total watershed, especially in the Western part, are rather gradual. ELCs are sometimes so large, that they themselves occupy one or two sub-catchments. Therefore, locations of causes and impacts of seasonal water flow changes can frequently be observed in one and the same ELC.

Pollution has been small under the forest cover in 1992, and ongoing deforestation affects the Upper Prek Tnoat riverbanks in 2012 and 2016 and in some niches. However, pollution spreads almost into the whole country, if no buffer zones along water systems are created and maintained. As apparently hardly any agricultural producers maintain buffer zones, all agricultural producers can be held responsible for pollution.

The impacts of sediments are felt mainly locally, therefore area of causes and impacts almost coincide, while the major impacts refer to the sedimentation of rivers, increased sand loads, widening of the riverbeds, and

increased flood risks, in addition to the ones identified under points. Sedimentation affects in particular also dams and reservoir areas.

In summary, Table 28 lists the interdependencies between ecosystem polluters and affected land user groups. About 80% of the mentioned costs have been created through deforestation, and out of this 80% by ELCs.

Table 28: Interdependencies between Ecosystem Polluters and Affected Land User Groups

Ecosystem services which are Affected	Cause	Stakeholders who are affected by the damage	Cost of damage (USD)	Measures for Rehabilitation
Soil fertility	Loss of livestock manure due to urban and construction areas, plantations	Farmers who keep livestock	**20444 / 82000 (annual)**	Expansion of Grazing Areas
Soil -stability	Forests decline, absence of SLM	All water and land users	8,750,000 USD (70,000 ha) (2000-2015)	Prevention (SWC)
Erosion Protection	Forests decline, absence of SLM	All water and land users	4,174,634 (2000-2015)	Rehabilitation SLM, Erosion Protection
Sediment retention	Absence of buffer strips, absence of SWC, deforestation	All water and land users, dam operators	1,500,000, annual	Rehabilitation (Dredging)
Water Purification	High application of chemicals, forest conversion, absence of buffer zones, loss of filtration capacities of water resources due to deforestation	All water and land users, water service providers, hotels	of 4,792,240, Health Impacts and Human Live, annual	Chlorinization
Biodiversity of Aquatic Systems, Fishery	Eutrophication of Water Bodies through	Fish-dependent households,	16,240,000 /81,200,000 (2000-2015)	Fish Mortality
Filtration	Pollution	Chemicals, Intensive and medium intensive farming	**Loss of 30% Species richness (2000-2015)**	Local and Global Community
Climate regulation	Logging	Global Warming due to carbon losses since (future services), foregone losses 2000-2015	**15,000,000 (2000-2015)**	Local and Global Community
Wood	Logging		30,000,000 (2000-2015)	Local
Drought and flood mitigation, Crop	Change of seasonal flow due to deforestation	Downstream crop farmers in the West through declined baseflows,	40,000,000 (JICA) 200,000,000 (UNDP), annual	Crop Farmers Downstream

Water Retention	Change of seasonal flow due to deforestation	Upstream Forest Communities due to enhanced baseflows	479,000,000, Human Life and Security, Dam Operation, annual	**Upstream Forest Users, PAs**

It is 3 criteria, which have to be considered, when screening for potential buyers:

a) Impacted by environmental degradation
b) Capacity to pay
c) Willingness to pay

Potential buyers are the ones, which expect a financial advantage in future, if environmental services are rehabilitated. Therefore, they are the ones, who already currently face financial damages through the impairment of environmental services. These might be

- Wood related industries: Industries which rely on a sustainable wood supply also in future will feel negative impacts by deforestation as long as prices for wood imports are higher than locally available. These could be paper and furniture industries.
- Water related industry: Many industries rely on water, but the sector which relies mostly on water is irrigation agriculture, especially horticulture and fruticulture, which is mainly practiced in the ELCs. water bottling and water supply companies, will face the highest costs, if pollution and sedimentation increases. Hydroelectricity production can be especially hampered by reduced water flow and enhanced sedimentation but plays a minor role in the Prek Tnoat Watershed.
- Tourism and hotel industry: The tourism industry is affected by reduced scenic quality due to loss of biodiversity and has usually not many difficulties in generating funds itself for usage, recreational, or access fees. At least for Chambak forest the impression was, that entrance fees into the forest could easily be doubled, tripled or quadrupled, especially from tourists from overseas, as the usually had to spend a lot to enter Cambodia, therefore probably would not be unwilling to pay 3,4,5 USD as an entrance fee instead of 1 USD. There is also the possibility that hotels increase their charges, which is then shared with communities for PES.
- The food industry is impacted by lower quality of food. Organic agriculture is more and more negatively impacted by increased pollution through ELCs. Therefore, improved collaboration with organic agricultural organizations might help to receive at least indirect paymnt.
- Infrastructure, human life and health are increasingly impacted through the enhanced threats by disasters. While human life and health cannot be priced, but the ongoing deforestation in the uplands subjects increasingly the downstream communities to flooding, such as Pnom Penh, which will lead to high costs to protect against damages or repair them.
- International organizations: The world community is mostly impacted by climate change as a consequence of carbon losses due to deforestation, as well as by genetic erosion. The major institution to pay for global environmental concerns is GEF and UNDP, but GEF has reduced its contributions to the RCG in the last years. New environmental transfer schemes under the CBD are also discussed, due to the low capacities in many developing countries to establish a financially well-equipped buyer community.
- Other options to generate payments are charges and royalties. It has already been foreseen in the Environmental Code, that charges for EIAs and royalties for commercial use of forests should be fed into the Environmental Trust fund, which partly could be used also to finance PES.
- Charges and transgression fees: It is the impression of the consultant that a lot of fees could be collected, if just the Polluter Pays and User Pays Principles would be enforced and also transgression fees would really be collected, as foreseen in the Environmental Code.

The general way to identify national organizations which would contribute to PES, requires to screen stakeholders in the potentially affected sectors according to the locations which are affected, as mapped out above.

11.4.5. DETERMINING PREFERABLE PAYMENT SCHEMES

The Environmental Code has already drafted the most important fundament for a saving and payment scheme for environmental services, the Social and Environmental Trust Fund. Besides this, schemes which are practiced in other countries are

- Water funds
- Certification Schemes
- Permanent conservation easements
- Contract farmland set asides
- Co-financed investments
- Payments for proven investment in land conservation
- Subsidies
- Taxes, tax breaks, environmental fees
- Conservation banks
- Tradable development rights
- Direct payments for environmental services
- Conservation concessions

Each of these schemes need specific institutional settings to be successful, and not all would work well in the Cambodian context, as some mechanisms are simply not in place, or require certain conditions like very strict laws, law enforcement, transparent institutional structures and hard land titles. The most promising way seems therefore to be schemes which are already foreseen by the law, which are the social and environmental trust funds, water funds and individual agreements. The previous paragraph has already elaborated, which ingredients are necessary to make these funds work. Voluntary payments, compulsory payments, accession and conservation fees and water funds are especially an option for the payments of downstream users to upstream users.

As the institutional mechanism under which these schemes are working, is normally the collaborative management, it is “the Collaborative Management Committee”, which “may solicit and receive donations, endowments, and grants in the form of contributions, sustainable financing, and payment mechanisms for natural resource and ecosystem services, including the entitlement for communities to be compensated for the provision, maintenance, stewardship, restoration, or enhancement of flows of natural resource goods and services originating from the Collaborative Management Protection Zone, including those originating from ecosystems, through payment mechanisms established in accordance with Book 8 Economic Measures, Fees, and Funds for the Environment. (Echerrevia 2016).

Under collaboration with an organization experienced in certification schemes, it might be possible to develop also an own brand or marketing label and an associated certification scheme for sustainable production of non-timber and timber forest products. While organic labelling and sustainable labelling might face a lot of market barriers, there has been once the idea created of producing a “pro-poor” label forest products, if all production is conducted under a pro-poor forest policy.

11.4.5 STAKEHOLDER CONSULTATIONS AND NEGOTIATIONS

The value of a good or a service is not equal to the price. Usually the buyer tries to get a higher value from goods or services, than the price he or she pays. The difference is the consumer surplus. Therefore, the values calculated in the preceding chapters do not all necessary indicate the baselines for prices to be charged, but of the value the buyer might obtain. Nevertheless, the findings give also an overview over the prices to be paid, which are the opportunity costs. Opportunity costs are the minimum prices which have to be paid, to convince potential providers to produce the specific services, as in cases payments for ecosystem services lie below these price levels, it is very likely that the provider will switch to other economic activities and will abandon the provision of ecosystem services. However, also opportunity costs can be lower than the full commitment to another economic activity, if the provision of economic services is only considered as a side activity. For instance, previous payments for ecosystem services especially for the conservation of different species have been very low (Table 29).

Table 29: Current Types of PES in Cambodia

Type of PES	Location	Price	Remark
Saving fish species	Tonle SAP	4 – 5 USD/month	Does not take ES approach, payment too low
Bird nest protection Program	Cardamom Mountains	5-10 USD/month	Does not take ES approach, payment too low
Avoided Deforestation and Ecotourism	Siem Riep	15-30 USD/month	Area advantage due to historical site
Carbon Services	South West, paid by Disney	1 USD / ton of carbon	Does not reflect the social costs of climate change
Water Purification Services	Kampong Seu, LWD and VITELLL	Not known.	There is no real economic relation between buyer and provider of ES

Besides the minimum prices the provider will provide services, the other baseline is the capacity and willingness to pay by the buyer, where high variations exist.

Table 30 gives a broad overview over the willingness and capacity of different stakeholder groups to pay for different services. It indicates how hard negotiations will be over potential payments for ecosystem services. “Willingness to pay” is here used in its literal sense, not as an economic research tool on consumer-surplus.

It is assumed, that local communities do not have any capacities to pay for PES, therefore, they are not considered as buyers, instead as beneficiaries.

Table 30: Capacity and Willingness to Pay of Potential Beneficiaries of Ecosystem Services

Ecosystem Services	Beneficiaries	Benefits	Potential to Pay	Willingness to Pay
Carbon	Global Community	Climate Stabilization despite high use of fossil fuels	+++	+
Biodiversity	Global Community	Genetic reserves for breeding and ecological resilience	+++	+
	Rural farmers	Enhanced Disease Resilience, genetic reserves for breeding		-
	Tourism/tourism industry, tourists	Income through wildlife tourism, birdwatching, rare plant species etc.	+++	++

	Local Communities	Income opportunities through a high diversity of items (see below)		-
Water	Local Downstream users: Navigation, irrigation agriculture, hotels, water supply industry	Income opportunities	+	+
Sediment Retention	All ecosystems, particularly water resources, agriculture and forestry	High costs through improved costs for dredging or water purification and sanitation Reduced water resources for agriculture Still benefits for construction industry, because of better access to sand.	+++ ELC	- ELCs
Nutrient Retention	Agriculture	Higher yields or lower input costs/ higher net revenues		
Cultural Services	Pagoda, Spiritual communities Artists Tourism Industry	No impacts of spiritual ceremonies, Inspiration Income generation	++	++
In General	International Advocacy Groups and Organizations	All services	+	++

Negotiations need also advocacy work and lobbying. In the following two suggestions are mentioned

Advocacy and Collaboration with Like-Minded Partnerships Overseas

There might be like-minded organizations overseas, who are as critical to textile production under inhuman conditions, timber and sugar export to Europe as many Cambodian organizations are. Therefore, one might find environmental organization who would be ready to pay for sustainable forest use, if it can be made clear, that this will save workers from inhuman conditions in textile factories.

There might be health initiatives, who might pay for restoration of forests on abandoned sugar plantations, if it would come to the point, that those plantations would leave.

This requires also national and international advocacy work. There are already local organizations in Cambodia, which are doing this advocacy work. Harnessing these organizations for advocacy work on international level under one common goal would be more effective than confronting them.

