OPTIONS TO ALLOCATE THE FREL DRAFT REPORT

Support to the development of an updated Forest Reference Level and develop options to allocate the FRL at multiple spatial scales for REDD+ implementation in Cambodia.

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Client: UNDP Cambodia

PROJECT: Support to the development of an updated Forest Reference Level and develop options to allocate the FRL at multiple spatial scales for REDD+ implementation in Cambodia

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BACKGROUND

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) estimates that Forest and Other Land Use (FOLU) sector accounted for about 12% of emissions from 2000 to 2009 of anthropogenic CO_2 emissions. At the same time, atmospheric measurements indicate the land as a whole was a net sink for CO_2, implying a “residual” terrestrial sink offsetting FOLU emissions (GFOI, 2016).

(IPCC, 2006) quantify global forest loss in 230 million ha from 2000 to 2012. This estimation was updated by the Global Forest Watch for the period 2000 to 2018, resulting in 361 million hectares of forest loss, equivalent to a 9,0% decrease in tree cover since 2000 and 98.7Gt of CO_2 emissions (GFOI, 2016).

Meanwhile, (Hansen et al., 2013) identify that emissions from net forest conversion decreased significantly, from an average of 4.0 Gt CO_2 yr^{-1} during 2001–2010 to 2.9 Gt CO2 yr^{-1} during 2011–2015. Besides, this report considers that remaining forests continued to function as a net carbon sink globally. They have estimated an average net removal of −2.2 Gt CO_2 yr^{-1} during 2001–2010, and −2.1 Gt CO_2 yr^{-1} during 2011–2015. This study, such as many others, highlight the important function of forests as a natural sink CO_2, contributing to reduce greenhouse gas emissions.

In this regard, the United Nations Framework Convention on Climate Change (UNFCCC) adopted the policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries, globally known as REDD+.

REDD+ has been discussed under the UNFCCC Conference of the Parties, since 2005 until today, as a mechanism to mitigate climate change and to provide co-benefits. Developing countries interested in REDD+ can progress through three phases, which are closely linked with one another:

- **Phase 1:** Readiness, involving the development of the four elements describes in the Warsaw Framework for REDD+: i) National Strategies or Action plans, ii) Forest Reference Emission Level (FREL) and-or Forest Reference Level (FRL), iii) National Forest Monitoring Systems (NFMS) and iv) Safeguards Information Systems (SIS);
- **Phase 2:** Implementation of national strategies and demonstration activities, enacting REDD+ actions and domestic policies or plans, including the operation of the NFMS and SIS;
- **Phase 3:** Results-based payments (RBP), based on the demonstration of results of REDD+ activities implementation, in terms of emission reductions, fully measured, reported and verified.

Currently, several countries have advanced to the REDD+ RBP phase, achieving finance from multilateral initiatives, such as:

- the Green Climate Fund (GCF): Brazil, Ecuador, Chile, Paraguay, Colombia, and Indonesia
- the REDD+ Early Movers (REM): Brazil, Ecuador, and Colombia,
- the Carbon Fund from the Forest Carbon Partnership Facility (FCPF): up to date Democratic Republic of Congo, Mozambique, Chile and Costa Rica have signed their respective Emission Reduction Programs Agreements. However, up to date, no payments related to these agreements have been made.

Multilateral initiatives are focused on national REDD+ programs, managed by governments at the national or subnational (e.g., biome) scale. However, at the same time, several REDD+ projects have been implemented under the voluntary carbon markets, such as the Verified Carbon Standard (VCS) and the Japan Crediting Mechanism (JCM), at a local or province scale, achieving results and transactions mainly, from the private sector.

The readiness phase of REDD+ at a governmental level, in general, has taken several years to advance into the implementation and to achieve RBP phases, due to the costs and capacity needed to develop, adapt or improve the necessary data, information, agreements and governance systems by countries. On the other hand, voluntary carbon projects, have been developed faster because the preparation and implementation costs are substantially lower, and can achieve results, and therefore issue carbon credits, in a shorter period.

Voluntary carbon markets are used mostly by companies to achieve their corporate responsibility commitments. At the same time, the UNFCCC framework operates in a context where governments have climate finance obligations and can meet this obligation through the provision of both ex-ante and ex-post finance. REDD+ is a mechanism created to enable to provide ex-post finance to developing countries that achieve mitigation results in the forest sector.

This mismatch in the development of REDD+ at different scales caused that various methodologies and assumptions were applied between the elaboration of project baselines and national program reference levels, both used as benchmarks to estimate results. This scenario can impact on the aggregation of emission reductions and affect the transparency and consistency of carbon accounting, at the projects and national program's scale.

Bearing in mind that emerging carbon markets may provide new opportunities for forest carbon finance, to align or nest the carbon accounting, and other REDD+ related elements, has become a need for several governments and project developers. Further, the carbon accounts alignment between projects and national programs is becoming an essential issue for voluntary carbon market standards and multilateral initiatives, especially in countries where projects make an important contribution to the governmental policies, where governments have become a counterpart to these initiatives. In other countries, the voluntary carbon market can continue to operate in parallel to compliance mechanisms, for different purposes.