Lobbying at COPs of Rio Conventions

There is a widespread recognition that agriculture and the burning of tropical moist forests contribute to global warming but to a much lesser extent than the combustion of fossil fuels and industrial activities in the developed world. Highlighting this fact is necessary for advocacy work to further elevate the price of carbon in international organizations. Similar work might be necessary at the CBD and UNCCD. Collaboration with engaged organizations at the Rio-Conventions is also an opportunity to find funders for PES.

Collaboration with the Landcare International Initiative

Landcare is an initiative which involves all stakeholders who have an impact on are affected by the management of a certain land use unit in a collaborative way, including the urban population. Landcare International has originally been founded in Australia and has been highly successful also in countries such as Iceland, Mongolia, the US etc. Landcare Philippines for instance is the initiative closest to Cambodia and mentioned by WOCAT as a sustainable land management initiative. The advantage of linking up with Landcare International is that it gives access to a network which enables continuous exchange of experience, lessons learnt and best practices.

Fairness and Equity Considerations

According to the Environmental Code, PES should be implemented under full considerations of fairness and equity criteria, with high commitment to gender aspects and vulnerable groups. Table 31 shows different possibilities to design those payments, where the pro-poor focus increases from top to bottom in the Table, while the effectiveness of indicate scarcity of environmental services is going from bottom to top.

Table 31: Fairness and Equity Design in PES

Fairness Criterion	Design Implications
Compensation	**Payments compensate land holders for foregone benefits related to the provision of environmental services. Payments are differentiated according to the cost of provision**
Public	**Payments are invested into public goods, so that all providers benefit indirectly and according to their relative use of the common goods in question. Payments are not differentiated**
Egalitarian	**All providers receive same fund, independently of the level and cost of the environmental service provision Payments are not differentiated.**
Maxi-min	**Payments aim to maximize the net benefit to the poorest landholders, even at a cost of efficiency loss. Payments are differentiated according to the income of providers**
Actual provision	**Payments are differentiated according to the actual level of provision**

11.4.6 EFFICIENCY AND EFFECTIVENESS CONSIDERATIONS

Efficiency considerations refer to the target area of environmental rehabilitation, the chosen payment scheme and the choice of the payment schemes and of parts. It relates to the prioritization of target areas and of communities who would run the scheme. With regard to target areas, for instance a focus either on biologically and ecologically high-value areas or on almost vulnerable areas is possible.

Law Enforcement

To support communities to protect forests and watersheds effectively, they protection of forests need to be linked to national or provincial enforcement of the judicial system. It has also to be ensured that they really work under registered management and land titles. Higher transparency and improved law enforcement and secure land titles will help to de-escalate these conflicts, which is the necessary fundament for effective PES implementation.

Clearly Defined Rights and Land Title Security

PES require land title security. Without proper land titles there are also no legal instruments to claim users to attain to environmental legislation, such as observing buffer zones around wetlands or to ensure that ES are provided and paid for. Also, to identify the winners and losers from environmental change requires the clear identification whose land belongs to whom, and is affected by whose activities in neighbouring or upstream areas, and whose environmental activities benefit whom.

Also, rights on PES charges, such as carbon rights have to be defined and clearly appropriated among the stakeholders. The clarity of rights to PES is a key for effective and equitable benefit sharing arrangements.

Capacity Building

- Spatial Management: Capacity building for environmental officials is foreseen in the Environmental Code. There is in particular a need for improved spatial management on all level, from governmental level to community forest management committees. Not applying spatial management techniques to supervise land resources can lead to misallocations. Therefore, capacity building in GIS and GPS technologies would be a priority and important requirement for the implementation of PES schemes.
- Monitoring: To guarantee that environmental benefits have been created requires appropriate monitoring capacities, especially it would water meters to measure irrigation water consumption, water quality monitoring sets, and more river gauging stations for flood monitoring. A promising option for monitoring indicators which occur in high numbers in many places, such as hotspot of endangered or invasive species or wildlife or fish migration, or land degradation is citizen science, which involves many citizens in the observation of single indicators, mainly through mobile phones. An example for such a monitoring initiative is LandPKS[15] – a monitoring system for land degradation and land use practices, which would also require an initial training.
- Ecotourism: Ecotourism is considered currently as the most promising solution to earn payments while at the same time protecting the environment. Mlup Baiting is the organization, which supports communities in establishing ecotourism schemes. Nevertheless, most communities do not have a clear vision what running an ecotourism project really means.

Liability 'and Transparency

Every person who pays somebody for services expects a certain responsibility, reliability and transparency about the progress of this activity. Therefore, avoidance of leakages, liability regimes and combatting corruption are necessary preconditions for successful PES implementation. One field, where greater transparency is particularly necessary, is the management of ELCs, who should give full insights into use of resoures and application of chemicals, quality of wastewater to the responsible Line Ministries and surrounding communities. Corruption can give adverse incentives, which might offset any financial efforts to support ecosystem services conservation through PES schemes. Addressing corruption is therefore equally important as better law enforcement to conserve ecosystems.

Full Hydrologic and Land Use Research and Modelling

Developing a fully integrated interdisciplinary ecological/hydrological/climate change model, which is based on results from detailed field studies on all relevant ecological parameters, is urgently recommended, as currently ongoing research efforts are fragmented and not well aligned.

Better data access and storage

Some data are monitored in high resolution with high technology. Nevertheless, they are not stored and compiled, therefore not available for the assessment of long-term environmental improvement

Coordination and Management

[15] See www.landpotential.org, also www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1043054/

For effectiveness of PES schemes, administration costs should be low, which requires high institutional effects. Costs of USD 4-9/ha was for instance the average administration price related to PES schemes in 2008 in selected African, South American and South Asian countries.

11.5 SUPPORTING POLICIES AND OTHER INTERVENTIONS MEASURES

Pro-Poor Policies to Avoid Poverty Traps

The implementation of pro-poor policies, could stipulate sustainable extraction schemes for non-timber forest products and related value chains. Currently non-timber forest products face different challenges, such as market competition, decline of the species through habitat extinction, or simply, no development of a potential species. For instance, mushrooms, which had a good market before for the production of medicine, face now competition from cultivated species. Still the announcement that these species come directly from the wilderness, might create a new label and improved marketing capacities. Rewards for protection of habitats might regenerate wild orchids, and other species, such as the noni, which create high prices on the world market, are simply not developed in Cambodia.

Improving Financial Capacities of Potential Buyers and Value Chain Development

Improved financial capacities will enhance the willingness to protect the entity which provides these improved financial capacities. The more value chains are connected to a specific ecosystem service, as the more valuable this ecosystem service is classified, and the more its impairment is prevented

Liquidity Planning

Why governments clear forests, and why smallholder cut wood for charcoal, is normally not based on long-term views about the future value of natural resources, but on short-term needs for cash and financial liquidity. Smallholders might need cash for daily food, school feel, health services etc., government might need cash for debt repayment, development, political power. The CSES studies have also evaluated the annual financial expenses of smallholders. Recommendations on liquidity planning for the government go beyond the capacities of this study. When, however, forests are cleared for short-term financial liquidity, the purpose should be made transparent.

11.6 COLLABORATION PARTNERS

Scientific Institutions

Sound ecological economic valuation as the pre-requirement for developing sound PES schemes has to be based on sound environmental valuation. As the Environmental Code demands, this valuation has to used best and most updated statistical information. This requires also more detailed modelling based on detailed field assessments to understand and tackle this situation. Partnerships with research-based institutions, such as Universities, the Mekong river Commission and JICA, which are ongoing, should therefore be intensified.

Scientific support is needed in almost all activities, in monitoring, classification and modelling. Currently scientific institutions are mainly using data from NGOs. The ideal situation would be that the government monitors data regularly and approaches research institutions to address certain emerging questions, and then research institutions complement data collection and address the respective research questions.

Marketing Organizations and Innovative Organizations

The development of new products, such as vegetables, or new value chains, is mainly hampered in the watershed due to a lack of marketing opportunities. Collaboration with effective marketing organizations is therefore recommendable, also the collaboration which can introduce technological and business innovations, such as

bioprospecting companies, organizations which can develop new production chains from the existing vegetation etc. To capture higher amounts of value chains from tourism, the collaboration or domestication of travel agencies will also be helpful to increase financial capacities.

Supporting Frameworks

Policy frameworks which will support the collection of payments and the implementation of PES schemes especially for forest services are the REDD (Reduced Emissions from Deforestation and Degradation) and the FLEGT VPA (Forest Law Enforcement, Governance and Trade Voluntary Partnership Agreement) Programme. (FLEGT VPA), as they strengthen opportunities for improved laws and regulations, transparency, reduced corruption, technical and rights-based approaches to sustainable forest management, and monitoring and reporting systems.

11.7. PROPOSED LOGFRAME AND ACTIVITIES FOR THE UPCOMING 3 YEARS

Table 32: Logframe for Implementation of PES Scheme in Upper Prek Tnoat Watershed

Overall Purpose: Introduction of PES Schemes in the Upper Prek Tnoat Watershed		
1	**Objective 1: Provision of Environmental Services by all Relevant Stakeholders Designed and Implemented to conserve and improve the productivity of land and water**	
1.1	*Subobjective 1.1: Building Initial Capacities*	
	Capacities in Spatial Management Built or Enhanced	National Trainer in Spatial Management Hired for on-the job training in spatial Management (GPS and GIS) Local officials and local community forest management community members equipped with GPS Local officials have downloaded QGIS and are able to use it Local officials and local community forest management trained in spatial management
	Future Land use Plan and Major Environmental Challenges Identified	Stakeholder Workshop conducted to verify/identify major environmental challenges and their locations, their causes and impacts and to conduct land use planning for a sustainable scenario in future
1.2	*Subobjective 1.2: Avoided Deforestation Implemented*	
	Demarcation of Forest Boundaries marked and mapped	Community Forests boundaries discussed with communities, marked and mapped Community Management Team Established and trained
	Roles of Communities to ensure avoided Deforestation Defined and Implemented	Workshops conducted with Communities on roles and Responsibilities (safeguarding, patrolling and monitoring) defined and accepted by relevant stakeholders, design of bylaws)
		Management Plan on sustainable non-timber forest product extraction designed and implemented for at least 3 valuable forest products (mushrooms, orchids, snails, noni as well as rattan)
	Sustainable Timber Extraction in Place	Forest Areas for sustainable timber extraction demarcated, which could partly overlap with areas for sustainable non-timber forest product extraction
1.3	**Subobjective 1.3.: ANR and Enhanced Forest Area Designed and Implemented**	
		Regional Consultant (preferably from Philippines) hired
		Workshop Conducted by Regional Consultant and communities to decide on Locations and Technologies for ANR and Enhanced Forest Areas
		ANR and Enhancement of Forest Areas / Aforestation Activites implemented (with a Focus on Degraded Forest Areas and the Western Boundary of the
1.4	**Subobjective 1.4. Clear Land Titles on Community Forest Areas Established**	Communal Land Titles for Community Forests are officially registered and recognized Collaborative Management Titles are officially registered and recognized
1.5	**Subobjective 1.5. SLM established in agricultural areas**	ELCs give MAFF insight into management practices including pesticide use, fertilizer use, wastewater management, planting distances, productivity functions etc.
		ELCs switch to sustainable land management practices
		Farmer field schools or model farmer systems introduced for dissemination of SLM
		Farmers adopt at least 2 SLM methodologies
1.6	**Subobjective 1.6. Grazing Areas for livestock Enhanced**	Workshop conducted in livestock nutrition and management with regard to restricted grazing areas

		Location of potential future grazing areas identified and access negotiated with current owners,
1.7	**Subobjective 1.7. Development of culture-based fisheries in inland lakes, rivers, floodplains, and permanent and temporary reservoirs and barrages encouraged and implemented**	Trainer on sustainable fishery management hired
		Sustainable Extraction for Fishery Introduced and Implemented Reproduction of fish stocks stimulated through - Fish ponds - Fish pens and fish cages - Floating rafts, lines, and stakes for molluscs and seaweeds
1.8	**Subobjective 1.8. Erosion and Sedimentation Control Measures Introduced in Most Vulnerable Areas**	Priority areas/hotspots of erosion and sedimentation identified and verified in Stakeholder workshop
	Erosion Control	Technology of monitoring indicators of land degradation (for instance through mobile technologies with LandPKS or based on WOCAT questionnaires etc.) introduced and applied
		Consultant for SWC Hired
		Rehabilitation and Restoration (SLM), introduced and Implemented
	Sedimentation Control	Sedimentation, siltation, erosion is minimized through physical measures (with consultant above), based on technologies Annex IV
		Dam operation improved through desiltation of gates
		De-siltation of irrigation channels
1.9	**Subobjective 1.9: Pollution Reduced and Pollution Control Legally Enforced**	Buffer zones around wetlands in the distance of 50 m around surface waters established by communities Use of pesticides reduced through improved transparency by ELCs into chemical use and control of upper limits Use of pesticides by small scale farmers improved through improved information about doses Government supported in better control of hazardous pesticide use
2.	**Objective 2: PES schemes designed and Implemented 2**	
2.1	**Subobjective 2.1. Buyers for Biodiversity Identified**	Expert on Land Conflict Resolution Hired to manage potential land use conflicts emerging from PES implementation (20 days)
		Preparatory study conducted by UNDP on identification or verification of local/national stakeholders which are affected by environmental degradation
		Stakeholder Meeting Conducted with relevant industries, ELCs, private companies, civil society organizations, from fishery, water, agriculture, food, tourism, wood and paper sector, which are affected by environmental damages to establish PES schemes
		Assessment of their willingness to pay during workshop and/or subsequent survey
2.2	**Subobjective 2.2. Review of further other options to finance PES schemes**	Capacity Building of Government to collect Transgression fees for environmental damages, and fees under the Polluter Pays and User Pays schemes
		International Organizations approached to finance PES schemes (GEF, IUCN, etc.)
		Visitor's fees to ecotourism sites elevated from 1 to 3 USD
		Travel agencies pay a fixed amount to community forest projects
		ELCs pay fixed amount to communities for polluted water
2.3	**Subobjective 2.3. Design of Payment Schemes Decided**	Workshop on Design of Payment Schemes Conducted
		Negotiations among sellers and buyers of ecosystem services about appropriate pricing
		Equity, Fairness, Pro-Poor and Efficiency Criteria Incorporated into that Scheme
		Contracts about Voluntary Paymets for PES signed among buyers and providers

		Environmental Fund established under Guidance of MoE
		Water Fund established under Guidance of Water Agency
3.	**Objective 3: Enabling Conditions for PES Schemes Established**	
	Basic Studies and Plans	Detailed Hydrological Study on Prek Tnoat Watershed based on Field Measurements Conducted Land use Plan established (under guidance of Government) Integrated Water Management Plan established (under guidance of Government)
	Advocacy Work conducted	A stakeholder Meeting is conducting together with Line Ministries, NGOs and INGOs to develop a national and international awareness raising strategy of environmental problems within the Prek Tnoat Watershed (MOE, MAFF; FoA, JICA, APFNet, Conservation International, Mlup Baitong, LWR, Cambodiadevelopmentnet etc..)
		Linkages to International Critical Campaigns on Sugar Plantations, Sustainable Wood Production, Hazardous Pesticides etc. established
		Further Linkages made during conferences of Rio Conventions
	Commune and District offices equipped with Monitoring facilities to Prove Successful Provision of ES and to trace environmental transgressions	Equipment purchased on water quantity and quality monitoring (water meters, chemical and biological water testing kits, linkages to water laboratory established which conduct initial water quality measurements)
		Fish population monitoring started based on citizen sciences
		Company hired for desiltation of river beds and solving of other operational mechanical problems of gate operation

12. CONCLUSIONS

1. Prek Tnoat Watershed has is considered as a highly vulnerable watershed to climate change, biodiversity and general resilience loss, which is why for instance it has been listed by IUCN as one of the watersheds to be put under protection. The introduction of schemes for payments of environmental services might trigger, support or enhance efforts to protect the highly vulnerable ecology of the watershed.
2. To design payments on environmental services, it requires to identify damages to environmental services, which happened in the past and will occur in future. Furthermore, it needs to address the major drivers, which have caused these changes within the provision of environmental services.
3. Deforestation is the driver with most detrimental impacts of environmental services in the Prek Tnoat Watershed. While in 1937 almost all over Prek Tnoat Watershed had been covered by forest, the Lower Prek Tnoat Watershed – meaning the Eastern part – was transformed later on successively into cropping land by small-scale farmers to meet nutritional needs, keeping up with demographic growth. Deforestation in the Upper Prek Tnoat set in mainly in the 1990es, starting with the most valuable evergreen broadleaved forests, which were cut mainly for timber values. Deforestation from 2000 could be traced in more detail. The total net deforestation between 2000 and 2015 was about 72,000 ha, out of which 95% were deciduous broad-leaved and mixed forests, therefore the less valuable remainders. 2012 to 2014 were the years of highest deforestation, the bulk of it for plantations, which made use of the benefits of conversion timber. According to MAFF data (2018) about 44,000 ha were transformed into ELCs, earlier and other data indicate that ELC areas were about 68,000 ha.
4. The total stock value of the remaining forest in 2008 prices is estimated to range between 1,454,296 and 3,650,424 thousand USD in 2018. Between 2000 and 2018 values between 1,878,977 and 4,716,416 thousand USD have been lost, and if practices continue, values between 644,490 and 1,617,723 thousand USD will be lost in future – assuming that prices are only determined by the deflation rate and increased scarcity does not play a role.

5. The carbon value of the remaining forest in 2018 was 7,594,310 USD if carbon prices would have been 10 USD, 15,188,260 USD, if carbon prices would have been 20 USD/metric ton, and 22,783,390 USD/metric ton, if carbon prices would have been 30 USD. If forest logging had been stopped in 2000 and REDD schemes would have been implemented, the total carbon value captured in 2018 could have been between

Year from 2000 to	Assumed Carbon Price [USD/metric ton]		
	10	20	30
2018	91,439,169	182,878,339	274,317,508
2030	294,900,460	589,800,920	884,701,380
2060	5,508,500,511	11,017,000,000	16,526,000,000

If under a SEM scenario carbon values would be captured starting a REDD scheme in the remining forest now, the carbon values captured could still be

Year from 2000 to	Assumed Carbon Price [USD/metric ton]		
	10	20	30
2030	24,491,828	48,983,656	73,475,483
2060	457,487,404	914,974,809	1,372,462,213

This means, there is still the option, to outcompete stumpage values of forests through clear cutting through carbon sequestration of he remaining forest until 2060, if carbon prices rice to 30 USD/ha, a figure, which might also be used for carbon price negotiations on international levels. Anyway, there is a certain likelihood, that future carbon prices will rise far above these levels.

Ecological Issues

6. Besides the forgone losses of direct use values from forests, deforestation in the Upper Prek Tnoat had some critical impacts on erosion, nutrient export and the overall hydrological regime, with increasingly negative economic impacts on provisioning services such as agriculture, fishery, livestock production, as well as on non-monetary values such as human health and human life, which will become worse, if current practices continue.
7. One of the most devastating impacts of deforestation is the one on seasonal flows. Deforestation in the Upper Prek Tnoat basin between 1992 and 2012 led to an annual increase of 1,25% recharge, while discharge was reduced about 1% annually on an in the lower Prek Tnoat basin, enhancing flood risks particularly in Trapeang Chour, Tasal, Chambak and parts of Krang Devay. Within the sub-watersheds especially in downslope areas in niches close to forests, water accumulates, therefore, here the probability of flood occurrence is higher. BAU scenarios assuming deforestation to continue until no forest is left predict a tipping point, where the whole basin becomes wetter and floods could affect Pnom Penh.
8. The land in the Upper Prek Tnoat Watershed (Western part), which was converted after 2000 is much more vulnerable to erosion than the the land in the Lower Prek Tnoat Watershed (Eastern part), which led to high erosion rates especially in certain erosion channels, which carved partly large gullies into the landscape, such as the area below Krang Devay and within Tasal. Simultaneously, surface waters impacted by sedimentation, which arises from the enhanced erosion rates. There is an indication, that fish population was reduced about at least 50% since 2000 under very conservative estimations. Fish population and the resilience and environmental integrity of water systems are apparently currently the most vulnerable ecological parameter affected by deforestation, and severely threatened in the nearer future, if current trends are not reversed. Indeed, regressions and the extrapolation of comparable data from Tonle SAP indicate that there might be a total extinction of the fish population with all ecological side effects even at the end of the next decade.
9. With erosion not only sediments, but also nutrients are exported, which contributes to increased fish mortality mentioned above. Additionally, nutrients are not only exported to surface waters but also into groundwater. As a rule of thumb, 20 – 80% of nutrients in the soil organic matter are released in the first

years after deforestation, increasing nutrient loads to groundwater about 100 kg N/ha. Additionally, nutrients and pollutants from chemicals used for agriculture are exported from farms to surface and groundwaters, depending on the rate of chemicals applied. The average fertilizer rate amount smallholders apply is 25.7. There are no data about application rates of chemical fertilizers by ELCs, but to ensure minimum productivity, a rate of 100 kg N at least is assumed. Phosphorous amounts, which are particularly damaging to groundwater, are assumed to have a proportion of 10% of the rate of N. As a consequence, groundwater below agricultural areas of smallholders and surface waters around are assumed to have nitrate concentrations which are at least four times higher than WHO standards for drinking water under average smallholders farms, and values 20 times higher than WHO standards below ELCs. This means, that nowhere in these areas opportunities to obtain safe drinking water exist, enhancing either the need for the people to travel to forest areas farer away or creating costs for drinking water.

10. No information is available the use of chemicals by ELCs. However, FAOSTAT reports on a continuation of high use of hazardous chemicals in Cambodia, though these were prohibited after 2012. It is assumed that ELCs are applying them in high doses according to reports from the neighbourhood.

Economic Issues

11. Total values from provisioning services measured as net returns were for all sectors - agriculture, fishery and livestock – not higher than 280 (Kampong Speu) and 360 (Kandal) USD/ha, aggregated for dry and wet season. Estimated gross returns from ELCs were ranging between 600 up to 2000 USD/ha and more, therefore about 2 to 5 times higher than the ones from smallholders. Only a small proportion of ELCs was devoted to wood crops, the bulk of ELC land is used for sugar cane production.
12. The average gross incomes of ELCs were estimated of at least about 1700 USD/ha on an average, while maximum values such as for rubber of up to 3000 – 7000 USD could be achieved. The envisaged amount of 25 USD/ha, which ELCs promised to share with forest communities in Tasal, as the first initiative of benefit-sharing at all, can therefore hardly be considered as fair and equitable, given the fact that the foregone losses of communities from forest use, which is about 200 USD / ha and in certain areas about 2000 USD/ha incidentally, let alone the fact, that most ELCs have not shared any benefits with communities at all.
13. ELCs cause substantial damages to protected areas. Their total area in ELCs is 13,175 ha. In these areas ELCs cause about 17,833,000 estimated gross incomes USD annually for those ELCs. the total damage done through foregone losses for communities and through ecological damages is about threefold.
14. The impact of pollution hits the poor mostly. The costs of pollution, if really covered, are highest for water purification. As pollution, however, impacts environmental services which have rather non-monetary values, such as human health, it is also easy to ignore them by not putting sufficient efforts into water purification, one of the most critical examples, where non-monetary values, such as human lives and human health, are traded off against monetary values, such as high productivity of provisioning services without taking care of the environmental costs to the direct detriment of those who do not have political voices.