The situation described above is representative of the current status of REDD+ in Cambodia, on the one hand, the Royal Government of Cambodia has made significant progress in efforts to reduce emissions from deforestation, to fulfil all the requirements from the Warsaw Framework for REDD+ and to implement the REDD+ approach at a national scale, highlighting the following achievements:

- The RGC approved the National REDD+ Strategy (NRS) in 2017. The NRS considers three strategic objectives i) improve management and monitoring of forest resources and forest land use; ii) strengthen the implementation of sustainable forest management and iii) mainstream approaches to reduce deforestation, build capacity, and engage stakeholders. The NRS was primarily built upon three national policy frameworks that guide forest management i) the National Forest Program 2010-2030 (NFP), ii) the National Protected Areas Strategic Management Plan 2017-2030 (NPASMP), and iii) the Strategic Planning Framework for Fisheries 2010-2019 (SPFF).

- In 2017, Cambodia submitted to the UNFCCC its first Forest Reference Level (FRL). The proposed FRL based on historical average net emission from deforestation from 2006 to 2014 estimated at 78.953.951 t CO2eq/year. The information on activity data (AD) used in constructing the FRL was extracted from a historical time series of land-use maps for 2006, 2010 and 2014 and the information on emission factors (EF), having into account that did not exist a National Forest Inventory at the reporting date, was developed from a literature survey and data from various forest inventory surveys implemented in Cambodia[1]

- As a result of the improvements of the National Forest Monitoring System (NFMS), mainly due to the support provided by the REDD+ readiness, the data and methodologies for both EF and AD have been progressively enhanced, building more robust datasets that enable Cambodia i) to endorse the First Technical Annex of REDD+ Results to the Biennial Update Report, during 2020, and ii) to update the National FRL in 2020 for its submission to the UNFCCC in 2021.

- The RGC has also been working to fulfil other Warsaw Framework for REDD+ requirements, such as the Action and Investment Plan for NRS implementation, the Safeguards Information System (SIS) and the Summary of Information on Safeguards (SoI).

On the other hand, several forest carbon projects are being implemented in Cambodia by various actors in different geographical areas and over different periods. These projects currently consider specifics guidance and standards to estimate GHG emission baselines or reference levels and Measuring, Reporting & Verification (MRV) systems that use different methods, parameters and assumptions to measure carbon performance (Table 1 and Figure 1):

- Southern Cardamom REDD+ VCS project, approved by the Ministry of Environment (MoE), is located at the Koh Kong Province, covering 445,339 ha. The estimated avoided emission by deforestation is 3,867,568 t CO2eq/year.

- Tumring REDD+ VCS Project, approved by the Ministry of Agriculture, Forestry, and Fisheries (MAFF), is located at the central part of Cambodia, to the west of the Mekong River, covering 66.645 ha. The estimated avoided emission by deforestation is 378.434 t CO2eq/year.

- REDD+ in Keo Siema Wildlife Sanctuary VCS project, approved by the MoE, is located mainly in Mondulkiri Province with a small area extending into Kratie Province, the project area cover 292.690 ha. The estimated avoided emission by deforestation is 1,426,648 t CO2eq/year.

- Prey Long, Joint Crediting Mechanism (JCM) Project REDD+, approved by the MoE, is located at the Kampong Thom Province, Kratie Province, Stung Treng Province, and Preah Vihear Province west of the Mekong River in Cambodia. The project boundary is estimated at 400,000 ha. The estimated avoided emission by deforestation is 1,136,158 t CO2eq/year.

[1]Report of the technical assessment of the proposed forest. https://unfccc.int/sites/default/files/resource/khm.pdf

Table 1. National and Project scale existing GHG emission reports and MRV systems in Cambodia.

Scale	GHG reporting/accounting	Current guidance or standard used	Reference Period	Proposed Reference Level (tCO2eq/year)	Estimated Emission Reductions (tCO2eq/year)
National			2006-2014	FRL (Map-Based)	TA (Map-Based)
	UNFCCC reporting including:	UNFCCC.		78,953,951	2015-16: 35,245,948
	· NCs, BURs	IPCC Guidelines.			2017-18: 46,337,172
	· REED+ FRL & Technical Annex	Warsaw Framework guidelines.		Sampling-Based estimation:	Sampling-Based estimation
				64,025,801	2015-16: (-8,958,247)
					2017-18: 4,767,437
Projects	Southern Cardamom REDD+ project	VCS VM0009	2006-2014	4,461,598	3,867,568
	Tumring REDD+ project	VCS VM0009	2006-2014	474,029	378,434
	REDD in Keo Seima Wildlife Sanctuary	VCS VM0015	2005-2009	2,312,063	1,426,648
	Prey Long – JCM Project	JCM	2006-2014	1,136,158	1,136,158

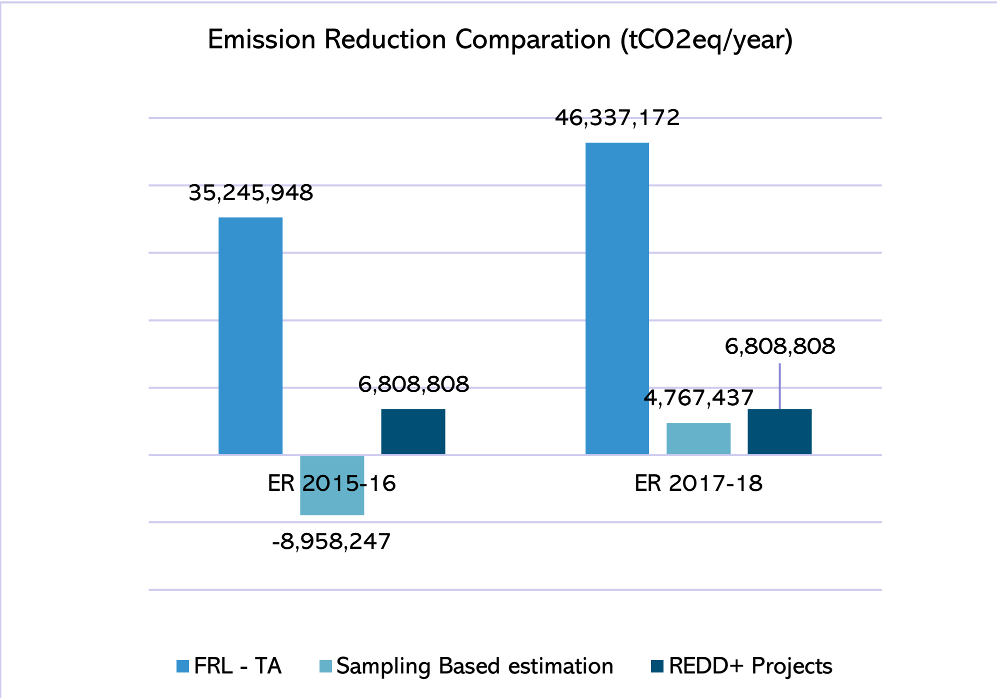


Figure 1. Comparison of estimated emission reduction from FRL and TA results, Sampling-based estimation included as an Annex in the TA report and REDD+ Projects ex-ante estimations.

Project level activities and investments from the private sector is an approach that fits and supported by the RGC. Besides the projects listed above, the RGC and stakeholders are currently under negotiations to develop additional forest carbon projects under voluntary carbon markets.

Meanwhile, the VCS Program is currently updating the requirements for its Jurisdictional and Nested REDD+ (JNR) framework aiming to align national programs and project reference levels to ensure that finance continues to flow to critical mitigation activities at all levels (Verra, 2019). These requirements could apply to all REDD+ VCS projects, those under the JNR framework, and those subject to non-jurisdictional methodologies. In parallel, CORSIA has decided to accept only projects developed under nesting systems.

Taking into account that the RGC aims to implement REDD+ at multiple scales, seeking to mobilize carbon finance through REDD+ RBP from both multilateral initiatives (GFF), voluntary carbon markets (VCS Program and JCM), and, potentially, emerging carbon markets (i.e., CORSIA) there is a need to identify, purpose and clarify rules and methodologies to account for and keep track of emission reductions at multiple scales and, an agreed system to distribute REDD+ benefits at multiple levels and will impact on Cambodia´s NDC moving forward.

Therefore, Cambodia has initiated a strategy for “nesting” or integrating smaller-scale activities into national (or subnational) programs. The term “nesting” was originated from a desire to integrate existing forest carbon projects into larger-scale REDD+ programs while allowing them to continue generating and trading carbon units.

This report describes a set of methodological options to allocate the national FREL at the project scale, considering the different pressure/ drivers on the territory. The following sections describe the steps followed in the construction of a deforestation risk map, and the process carried out to allocate the FREL.

Design methodological options for allocation the national FREL at different spatial scales, including jurisdictional and project scales, requires the collection of several datasets to analyze spatially explicit deforestation drivers and risk models. Thus, aiming to identify proposals to nest REDD+ activities implemented and mitigation results in terms of ER at multiple scales (national, subnational or local levels). The ultimate goal is to give the appropriate incentives for the development of projects in areas with higher deforestation/ forest degradation pressure.

Taking into consideration the above paragraphs, two separates processes to design methodological options for allocating the national FRL at different spatial scales were carried out. The first step is the development of a deforestation risk map, and the second step is the application of a set of methodological options to allocate the FRL. Figure 2 lists the steps to be carried out.