Legal and Institutional Issues

15. Communities and even governmental officials on commune levels reported that they were usually not informed about land concessions, which violates the paragraphs on prior informed consent of communities in the Environmental Code and the Principles of full Transparency and Information of communities.
16. A campaign on land registration has taken place since 2012, but most of the communities were not covered fully by that campaign, so that most of them have only certificates, but no hard land titles which are registered. The lack of hard land titles in the context of the development of an increasing economic dichotomy, where one part can produce in a highly productive way through high investments and making use of the economy of scale on the one hand, and the other part, which is captured in poverty traps through lack of labour distribution, lack of investments and necessary means, leads to a development where land terminates to be the refuge of the poor. Accompanied by degradation of environmental services, such as accessibility of fresh water, wild fruits, vegetables, energy and construction materials, this development can lead to continuously increasing marginalization of the poorest and the landless.

17. PAs are in particular affected by the coverage of five ELCs in the sustainable management zones. The impacts are mainly: erosion, sedimentation, pollution, enhanced inundations, and as a consequence species loss of about 30% and change of vegetation patterns. As those effects have impacts far beyond the boundaries of ELCs themselves, their environmental impacts might reach even into the core zones of PAs. Apart from that, ELCs have also been caught at illegal logging activities within the core zones of PAs, which could also be confirmed by tracing logging activities via GIS. Within PAs the coverage of ELCs is 13,175 ha, creating about 17,833,000 USD gross incomes. However, the costs for ecological damages done in the PAs as well as foregone losses for communities and other stakeholders from forest products and ecotourism and carbon credits are more than threefold.
18. In terms of SDG fulfilments, ELCs therefore neither served food security target, nor climatic nor environmental targets, and apparently also no poverty targets as no benefit-sharing with communities takes place.

SEM Scenario

19. The Sustainable Management Scenario (SEM) is difficult to develop for the next 15 years, as the best SEM scenario are the conditions of the 90es. This is most likely impossible to be implemented due to the presence of the ELCs in the major areas of the Prek Tnoat, which might have contracts of at least 15 years and more.
20. It is therefore important to apply a pragmatic approach in the short-term run and to proceed in a way, that those interventions, which are most easily to be achieved and the ones which prevent the continuation of the BAU, are prioritized and implemented in the first place, followed by interventions which revert the current conditions as much as it is possible, which usually requires more efforts than the first group of interventions.

Interventions for Conservation

21. The SEM scenario has to address the major ecological and socio-economic challenges which currently exist:

Ecological Challenges

- Very high deforestation rate, therefore also high erosion rate. Hotspot of land degradation
- Reduced biodiversity in the remaining forests
- Increased climatic dryness due to deforestation and extreme changes in the hydrological regime
- High ecological and economic vulnerability to climate change conditions of the population and the ecosystem
- Relatively low economic role of fishery
- Rather few rivers and waterbodies, although still high in international comparison, with increasing exacerbation of both dry and wet conditions, leading to higher seasonal hydrological drought and flood risks.
- Increasing climatic dryness
- Overuse of groundwater
- In certain areas high arsenic concentrations

Socio-Economic and Institutional Challenges:

- Increased pressure on land
- Decline of land area per capita
- Reduced current and future incomes in comparison to the past
- Exacerbation of the above mentioned pressures through the occupation of about 12 – 14% of the land by ELCs
- Lack of law enforcement and lack of transparency
- As a consequence high level of land conflicts.

22. A SEM scenario, which could address these challenges must have at least the following elements, which should be incorporated into a detailed land use and integrated water management plan in collaboration between government and local stakeholders prior to implement;.
    - Absolute protection of all forests feasible for REDD projects from timber harvesting

- Sustainable Extraction in multiple use forests
- SLM measures, ANR and forest enhancement in all areas which have been degraded due to deforestation after 1992
- SLM measures in agricultural areas
- Erosion, sedimentation flood, drought control, adaptation, and mitigation in hotspot areas which are mostly at risk
- Buffer zones along wetlands
- Improved hydrological management

23. The communities to be involved into these interventions and to received PES are Trapeang Chour, Tasal, Reaksmei Semeakki, Chambak, Sangkae Satobi, Krang Dei Vay, Traeng Tryaueng.
24. Interventions for conservation should target the conservation of all broad-leaved and needle-leaved forests by protecting them from large-scale logging and using them for REDD+ projects as much as possible. For all other forests a timber extraction rate of 5% should not be exceeded. In all community forests also sustainable harvesting / sustainable extraction rates should be applied for non-timber products, which requires detailed management plan, to avoid regeneration of those products and ensure fair and equitable access. In parallel value chain development especially through bioprospecting, including improved marketing and cultivation of some valuable non-timber forest products could help non-timber forest harvesting communities to get out of poverty.
25. ELCs are to be involved into the introduction of SLM practices on their plots, but without being eligible to receive PES (which includes REDD), as these activities would be on recently deforested primary forests, a condition, which explicitly excludes actors from REDD. There are not explicit rules on the reception of voluntary PES, but ELCs are among the major stakeholders to contribute payments rather than receiving them, due to transgression of the Principle of Prior Informed Consent, the Principle of Transparency and Public Information, the Principle of Polluter Pays and the Principle of User pays. However up to now no monitoring of contamination of soils and sewage water takes place, also not of consumption of irrigation water. Therefore, transgressions cannot be traced and charged for, which preferably costs the state a lot of money due to foregone losses for transgression charges. In general the lack of environmental monitoring violates the paragraphs of full transparency and the regulations on water monitoring in the Environmental Code.
26. Therefore, the introduction of PES schemes would require the introduction of monitoring schemes first, including the instalment of proper and sufficient monitoring equipment.
27. Other prerequisites for the introduction of PES schemes are the detailed hydrological measurement and modelling of the Prek Tnoat Watershed and the establishment of a detailed land use and integrated water management plan in collaboration with all stakeholders.

Fees to be collected for PES

Fees for Carbon Services

28. Avoided deforestation, enhancement of forests and afforestation are the major activities for enhancement of carbon services. Proving success of carbon services can be difficult without appropriate measurements. But there is an ex-ante technology to determine the carbon quantities accumulated by different technologies through the Exact-tool, which is listed in detail in Annex V. The application has to be coordinated with the REDD office within the MoE, and precaution for the avoidance of the leakages has also to be implemented in collaboration with the REDD office. Recently deforested areas which are afforested again are not applicable for carbon services under REDD. However, there are other possibilities on the voluntary carbon market for carbon sequestration through climate smart agriculture, agroforestry etc. The further condition to make REDD schemes work for local stakeholders are clear land titles, in this case it might be community land titles

Fees for SLM and ANR

29. It is mainly the area which has been deforested between the 90es and now, which needs to be protected or rehabilitated through SLM and ANR. As SLM and afforestation schemes have also to be undertaken by ELCs as they are located in these areas, the scheme might be difficult to be implemented, due to the current lack of transparency into ELC management practices. It is suggested to hire an experienced consultant on land and resource conflicts, to conduct here a mediation and ensure improved practices within ELCs and voluntary compensation fees by ELCs to the communities affected by environmental damages.

Fees for Water Services

30. It should first be tried to collect fees from polluters. Polluters can be legally charged. As long as law enforcement is not strong enough to trace and charge polluters, long as polluters cannot be traced, or legal enforcement is not yet strong enough, well-known polluters together with users can be called for a meeting where decisions on voluntary payments for water purification are made. These could be in-kind such as the establishment of a water purification plant, as it has been established by Pnom Penh Sugar in one area, or financially by other polluters, who have not yet taken care adequately for water purification.
31. From all users, fees could be collected through a small fee for water consumption above a critical level. This limit could be for instance water consumption above subsistence level, meaning water consumption about household needs plus the amount of water required to irrigate 1 ha of farmland. As there is no legal regulation for this, it requires a consent by stakeholders, which are affected by water scarcity, enhanced floods, droughts or pollution. Therefore, the initial activities needed to implement these goals are screening of stakeholders who pollute and screening of stakeholders who consume more than average of water.
    - Methods to be applied could be – besides or before the installation of technical equipment for monitoring, a rapid appraisal with participatory methods including a stakeholder meeting.
    - Fees from international organizations: it is suggested to approach IUCN for fees for the protection of the Prek Tnoat watershed, as PTWS has once been prioritized by IUCN as a protected watershed.
    - Furthermore it is suggested to prepare at least one proposal for an Ecosystem Based Adapation project under the UNFCCC, to be funded by GEF, preferably, once the hydrological modelling will be finalized.

Distributional Issues

32. Water fees should be equally shared with all upstream stakeholder groups, but preferably with consideration of needs and efforts undertaken. SLM activities and afforestation are frequently more laborious than avoiding deforestation, which also has other income opportunities. Therefore,it is recommendabled to distribute the bulk of water fees to SLM activities and afforestation.
33. Potential buyers are the ones, which expect a financial advantage in future, if environmental services are rehabilitated. Therefore, they are the ones, who already currently face financial damages through the impairment of environmental services. These might be stakeholders from the tourism, beverage, water supply, wood, paper and food industry. It might therefore to be useful to conduct a meeting with representatives from these industries to discuss about the creation of funds to pay for upstream ecosystem services. In case severe upstream-downstream dependencies are also observed in the smaller sub-watersheds. Other options to generate payments are charges and royalties. It has already been foreseen in the Environmental Code, that charges for EIAs and royalties for commercial use of forests should be fed into the Environmental Trust fund, which partly could be used also to finance PES. Apparently a lot of fees could be collected, if just the Polluter Pays and User Pays Principles would be enforced and also transgression fees would really be collected, as foreseen in the Environmental Code. Besides this, schemes which are practiced in other countries and could be implemented in Cambodia would also be water funds for water services, direct payments for environmental services on a voluntary, though contractual basis and compulsory payments, accession and conservation fees and the implementation of certification schemes.
34. Further sources of payments could be international transfers from GEF and INGOs. It is highly recommendable to propose a GEF project on ecosystem-based adaptation to climate change in the Prek Tnoat watershed. Incomes from ecotourism is furthermore one of the most synergetic way of receiving additional fees, as ecotourism directly enhances and protects carbon and biodiversity services.

35. Under collaboration with an organization experienced in certification schemes, it might be possible to develop also an own brand or marketing label and an associated certification scheme for sustainable production of non-timber and timber forest products. While organic labelling and sustainable labelling might face a lot of market barriers, there has been once the idea created of producing a “pro-poor” label forest products, if all production is conducted under a pro-poor forest policy.
36. Price Negotiations: The value of a good or a service is not equal to the price. Usually the buyer tries to get a higher value from goods or services, than the price he or she pays. The difference is the consumer surplus. Usually the minimum price that has to be paid to ensure that environmental services are provided in a sustainable way is the opportunity cost. Opportunity costs are the minimum prices which have to be paid, to convince potential providers to produce the specific services, as in cases payments for ecosystem services lie below these price levels, it is very likely that the provider will switch to other economic activities and will abandon the provision of ecosystem services. The other side, which determines prices to be paid is the willingness of the buyer, to pay the price.

Supporting Measures

37. Finalizing land registration and supporting communities who collaboratively manage land in obtaining communal land titles and collaborative land management titles is a basic requirement to implement PES schemes successfully. Sticking to the regulations outlined in the Environmental Code and other laws and enhancing law enforcement would be other essential ingredients to facilitate the introduction of PES.
38. Supporting measures are advocacy work, especially linkages with like-minded groups on national and international levels and collaboration with scientific and research institutions such as Universities, JICA, the Mekong River basin, which could help with monitoring activities and hydrological modelling, which could provide the primary insights of the major impacts and consequences of environmental degradation.