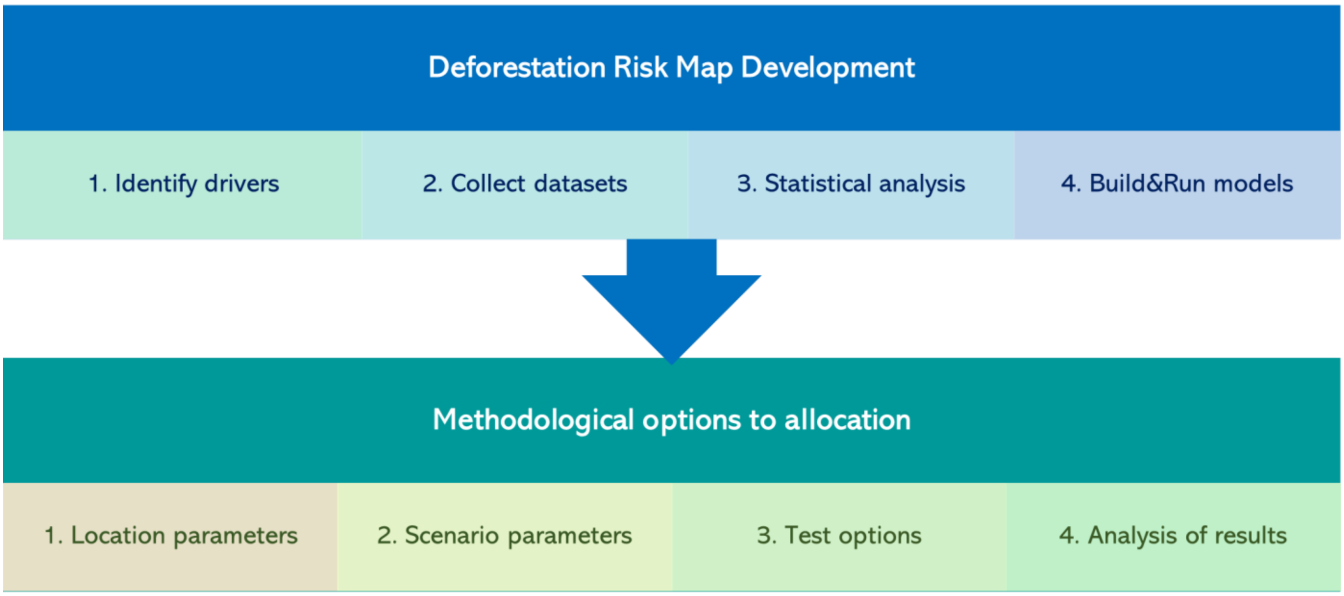


Figure 2. Steps to develop a deforestation risk map and methodological options to allocate the FREL.

DEFORESTATION RISK MAP

The use of a deforestation risk map increases the allocation equity due to the inclusion of parameters linked to current deforestation trends to identify the potential deforestation. Thus, promoting and benefiting the actions to be carried out to reduce deforestation in the future, and bringing in investments and likely change to areas of high pressure.

The following steps were carried out in the development of the Cambodia National Deforestation Risk/Prediction Map:

1. Identify direct and underlying drivers and risks of deforestation.
2. Collect and analyze spatial datasets linked to drivers and risks of deforestation.
3. Analyze the explanatory variables and propose deforestation models.
4. Built and run the final spatial model of deforestation risk or prediction.

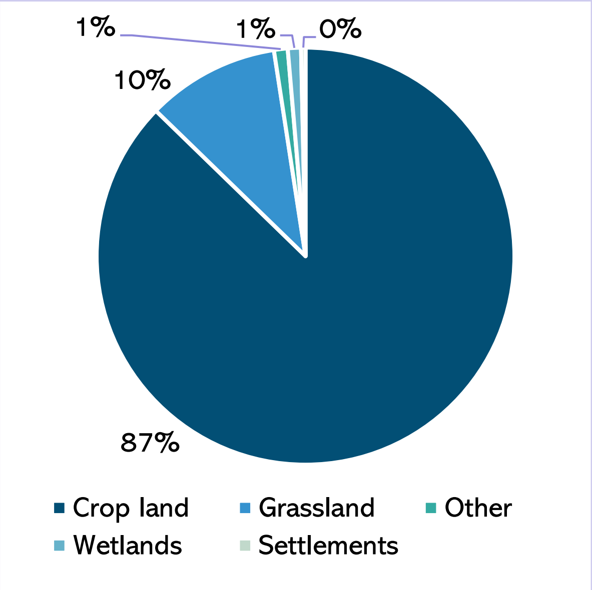
Following, a description of procedures and results step-by-step is detailed.

DRIVERS IDENTIFICATION

According to the national Forest Cover Change (FCC) maps, between 20016 and 2018, the total deforestation area in Cambodia was 280,811 ha. From the total area deforested, 87% was converted to Croplands, and 10% to Grasslands (Table 2 and Figure 3).

Table 2. Land use area and percentage after deforestation, period 2016-2018.
Figure 3. IPCC Category of Land-use percentage after deforestation, period 2016-2018.

Land use after conversion	Area (ha)	Area (%)
Cropland	**245.103**	**87.28%**
Various Cropland	191.509	68.20%
Paddy field	32.725	11.65%
Rubber plantation	20.507	7.30%
Oil palm	363	0.13%
Grassland	**28.900**	**10.29%**
Wood shrub	26.745	9.52%
Grassland	2.155	0.77%
Other	**2.980**	**1.06%**
Sand	2.685	0.96%
Rock	294	0.10%
Wetlands	**2.867**	**1.02%**
Water	2.867	1.02%
Settlements	**960**	**0.34%**
Village	857	0.31%
Built-up area	103	0.04%
Total general	**280.811**	**100.00%**



Land-use change analysis at Province scale (Figure 4), in the period from 2016 to 2018, shows that trends are similar for all provinces. i.e., a high percentage of deforested area is converted to croplands.

Further, this analysis shows that deforestation rates are very heterogeneous across the country: Preah Vihear and Kratie provinces accumulate almost 40% of total deforestation; Kampong Thom and Stung Treng represent about 10% of the total deforestation each; Siem Reap, Kampong Speu, Oddar Meanchey, Mondul Kiri, Pursat, Battambang, Ratanak Kiri, and Kampong Chhnang represent from 6,5 to 3,4% of total deforestation. These 12 provinces represent 95% of the total national deforestation within the period 2016-2018.

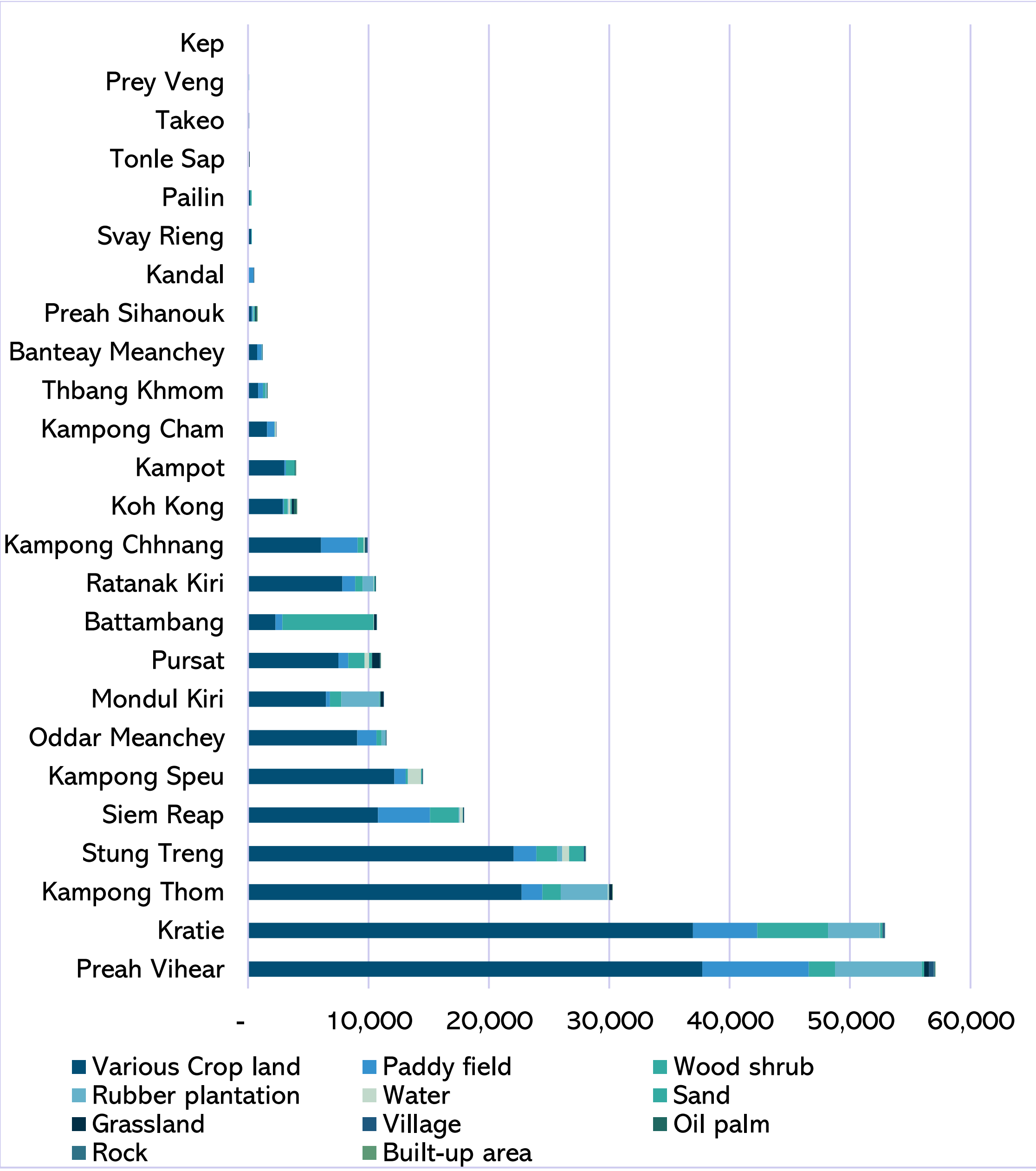


Figure 4. Land use after deforestation by province. Period 2016-2018.

The study "Drivers of Forest Change in the Greater Mekong subregion" (USAID, 2015), describes the main drivers of deforestation in Cambodia as:

- Economic Land Concessions (ELCs).
- Social Land Concessions (SLC).
- Directive 001 policy.
- Hydropower dam construction.
- Road construction.
- Illegal forestland conversion at the household scale.

From these significant drivers, five over six are related to planned deforestation, while only the illegal forestland conversion at household scale would be considered as unplanned deforestation. It is worth noting that ELCs, SLCs and Directive 001 were designed to give the exploitation rights to private investors and communities. Most of the initiatives or management plans were related to the development of industrial agriculture and forestry activities. Figure 5 shows the location of the main concession type.