Final Conclusion

39. In general, it should be recognized that environmental protection and high land productivity do not cause trade-offs, but synergies, if managed accordingly. Decision making should therefore not be based on the question, which type of land use achieves the highest benefits, but rather be guided by the question: which land use patterns keep ecosystems diverse and alive, and which would be the economic and political framework, to achieve this in the most profitable and equitable way, which can also not be achieved solely by considering monetary values of ecosystem services, even of the regulating ones.
40. In summary, the total annual costs of deforestation without accounting for potential wood versus carbon losses are 121,102,855 USD annually. While the environmental costs of deforestation had in the majority to be borne by smallholders, it were the large plantation owners, who benefitted from the revenues.
41. Total costs for potential rehabilitation are 37,345,532 initially, with annual maintenance costs of about maximally 7,541,500 USD. The cost-benefit ratio the SEM scenario compared to the BAU scenario is therefore about 1:3 for the first year, respectively the period of establishing the SEM scenario, and will even be higher than 1:16 in future. It is therefore economically more favourable to stop deforestation and revert the current conditions towards the situation of 1992 or the SEM scenario, which has been drafted above.
42. Especially water ecosystems are highly endangered through increasing deforestation, followed by agricultural ecosystems, which lose more and more their productivity due to loss of environmental services. It is therefor high time to act.

Annex I

General Data

	Subdivision	Area (m2)	HH [number]	Population [number]
Kampong Speu	Forest	Varying 1992	11690	60583
	Agric	Varying 2015	90943	479224
Kampong Speu		6229320000	102633	539804
Pnom Penh		188121101	214320	1119234
Kandal		186448899	68975	414792
Total		**6603890000**	**385928**	**2073830**

Community Data

Costs [in Mio Riel] Per Sector

2014	**Pnom**	**Plain**	**Plateau**
Livestock	6919	571599	86784
Fish	17	2783	1859
Forest	2152	83205	19072
2015			
Livestock	789	568682	274433
Fish	0	18102	4025
Forest	381	269216	20298
2016			
Livestock	117	632864	145889
Fish	981	75362	25240
Forest	60	15690	51738

For crops no costs are indicated, as already the net incomes were presented in the CSES surveys

Net Income (in Mio Riel)

2014	Pnom	Plain	Plateau
Crop	154580	1146793	908785
Livestock	9416	418497	202606
Fish	9810	414068	152229
Forest	3572	495316	471216
2015			
Crop	18782	1914040	813597
Livestock	1434	977681	120581
Fish	8908	499039	154844
Forest	2479	358914	435949
2016			
Crop			
Livestock	1387	1225088	300872
Fish	17083	289570	108681
Forest	4471	587668	453830

Proportion of Households per Zone and Income Generation Activity

	2014	2015	2016	2014	2015	2016	2014	2015	2016
	Livestock			**Fishery**			**Forestry**		
Kampong Speu	68,2	63,5	73	54,7	57,6	63,6	78,2	87,9	90,6
Pnom Penh	3,2	0,9	0,6	1,3	0,5	0,8	1,5	1,2	1,7
Plain	61,4	63,5	63,7	41,7	46,6	40,8	78,7	78	70,4

Total Number of Households Practicing Land Use Activity

	2014	2015	2016	2014	2015	2016	2014	2015	2016
	Livestock			**Fishery**			**Forestry**		
Kampong Speu	69995,7	65171,9	74922,1	56140,2	59116,6	65274,6	80259,0	90214,4	92985,5
Pnom Penh	6858,24	1928,88	1285,92	2786,16	1071,6	1714,56	3214,8	2571,84	3643,44
Plain	42350,65	43799,125	43937,075	28762,575	32142,35	28141,8	54283,325	53800,5	48558,4

Income from NTFP in Tasal Community Forest while they still had forest					
	Item	Quantity harvested by household	Income per Unit	Period [months]	Quantity per year (USD)
1	Mushroom	2,5 kg per day	3 $ per kg	3	90
2	Bamboo	35 stems per day	1.25 $ per 1 tree	3	525
3	Orchid	15 kg per day	2.5 $ per kg	5	162.5
4	Rubber	2.5 kg per day	Irregular		50
5	Vegetable	12dollars/HH	Irregular	6	20
6	Fence	10 /day	2.5$ per fence	6	1200
7	Materials for Housing	1	8000 USD	30 years	275
Total					**2322,5**

(Source: Field Visit)

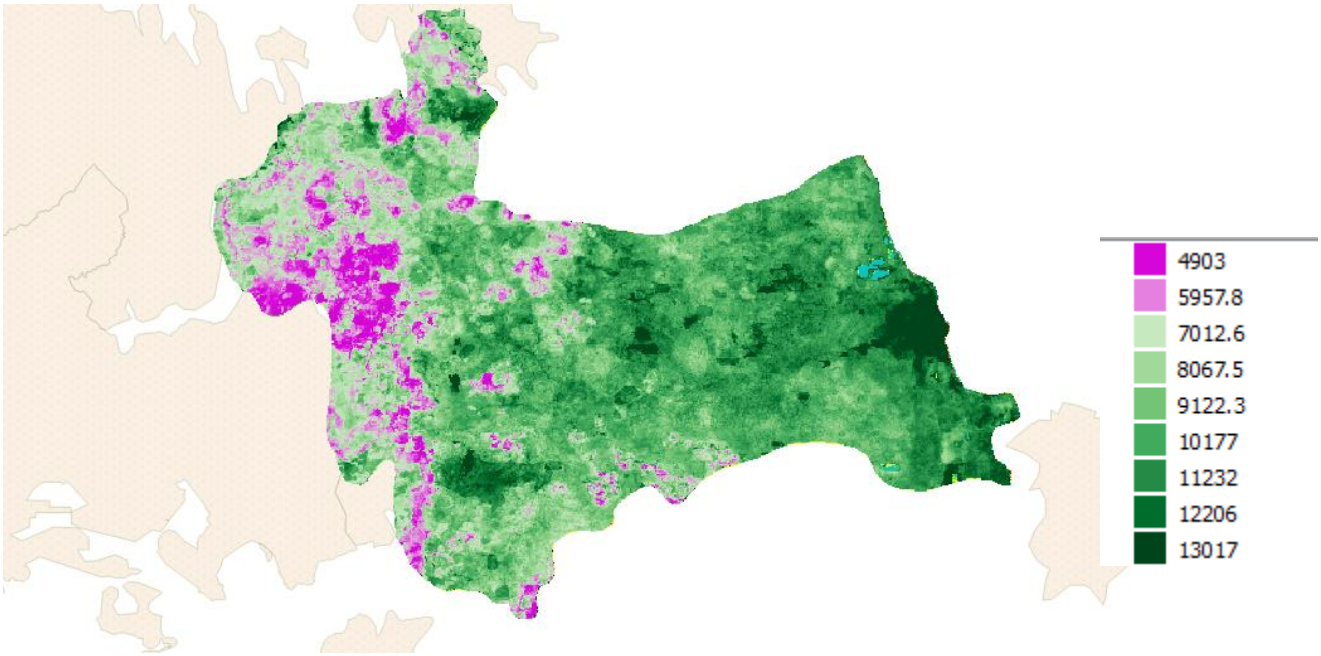
ELC Data

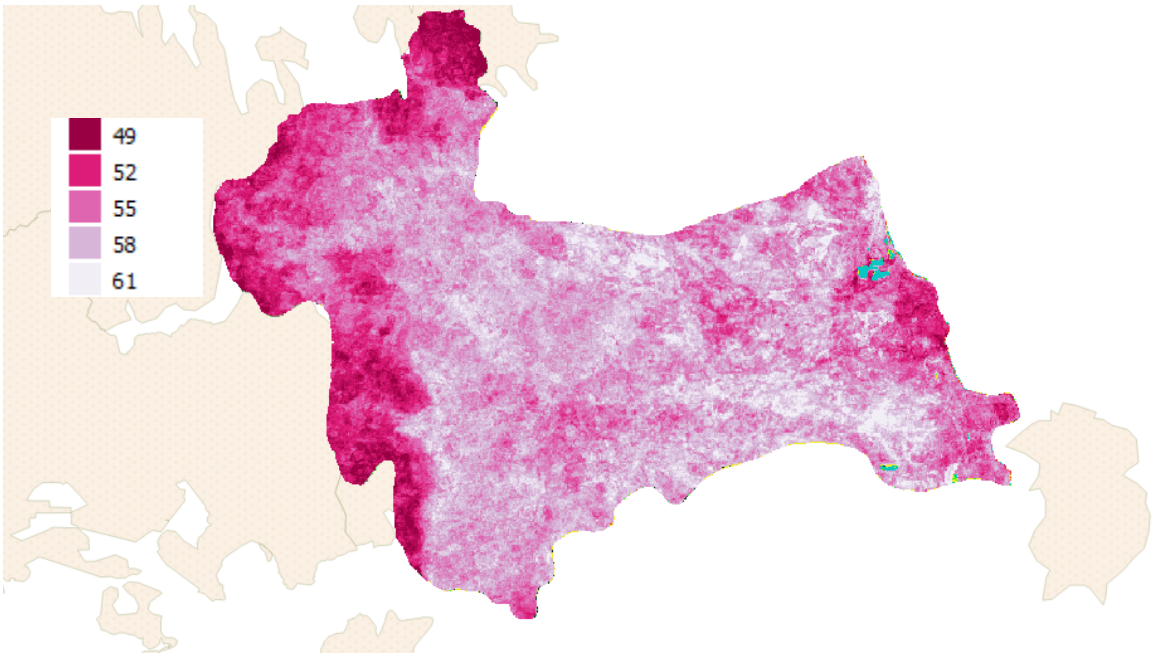
No.	Name of Company	Type of Crop
1	Phnom Penh Sugar	Sugarcane: 8,402ha
2	Kampong Speu Sugar	Sugarcane: 8,050ha
3	Kampong Speu Plantation	Sugarcane: 4,700ha
4	99 Agricultural development	Sugarcane: 1,400hz
5	Fortuna Plantation	Sugarcane: 482ha Rubber: 241ha Eucalyptus: 5ha
6	Great Field Cambodia	Sugarcane: 7,000ha
7	Grandes Terber	Teak: 4,732ha Acacia: 213ha Eucalyptus: 100ha
8	HLH	Cassava 3,798ha
9	CJ Cambodia	Sugarcane: 45ha Mango: 363ha Grass: 15ha Eucalyptus: 146ha
10	CJ Cambodia	Sugarcane: 376ha Mango: 71ha Acacia: 208ha Cashew Nut: 95ha Grass: 132ha Eucalyptus: 208ha
11	Ouk Khun	Cashew Nut: 52ha
12	Cambo Vector	Moringa Oleifera: 13ha

13	Tev Khin Seng	Cashew Nut: 50ha
14	Yellow Field Cambodia	Sugarcane: 6,507ha
15	Forestry	Sugarcane: 150ha Mango: 193ha
16	Sovann Development Trading	Mango: 350ha
17	Sanan Agriculture	
18	Best Industry	Sugarcane: 259ha
19	Golden Land Development	Cashew Nut: 25ha
20	You Hafa Limited	Eucalyptus: 642ha