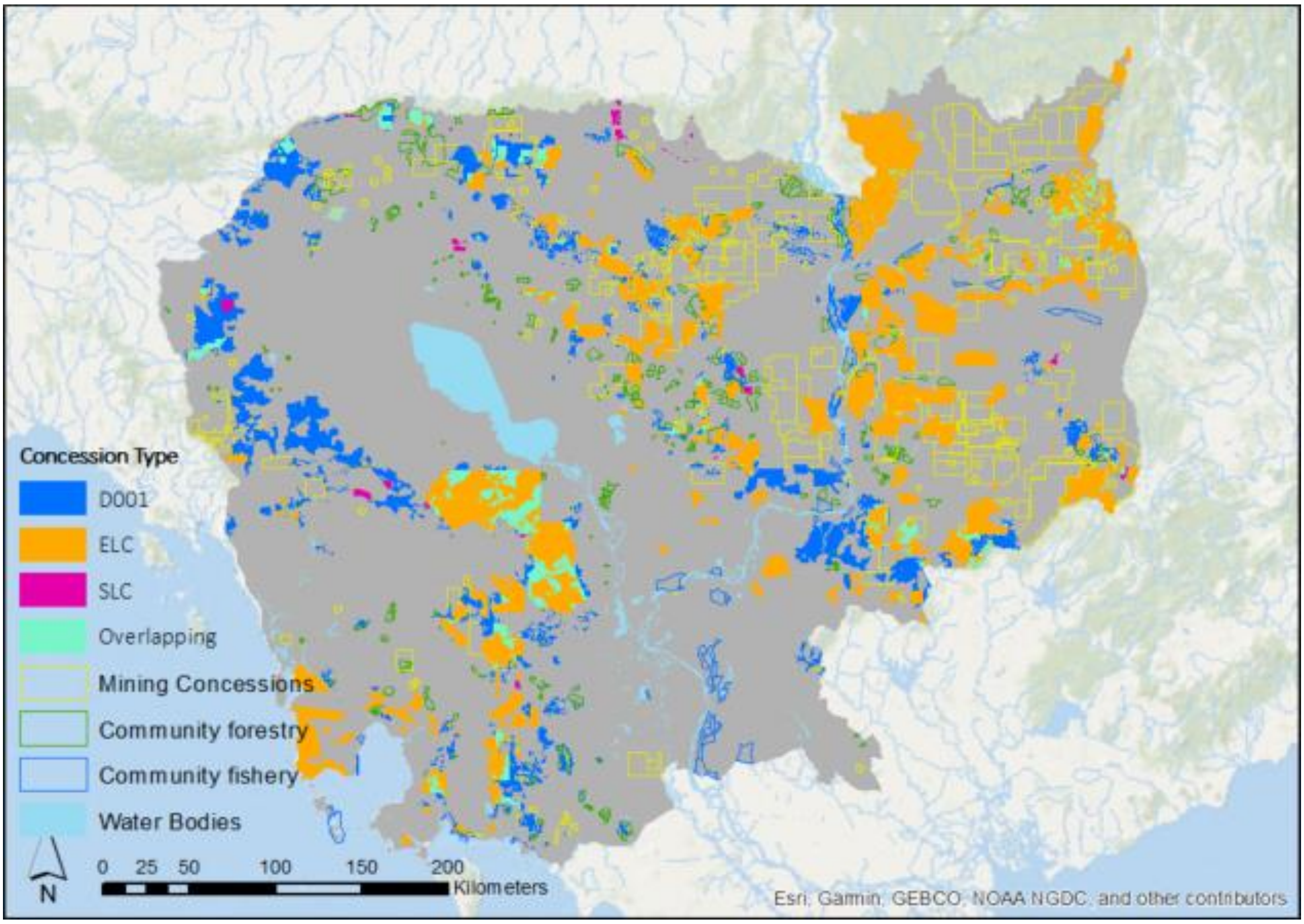


Figure 5. Location of D001, ECL, SLC, Mining concessions, Community Forestry, and Community Fisheries.

Planned Deforestation Drivers

An early analysis to identify the quantitative relevance of planned deforestation was carried out based on the available spatial information for ELC, SLC, Directive 001, and Mining Concessions[2]. The results (Table 3. Deforestation area inside ECL. Directive 001. Social Land Concession. and Mining Concessions.) shows that "planned" deforestation accounts for 54% of the total deforestation in the period 2010-2014. But this rate decreases for the periods 2014-2016 (42%) and 2016-2018 (38%).

Table 3. Deforestation area inside ECL. Directive 001. Social Land Concession. and Mining Concessions.

Period	Total Deforestation (ha/year)	Planned Deforestation (ha/year)	Planned Deforestation (%)	Unplanned Deforestation (ha/year)	Unplanned Deforestation (%)
2010-2014	579,059.23	313,698.40	54.20%	265,348.58	45.80%
2014-2016	181,385.85	76,094.05	42.00%	105,289.90	58.00%
2016-2018	139,957.10	52,621.60	37.60%	87,335.45	62.40%

The percentage of planned deforestation could be even higher if hydropower, roads, and urban development areas were included in the analysis. However, this information was not available for the present report.

The underlying drivers associated with planned deforestation are (

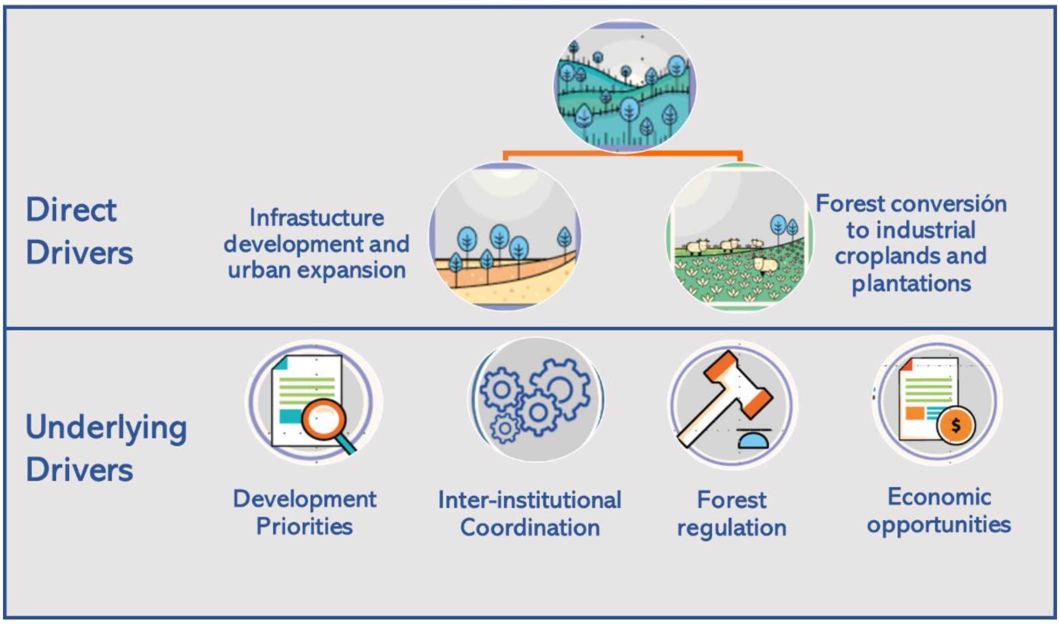


Figure *6*):

- The overlapping of the development priorities of the country and the forest conservation activities.

[2] Information from Open Development Cambodia (ODC)

- The weakness of forest protection legislation.
- The lack of inter-institutional coordination to establish land use planning policies.
- The low economic opportunities of forestland competing with croplands.

Figure 6. Planned Deforestation and underlying drivers.

All of these underlying drivers are related to political and planning decisions, so the predictability of their occurrence is mainly associated with econometric and political variables that make their spatial representation in the medium and long term very complicated.

However, in the short term, it is possible to identify the areas with the highest deforestation risk according to the existing development planning. To use this information accurately, it is necessary to update variables of interest, such as boundaries, planned and executed activities per year on ELCs, Directive 001, mining concessions, hydropower, routes and settlement developments, and SLC (Figure 7).

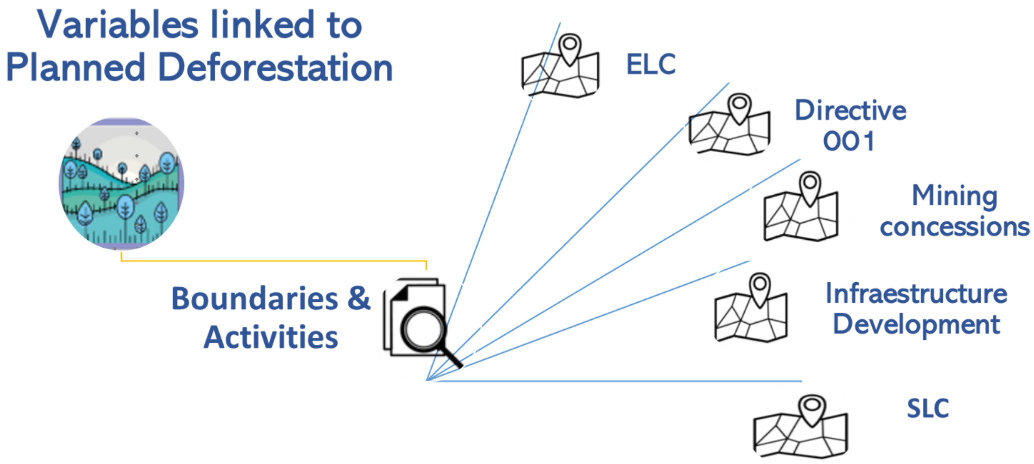


Figure 7. Variables linked to Planned deforestation

Unplanned Deforestation Drivers

To early analyze unplanned deforestation, the forest area converted to other land use within the boundaries of ELCs, Directive 001, Mining concessions, and SLCs, considered in the planned deforestation analysis, were excluded.

Unplanned deforestation is mainly related to illegal forestland conversion at the household scale, due to activities such as wood extraction for charcoal production, wood fuel, logging, and shifting cultivation. These deforestation drivers are often related to underlying socioeconomic and demography drivers, such as poverty, low employment, and a high rural population (Figure 8).