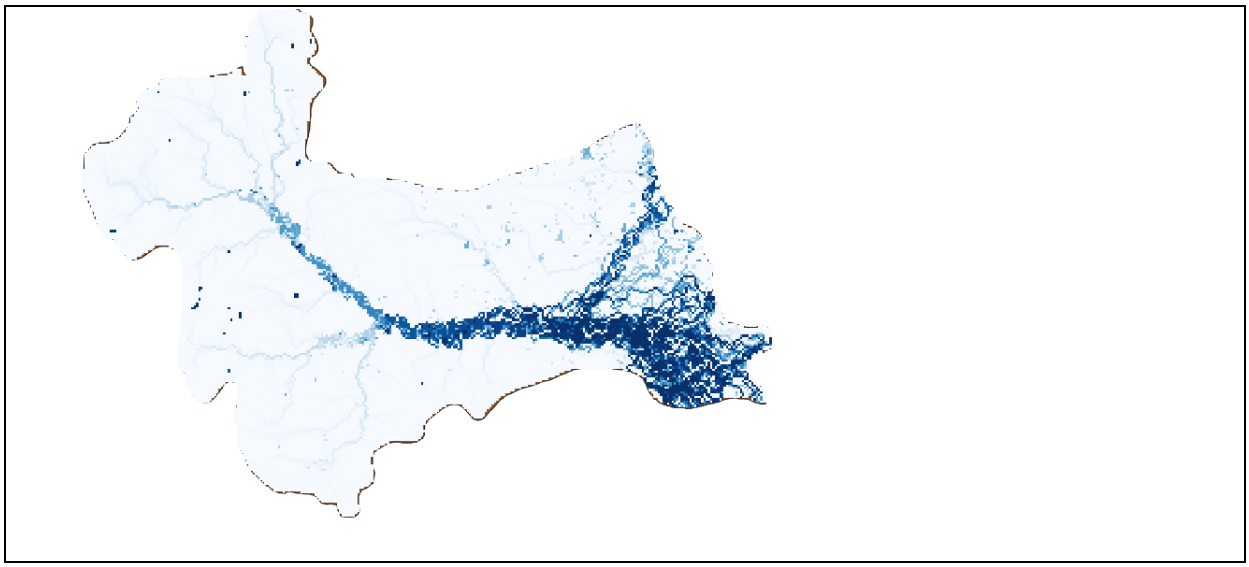
Annex II: Soil Data

Soil Depth





Flow Routing of the Prek Tnoat River



(Source: produced by SAGA tool based on DEM model from Hydrosheds 2008)

Annex III: Forest Community Data of Kampong Speu

Community Name	HH Number	Total Population	Poverty Rate
Trapeang Chour	1906	13094	28,47
Ta Sal	1548	6703	28,93
Reaksmei Sameakki	1195	6003	30,15
Chambak	719	4474	30,14
Krang Dei Vay	1601	7493	28,94
Traeng Trayueng	4721	22816	28,05

Community Data for Prek Tnoat Watershed outside Forest Areas

Amleang			
Chan Saen	233	10864	26,11
Chbar Mon	1525	7323	18,64
Cheung Roas	1827	9443	14,86
Choam Sangkae	1429	7504	22,26
Chumpu Proeks	1600	7763	27,76
Dambouk Rung	1491	7573	28,65
Damnak Reang	1460	7622	19,18
Dang Peaeng	181	8451	13,41
Haong Samnam	1012	4763	29,91
Kahaeng	1584	7921	21,56
Kandaol Dom	1488	8072	18,25
Khsem Khsant	2007	10917	20,52
Khtum Krang	1770	8622	26,29
Kiri Voan	1376	6463	23,04
Krang Ampil	1762	8773	22,77
Krang Chek	3125	15477	21,71
Mean Chey	1304	6668	22,61
Moha Sang	2578	13002	25,82
Ou	2930	15366	28,84
Ou Bak Roteh	363	3470	11,83
Peang Lvea	1680	8661	20,8
Pechr Muni	1291	6329	21,2
Phnom Touch	2234	11665	19,25
Pneay	2629	12730	21,8
Prambei Mum	1230	11395	23,43

Prey Kmeng	874	4454	25,79
Prey Krasang	1736	9151	26,59
Prey Rumduol	1035	4657	23,36
Rokar Thum	2968	15928	16,29
Roleang Chak	1937	9468	22,53
Roleang Kreul	2783	13702	20,37
Rung Roeang	1944	9676	26,61
Saen Dei	2732	13409	21,63
Sambour	1978	9447	16,91
Samrong Tong	1517	7219	23,48
Sangkae Satob	1578	8347	28,82
Skuh	2255	12207	25,12
Sopoar Tep	1351	7628	14,62
Svay Kravan	1654	8575	17,19
Tang Krouch	2010	9137	24,52
Tang Samraong	1963	10251	27,39
Tang Sya	2213	9799	23,46
Thummoda Ar	2218	11638	24,19
Toap Mean	718	3366	27,51
Trach Tong	1624	8326	24,55
Trapeang Kong	3440	16500	19,66
Tuek L'ak	1375	6547	19,8
Tumpoar Meas	1591	7394	25,13
Voa Sar	2970	14314	23,18
Yea Angk	2063	9995	26,3
Yutth Sameakki	1576	7914	23,19

Community Data of the Plain Part in Prek Tnoat Watershed

Ampov Prey	1571	7368	15,07
Baek Chan	2783	13782	8,71
Boeng Khyang	1565	6737	15,35
Cheung Kaeub	1002	4338	13,83
Chhak Chheu Neang	959	4207	13,16
Chhveang	2035	10200	14,94
Chrey Loas	1957	9452	15,04
Daeum Rues	2133	9873	13,45
Damnak Ampil	1401	6048	10,27
Kandaok	1548	6825	11,36

Kouk Trab	1071	4773	14,06
Krang Mkak	1206	5685	13,3
Krang Thnong	2043	9766	15,3
Lumhach	1824	9239	12,6
Mkak	2245	11957	11,23
Peuk	1764	8882	13,81
Phnum Bat	2598	12024	15,94
Phsar Daek	2033	8885	14,07
Ponhea Lueu	777	5005	22,14
Pot Sar	2429	12384	13,22
Preaek Koy	3088	17164	17,1
Preaek Roka	1168	5213	14,69
Preaek Slaeng	988	4266	13,2
Preaek Ta Teaen	1832	8696	19,58
Preah Nipean	2756	14424	21,44
Preah Putth	556	2526	9,02
Prey Puoch	1750	8379	11,23
Roka	743	3707	10,63
Roka Kaoh	1821	8022	19,21
Roka Khpos	2655	13246	18,15
Roleang Kaen	1324	6246	13,43
Samraong Leu	1975	10587	12,29
S'ang Phnum	3204	16038	18,18
Siem Reab	1098	5891	16,04
Thmei	550	2544	10,49
Trapeang Veaeng	913	4155	14,19
Trea	1358	6087	12,41
Tumnob Thum	1778	8610	13,55
Tuol Prech	1573	8062	10,81
Veal	1972	10136	19,79

Community Data for Pnom Penh Part of Prek Tnoat Watershed

Boeng Kak Ti Muoy	2398	13016	0,24
Boeng Kak Ti Pir	3997	22988	0,48
Boeng Keng Kang Ti *	1432	8343	0,2
Boeng Keng Kang Ti *	2978	17383	
Boeng Proluet	1319	7524	0,72
Boeng Salang	4790	26055	0,63

Boeng Thum	1627	7837	0,7
Boeng Trabaek	1610	8227	1,02
Boeng Tumpun	10683	58862	0,7
Chak Angrae Kraom	4712	23938	1,08
Chak Angrae Leu	3183	15337	2,8
Chaom Chau	17040	103481	1,51
Cheung Aek	1990	9755	0,51
Chrang Chamreh Ti M*	2235	11443	4,92
Chrang Chamreh Ti P*	2329	12189	
Dangkao	4204	18142	1,68
Kakab	6939	34156	1,34
Kamboul	1746	9027	0,59
Kantaok	1841	19492	10,01
Khmuonh	4336	18997	0,48
Kilomaetr Lekh Pram*	3670	18936	2,25
Kouk Roka	3370	16400	0,83
Krang Pongro	607	3679	0,05
Krang Thnong	1435	7528	0,5
Mittapheap	1639	8427	
Olympic	1165	6013	1,51
Ou Ruessei Ti Pir	1465	6696	0,05
Ovlaok	849	4388	2,54
Phleung Chheh Roteh	1022	5360	0,33
Phnom Penh Thmei	10242	45304	0,76
Phsar Daeum Kor	1929	11762	0,48
Phsar Daeum Thkov	2469	13481	
Phsar Depou Ti Bei	1248	6554	1,27
Phsar Depou Ti Muoy	1574	9131	0,28
Phsar Depou Ti Pir	1685	10251	0,06
Pong Tuek	1401	8552	1,09
Ponhea Pon	1650	7645	0,63
Ponsang	2330	11228	0,33
Prateah Lang	1144	6794	1,66
Preaek Kampues	1654	8247	1,11
Preaek Phnov	2871	14408	2,7
Prey Sa	2027	10335	0,69
Prey Veaeng	1339	6726	2
Ruessei Kaev	6556	31246	0,5
Sak Sampov	585	3259	

Samraong	1798	7852	1,01
Samraong Kraom	1421	8398	0,42
Snaor	1004	6266	1,39
Spean Thma	754	3337	0,28
Srah Chak	4089	19949	0,43
Stueng Mean chey	13257	72091	0,74
Svay Pak	2726	13388	4,2
Tien	623	2926	0,14
Trapeang Krasang	3562	16353	4,33
Tuek L'ak Ti Bei	4780	23663	0,82
Tuek L'ak Ti Muoy	2368	12449	0,97
Tuek L'ak Ti Pir	1889	10618	0,59
Tuek Thla	10384	61969	1,68
Tumnob Tuek	2110	11531	
Tuol Sangke	16426	65071	
Tuol Svay Prey Ti M*	2119	11811	0,35
Tuol Svay Prey Ti P*	1549	9087	0,57
Tuol Tumpung Ti Muoy	1339	8003	0,77
Tuol Tumpung Ti Pir	1519	8816	0,18
Veal Vong	3288	17114	0,07

Annex IV: Selected SLM technologies and Approaches from the Philippines and Thailand which are Recommendable also for the Upper Prek Tnoat Watershed

The description of the following technologies are copied from WOCAT from the respective websites lister after each technology

1. Technologies for Adressing Forest Regeneration and Enhancement

ANR (Assisted Natural Regeneration) for most types of Forests

https://qcat.wocat.net/en/wocat/approaches/view/approaches_1971/

Detailed description of the Approach:

The objectives of the Assisted Natural Regeneration (ANR) approach includes reduction of cost, speeding-up of forest restoration and enhancing plant diversity. It accelerates the succession process by removing or reducing barriers to natural regeneration such as competition with weedy species, soil degradation and recurring disturbances.

ANR is a method for enhancing the establishment of secondary forest from degraded grassland and shrub vegetation by protecting and nurturing mother trees and their wildlings inherently present in the area.

Stages of implementation: (a)Site identification wherein ideal sites for ANR implementation are those with 600-700 vigorous wildlings per hectare with 15-200 cm height of pioneer species, brush and other woody species relatively well spread on the area; (b) Survey, Mapping and Planning (SMP); (c)Locating and marking of wildlings which include tagging, measuring and identification for monitoring of growth and survival rates; (d) Liberation and tending of regenerants through ring weeding and placing of the cut grasses into the base of the wildlings to serve as mulch and protect them from direct exposure to sunlight and to serve as fertilizer overtime; (e) Suppressing the grass; and (f) Maintenance and protection of established ANR site.

Forest enhancement through Bamboo growing

https://qcat.wocat.net/en/wocat/technologies/view/technologies_1708/

Description:

Littuko (Calamus manilensis) is a large rattan variety belonging to the climbing-palm family Arecaceae which is commonly found in the Cordillera, Caraballo, and Sierra Madre mountain ranges. It matures in seven years and bears 50 to 70 kilos of fruits each year. Its fruits are sweetish sour when ripe and are gathered around April to September.

Purpose of the Technology: The littuko provides green cover to the trees even in the dry months and in case of wildfire,they reinforce the forest's capacity to serve as firebreaks or greenbreaks. It also attract a lot of wildlife ranging from insects (bees, fire flies, and beetles) to birds, bats, and cloud rats. Forests with littuko become equipped with natural guards since the littuko's spines with sturdy thorns discourage people and stray animals to freely enter the forest area and disturb the ecosystem. Conservation of trees is also promoted on this technology.

Establishment / maintenance activities and inputs: For the cultivation of littuko, the following procedures are done: (1) Before planting into a seedbed or polyethylene bags (plastic planting bag), the hilar cover of the littuko seed is gently scraped with the use of a sharp knife. Removing the hilar cover enables the tiny plant to easily break out of the seed. (2) The sprout is transplanted to the designated area under the host tree when it reaches six inches in height and with at least three leaves. The chosen host tree is where the littuko can cling on for support to prevent lodging or breakage of stems. (3) Within one to three years, ring weeding is done around the littuko plant. (4) Maintenance and inputs are needed after three years to ensure its growth.

Natural / human environment: Littuko grows underneath of growing trees in the natural forest. They grow best

in rainforests and no cultivation is needed.The area is under a humid agro climate with an average annual rainfall of 2000-3000 mm per year. Land users have an average holding of 0.5-1 hectare for the forestlands or woodlands. Most of them are stewards of the forest through the Community Based Forest Management Agreement (CBFMA) for 25 years and renewable for another 25 years.

Incentive-based policy to promote adoption and investment of smallholders to vegetable-agroforestry (VAF) System [Philippines

https://qcat.wocat.net/en/unccd/view/unccd_69/

Description and technical specifications of the technology

The provision of any type of support available through the Local Government's regular and special programs are provided in form of 'incentive' to farmers and farmer organizations that meet the conditions required, resulting in increased adoption of SFS and adaptation to climate change.
The following technologies are examples of SFS practices already adopted by farmers in Lantapan. These are considered fundable SFS practices (but not limited to these) under this policy:
1. Organic Farming Technology - Vermi-Composting, Bio-N, Nature Farming Technology Systems;
2. Integrated Crop Management (ICM)- Bio-fumigation, Integrated Pest Management, Soil Testing using STK;
3. Agro-forestry - Vegetables-agroforestry (VAF) Production System, Multi-story, cropping, agro-silvopastoral, apiculture;
4. Diversified Farming - Multi-cropping, inter-cropping;
5. Sloping Agricultural Land Technology (SALT) - contour plowing, contour hedge rows, any contour barriers, SALT I, II, III and IV (including livestock);
6. Soil and Water Conservation (SWMC)- Mulching, Cover cropping, Minimum Tillage, Drip Irrigation;
7. Farm Waste Management - Recycling, Composting, Segregation (Liquid and Solid)
8. Farm Forestry - Diversification of tree species (exotic, indigenous and fruits)
9 Clean Energy - Briquette Production (using rice hull, charcoal, farm waste)
10. Indigenous Knowledge System - Indigenous vegetables and medicinal plants, indigenous pest management
11. Community-wide clean and green project - Riparian Management, Water Quality Monitoring, Community Tree Parks

Environmental protection and sustained provision of ES resulted to improved soil fertility, increased tree cover, and improved agrodiversity and biodiversity.|
Formation of new farmer groups and strengthening of existing farmer organizations (e.g. Landcare, ATSAL, PAGLAMBU, Tigbantay Wahig, etc.) that resulted to greater responsiveness (receptiveness) to various VAF-related programs and projects and wider scope of SFS Incentive-based Program|
Diversification into high-value crops and adoption of various agroforestry systems, and other sustainable technologies are facilitated.|
Ensured water supply and quality and improved micro-climate which contribute to climate change adaptation of the agriculture and forestry sectors.
It is also resulted to improved monitoring and evaluation of LGU's agricultural programs and agricultural service delivery that is more responsive to farmers' needs.
Improved agricultural production thru increased yields and greater cropping productivity.
More efficient and effective distribution of assistance and more more encouragement for other non-practicing farmers to adopt SFS that could possibly lead to the improvement of farmers' lives and livelihoods, as well as the landscapes.|
The institutional changes within the LGU also provides important benefits in terms of more sustainable VAF-related projects on ground reaching the majority of the poor in the uplands.

2. Sustainable Technologies for Agriculture

Ecological engineering for biological pest control in lowland rice agroecosystems [Philippines]

https://qcat.wocat.net/en/wocat/technologies/view/technologies_1720

Description:

To counteract the negative impact of agricultural intensification, in particular the loss of biodiversity and ecosystem services, more sustainable management for crop land and surrounding habitats is required. 'Ecological engineering', in this case meaning the provision of habitats for beneficial arthropods, has recently gained considerable attention as a method of reducing pesticide input, through stimulating biological pest control by natural enemies.

Purpose of the Technology: The concept of ecological engineering is aimed primarily at the regulation of pest species, through the provision of habitats for their natural enemies. However, other ecosystem services, such as pollination and cultural services, may simultaneously be enhanced by using the same measures. One such measure, which is popular and effective in temperate countries where agro-environmental schemes are implemented, is the planting of flower strips as habitats.
In intensively managed tropical rice production systems, biological pest control, pollination services and landscape aesthetics could also benefit from the establishment of flower strips on the bunds within irrigated fields. The specific aim of the technology featured here is to increase biodiversity in rice fields and provide habitats for beneficial organisms such as predators of rice pests (e.g. spiders) or parasitoids (e.g. hymenopteran parasites), which in turn will help to minimize the use of pesticides. An additional benefit is landscape beautification.

Establishment / maintenance activities and inputs: The process comprises collecting seeds of flowering plants (e.g. flowering annuals such as Melampodium divaricatum) and planting them in a nursery. After a month or so they can be transplanted into rice fields on bunds, with a strip size of 0.25 x 5 metres, and a distance between strips of 5 metres (to enable access for farm operations such as fertilizer application). Farmers are requested not to spray insecticides when they test this system. The flowering plants should be pruned during the fallow period in the wet season; and they will require watering during the dry season when rice is cropped. The flower strips will need to be replanted after the rice crop is harvested, if an annual species are chosen.

Natural / human environment: While this SLM technology is for an irrigated rice ecosystem in the center of the island of Luzon in the Philippines, it has already been applied in other rice producing areas – for example in Vietnam and, with some adaptations, should be applicable to irrigated lowland rice production systems throughout Southeast Asia.

Organic-Based System of Rice Intensification (SRI) [Philippines]

https://qcat.wocat.net/en/wocat/technologies/view/technologies_1302/

Intensifying the irrigated rice production while at the same time reducing farm inputs including seeds, fertilizer, and water.

Description:

The Organic-based system of rice intensification modifies the usual rice farming system in terms of seedling condition, planting distance, irrigation time and water requirement, and with the incorporation of organic fertilization scheme. Furthermore, integration of rice duck is carried out. This makes the farming system reduce its farm inputs leading to a lower production cost. With the utilization of organic fertilizers and natural concoctions, soil fertility and soil structure is improved. It was also observed that rice grown under SRI can tolerate strong winds. This type of rice production management is currently part of the Caritas Foundation's project, a non-government organization, called Sustainable Learning Agricultural Farm which promotes diversified-integrated organic farming systems. With this, other practices (i.e. rice-duck farming) are being integrated in some SRI areas. Integration of ducks helps in the weeding since it eats weeds as well as harmful insects. In addition, its droplets/manure served as organic fertilizer in the rice field.

Purpose of the Technology: The purpose of this technology is to promote better soil management as well as

more efficient water management.

Establishment / maintenance activities and inputs: Under SRI, the following practices were implemented: In the land preparation stage, 25cm x 25cm plant spacing is made using the man-made implement.

Intermittent irrigation is applied up to the panicle initiation stage with the following irrigation schedule: (1) 3 days after transplanting, (2) 9 days after transplanting, (3) 14 days after transplanting, and (4) 19 days after transplanting. The field is irrigated up to 5-cm water depth level per schedule.

Fertilizer application includes compost and natural organic concoctions. This is applied on different crop stages.

Natural / human environment: The existing project sites are located in Samar experiencing Type IV climate wherein rainfall is more or less evenly distributed throughout the year. Most of the farmer practitioners of this technology belongs to the small scale and average type of land user.

Multistorey Cropping

Cultivating a mixture of crops with different heights (multi-storey) and growth characteristics which together optimise the use of soil, moisture and space.

Description:

Under the maramihang pagtatanim multi-storey cropping system, perennial crops (coconut, banana, coffee, papaya, pineapple) and annuals/biennials (root crops: taro, yam, sweet potato etc) are interplanted to maximise productivity and income. This is most applicable where farms are small and the system needs to be intensive. In this particular area, Cavite, coconuts are usually planted first. When they reach a height of 4.5 meters (after 3-4 years), bananas, coffee and/or papaya are planted underneath. Black pepper may also be part of the system. After sufficient space has developed at ground level in about three to four years, root crops are planted. At full establishment, the system develops different layers: coconut (tallest) followed by banana, coffee, papaya (middle), root crops and pineapple (lowest). In recent years, because of its relatively low productivity and decreasing price, coconut has tended to be replaced in the system with higher value crops like the fruit tree santol (Sandoricum koetjape), papaya and sometimes black pepper. However most multi-storey farms adhere to no specific planting layout. The multi-storey agroforestry system is intended to make the best use of resources (soil, moisture and space) for increased farm income. It is also very effective against soil erosion. Previously, continuous monocropping of annual crops resulted in erosion and serious soil fertility decline. Even though the land is sloping and rainfall during the monsoon is extremely intensive, multi-storey cropping provides adequate soil cover throughout the year, protecting the land from erosion.

Fertilization, weeding and pruning are necessary elements of maintenance. ‘Natural’ mulching through fallen leaves from leguminous trees helps restore and maintain soil fertility The system is applied in a volcanic-derived soil with distinct wet and dry periods (6 months wet season, 6 months dry season). There is the risk of a destructive typhoon every 10 years. Farm income is relatively high, but labour and input costs are also high - and the technology is mostly used by relatively wealthy landowners. There is strong spontaneous adoption, as maramihang pagtatanim has been proven to be effective and remunerative. This technology has been practiced in Cavite since the 1970s. Implementation is by individual farmers with strong extension support from the Local Government Units (LGUs), NGOs and the Cavite State University.

Modified Rapid Composting

Modified Rapid Composting is the in situ decomposition of rice straw using compost fungus activator, Trichoderma harzianum or Effective Microorganism, that helps in utilizing the residual Nitrogen-Phosphorus-Potassium (NPK) from the decomposed rice straw.

Description:

In search of reducing the vulnerability of the small farmers to the uncontrolled price of chemical fertilizer as well as the dependency on the usage of it, the Department of Agriculture through Bureau of Soils and Water Management (BSWM) developed a fertilizer cost reduction strategy by introducing a new composting technology that will produce organic compost as substitute and eventually decrease the utilization of chemical fertilizer. This is called Modified Rapid Composting.

It incorporates a farm residue management wherein the rice straw is scattered evenly in the field as compost material with the aid of fungus activator that hastens the decomposition process as compared to the traditional composting method. The compost fungus activators used are Trichoderma harzianum and/or Effective Microorganism. Eventually, this compost is mixed into the soil during land preparation. When decayed, it increases the supply of nutrients and improves soil structure.

Purpose of the Technology: This technology aimed to establish a cost-efficient, competitive and sustainable agricultural production system. It addresses the concern of soil fertility deterioration through organic based fertilization scheme. Further, it reduces vulnerability of small farmers to the uncontrolled prices of chemical fertilizers. It also prevent the unfavorable farmer's practice of burning the rice straw. This also serves as a promotional tool for the gradual conversion of rice land from conventional to organic-based farming system.

Establishment / maintenance activities and inputs: Primarily, this technology is applied and incorporated as part of the land preparation activity. Shallow plowing/rotavating is done to flatten down rice stubbles. The rice straw is then scattered in the field. Irrigation is applied at about 2-3cm depth. Soak the rice straw in the field approximately for 12 hours. Drain excess water. Spray Trichoderma harzianum solution prepared by dissolving 3 packs/knapsack sprayer (20 packs/hectare) in early morning or late in the afternoon. Effective Microorganism solution can also be used aside from Trichoderma harzianum. Broadcast at least 12 kg urea to hasten decomposition. Maintain sufficient moisture in the rice paddies during the decomposition period (15-20 days). Proceed with the usual land preparation. Apply 10 bags of vermicast/chicken dung at last harrowing as basal application.

Natural / human environment: It is introduced and currently practiced in the irrigated plain rice production areas in the Philippines such as in Talavera, Nueva Ecija. The soil type in Talavera is clay loam. Mostly, farmer associations, with an average farm size of 1.50 ha, comprising of small-scale to medium-scale land users are engaged to apply this technology in their rice areas during wet (May to October) and dry (December to April) season. The average rainfall ranged from 1500-2000 mm.

3. Technologies for Sediment Trapping and Erosion Control

Sediment Trapping through Pineapple and Silt traps

Description:

Strategic construction of water catchment in and around existing pineapple fields to collect runoff during rains, aim to minimize eroded soil cascading into natural bodies of water. Sediment trap structures are earth canals designed to reduce soil erosion. The cascading catchment canal length depends on the slope, a length of five meters or longer is excavated when the slope of the area is less than 2%. The higher the slope percentage, the shorter the length of the canal. Silt traps are built along diversion ditches by stacking bamboo pegs or planting pineapple. Catch basin are bigger canals than the cascading canals which trap sediments that are not trapped in the silt traps and cascading canals. Weeds in this structures are not uprooted to further trap eroded soils or silts.

Purpose of the Technology: The technology aims to: (1) control of dispersed runoff; (2) serves as water harvesting facility; and (3) serves as sediment retention / trapping.

Establishment / maintenance activities and inputs: In the establishment of sediment trap structures, the following activities are undertaken in the area: (1) Depending on the slope, sediment trap structure locations are identified; (2) Excavation of catch basin and cascading canals using back hoe; (3) Establishment of raised beds which are used for pineapple production; and (4) Construction of trenches with silt traps using bamboo pegs and pineapple plants. Cascading canals, trenches and diversion ditches are re-established every cropping season.

Sediment Catchment Channels

Pineapple plants serve as silt traps built along trenches

Small Bench Terraces Thailand

https://qcat.wocat.net/en/wocat/approaches/view/approaches_2670/

Detailed description of the Approach:

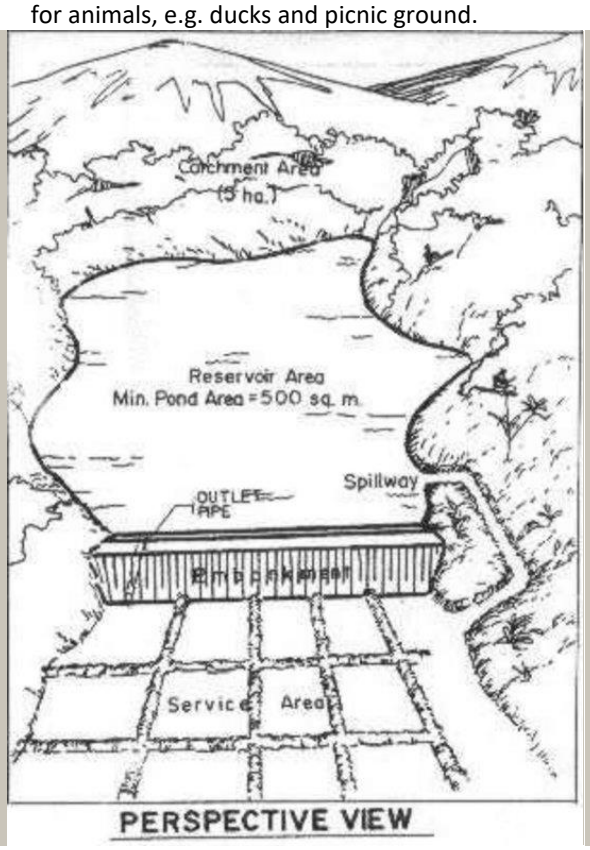
Aims / objectives: The small bench terrace is a kind of soil conservation measure constructed on sloping land. The main feature is that flat beds are constructed out of the land which is not level primarily to facilitate working in the field, but with benefit of conserving soil at the same time. Normally farmers will implement by themselves with their own fund. In few cases there can be some initiation from some organizations and some help will be provided. This approach has been imported from Taiwan from where some tea bushes were brought to grow in Chiang Rai Province.

4. Technologies for Enhancing Temporal Water Availability

Small Farm Reservoirs

Description:

The small farm reservoir (SFR) is a small water impounding earth dam structure to collect rainfall and runoff, designed for use in a single farm, and typically has an area of about 300-2,000 square meters. The embankment height above ground level is less than 4 meters. It can be easily constructed with a bulldozer or manual labor. Irrigation is done with PVC siphon pipes or pumps. SFR is used in rainfed-growing areas to provide supplemental irrigation to a wet season crop and partial irrigation to a dry season crop. Aside from irrigation and aquaculture, water in the reservoir could also be used for small scale livestock watering, wallowing areas for animals, e.g. ducks and picnic ground.



PERSPECTIVE VIEW

Alternate Wetting and Drying [Philippines]

https://qcat.wocat.net/en/wocat/technologies/view/technologies_1725/

Alternate Wetting and Drying is a water-use management technique wherein irrigation water input could be substantially reduced to as much as 35% without significantly affecting rice yields.

Description:

It was observed that most of the farmer's irrigation practice of continuously flooding their rice fields is wasteful and uneconomical. The imbalance amount of water, either in deficit or excess, might affect the development and productivity of the crops.
With this inefficient water use and coupled by the increasing frequency of drought, vulnerability to water scarcity is inevitable. Furthermore, it has been recognized that poor water management practices contributed to the process of land degradation. Hence, there is a need to practice proper water management in rice cultivation. As an integral part of the Palayamanan system, the Philippine Rice Research Institute (PhilRice) introduced a water saving technology to the farmers called Alternate Wetting and Drying (AWD).
The AWD modifies the irrigation scheduling and application and eventually the amount of water to be use in the field. Irrigation water is applied a few days after the disappearance of the ponded water in the so-called "observation well". Hence, the field is alternately flooded and non-flooded.

Purpose of the Technology: The following are the purpose of this technology: (1)reducing water use for irrigation so that it can be used for other purposes, (2) reducing the use of irrigation water because there is less of it, and (3) reducing the use of irrigation water to reduce the cost. Emission of greenhouse gas (GHG) specifically on methane is reduced since this is caused by flooding of ricefields.

Establishment / maintenance activities and inputs: Practical implementation of AWD is facilitated using a simple tool called a 'field water tube' as observation well, used in monitoring the water level in the field.It is made of a 25 cm long PVC pipe with a diameter of 10 to 15 cm. In some instances, bamboo can be used instead of the PVC pipe. The pipe is perforated with many holes on all sides to allow lateral movement of water in the root zone. It is installed into the soil by ensuring that 10 (dry season) or 5 (wet season) cm protrudes above the soil surface. Soil must be removed inside the tube so that the bottom is visible. During the first 21 to 30 days after direct seeding or transplanting, 2 to 3 cm of water is maintained to control weeds and to ensure that the crop has already
recovered from transplanting shock. AWD is imposed after 21 to 30 days where the water in the tube is monitored. Once the water inside the tube disappears, irrigation is applied to a water depth of 5 cm above soil surface. It is noted that during fertilizer application and flowering stage, sufficient water is maintained to avoid spikelet sterility. Terminal drainage from one to two weeks before the expected time of harvest is also done to promote uniform maturity of the crop and to facilitate easement of post-harvest operations in the field.

Natural / human environment: The area is under a humid climate experiencing wet and dry season with an annual average rainfall ranging from 1000-1500 mm per year. The technology was applied to irrigated rice field in flat and plain areas.

Small Water Impounding Project (SWIP) for Upland Area Development [Philippines]

Libasan small water impounding projects (SWIP) was established in Nabunturan for soil and water conservation, supplemental irrigation, and fish culture. The project consists of modified homogenous earth structure with a total storage area of 14 ha and service area of about 150-200 hectares. It has also provision for inland fishery production including fish hatchery for fingerlings production. Watershed management is a very important component of the system and was implemented through the LGU's Forest Protection Program. Seedlings (i.e. coconut, coffee and fruit trees) dispersal was initiated by the municipality thru a strong local and community policy framework.

The Libasan SWIP is currently being managed by the Libasan Primary Multi-purpose Cooperative (LPMC). It was primarily designed for soil and water conservation by collecting direct rainfall and surface runoff (rainwater harvesting). It has a reservoir surface area of 14 ha which is currently being utilized for supplemental irrigation, inland fish culture, fresh water fish hatchery , and for recreation. Its present irrigation service area is 150-200 hectares. The structural component of a typical SWIP consists of the following physical features: a) earth embankment, b) spillway, c) outlet works, d) irrigation system, and e) access road.
The best practice includes forest preservation, protection, rehabilitation and conservation of the remaining natural resources thru reforestation in the watershed. These efforts address the problem of siltation in the reservoir and denudation of the watershed and maintain the effective storage capacity of the reservoir. Trees provided by the local government and planted in the project watershed include:

1. Budded Rubber
2. Coconut
3. Coffee

In the service area, farmers raise ducks to control pests (golden snails) in the paddy field during crop vegetative stage and after harvest.

Cut-off Drains - Thailand

https://qcat.wocat.net/en/wocat/approaches/view/approaches_2622/

Detailed description of the Approach:

Aims / objectives: The cut-off drain is a kind of soil conservation measure which functions in the way that excess runoff will gather in these drains, which are constructed parallel with each other, and leave the cropped field without causing damage to it. This cut-off drain will be constructed only on steepland with large acreage. Fields smaller than 0.16 ha will not have it. The digging of the cut-off drain will be done before rainy season, using one hand hoe breadth and 20-30 cm deep. In the following year, loose earth material may be dug up and the drain may eventually be as large as 40 cm wide and 40 cm deep. This is an indigenous practice which farmers do it by themselves in their farm and they are not paid for their wages by any agency. In some cases poorer people may be hired by richer ones to dig cut-off drains. State agencies and extension workers have never promoted this T and A anywhere.

Photos of the Approach

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5. Integrated Approach to Sustainable Land Management

LandCare:

https://qcat.wocat.net/en/wocat/approaches/view/approaches_1934/

Detailed description of the Approach:

- In parts of the Philippines, farmers who are interested in learning and sharing knowledge about sustainable land management and new SWC measures organise themselves into the so-called 'Landcare' associations. These self-help groups are a vehicle for knowledge exchange, training and dissemination of SWC technologies. A main objective is the empowerment of farmers' groups in their efforts to improve their livelihoods as well as the environment. Landcare has three components and aims at strengthening collaboration between those: (1) grassroot farmers' organisations (Landcare organisations); (2) technical facilitators, for example the World Agroforestry Centre (formerly the International Centre for Research in Agroforestry: ICRAF) and government and academic agencies and (3) Local Government Units (LGUs). The Landcare associations are structured as municipal groups, village groups (barangay level or affiliate peoples' organisations), and village sub-groups (sitio or purok level). This ensures effective dissemination of technologies from the municipal level down to the smallest village. To give the associations a legal status, they are registered with the Securities and Exchange Commission (SEC). Landcare associations conduct regular monthly meetings to promote exchange of information, ideas, and experience, thus promoting spread of SWC technologies. Extension service is carried out through the Local Government Units, which allocate 20% of their development funds for Landcare related activities such as meetings, training and visits, and nursery establishment. Farmers organised in Landcare groups have better access to technical and financial support for SWC activities from LGUs and other technical facilitators.

  LGUs also enact local laws to encourage adoption of SWC technologies, such as giving tax incentives, and Landcare members are given priority access to programmes and financial assistance. Landcare acts as a guarantor against loans. The facilitating agencies provide technical assistance, and also help create an environment of dynamism among Landcare groups. A link is created between Landcare associations and these service providers. Landcare enhances sharing of labour, builds camaraderie, and encourages group decisions on matters relating to SWC. The approach is spreading rapidly: from the original one association with 25 members in 1996, this increased to 45 groups with over 4,000 members by 1999.