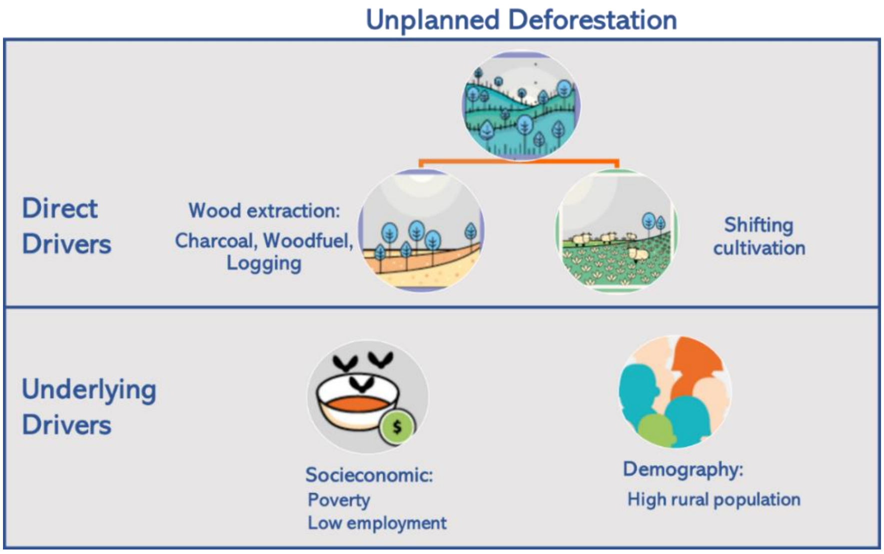


Figure 8. Unplanned deforestation direct and underlying drivers.

The main variables linked to the underlying drivers for unplanned deforestation are related to accessibility (Figure 9). Deforestation often happens in easily accessible areas and close to population centres. Variables such as distance to routes and distance to population centres are highly correlated to deforestation, as well as geographical relief (slope and elevation). Forest shape and fragmentation are also related to accessibility and hence to the risk of deforestation.

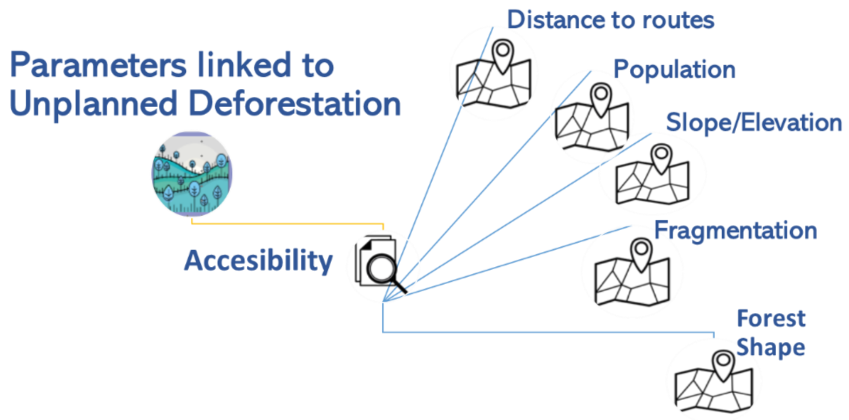


Figure 9. Parameters linked to unplanned deforestation.

Deforestation predictors

Besides the variables related to planned and unplanned deforestation drivers, additional sources of information could be used as predictors of future deforestation.

Historical deforestation trends are often used as a predictor of future deforestation. Several variables and tests must be set by expert judgment and carried out to be as accurate as possible, such as the length of the deforestation period and the distance to deforestation to be applied.

Suppose the period used to estimate deforestation risk, due to the national circumstances or due to the time extension, and it is not reliable to the current situation. In that case, it is highly possible to over or underestimates the prediction. Also, if the area of influence for a selected variable is not accurate, the results could under or overestimate the deforestation risk area estimated.

DATA COLLECTION AND ANALYSIS

Both planned and unplanned deforestation are of similar relevance in terms of area affected by year. Therefore, to apply methodologies that allow identifying risk areas for both types of drivers would be appropriate.

Future planned deforestation could be identified if updated data is available. However, this data is often sensitive, strategic, and, sometimes, developed by institutions that do not engage in the REDD+ process, which can make obtaining such data challenging.

Unplanned deforestation is hard to predict; however, the risk of deforestation could be linked to easily collectable variables. The combination of these parameters must be based on statistical measures and knowledge of the national circumstances.

Deforestation predictors are an excellent alternative variable to complement the deforestation risk identification; for its correct application, it is essential to set the parameters to be used, such as buffer distance and historical period.

The analysis carried out aimed to estimate the Planned and Unplanned Deforestation at the national level. The proxies used to define "planned deforestation" are Economic Land Concessions (ELC, excluding polygons classified as "Revoked in 2014"), Social Land Concessions (SLC), and Directive 001 (D001). All other areas are assumed to be "unplanned" deforestation.

The following workflow to review the relevance of drivers, based on the available datasets linked to the parameters for each driver was followed:

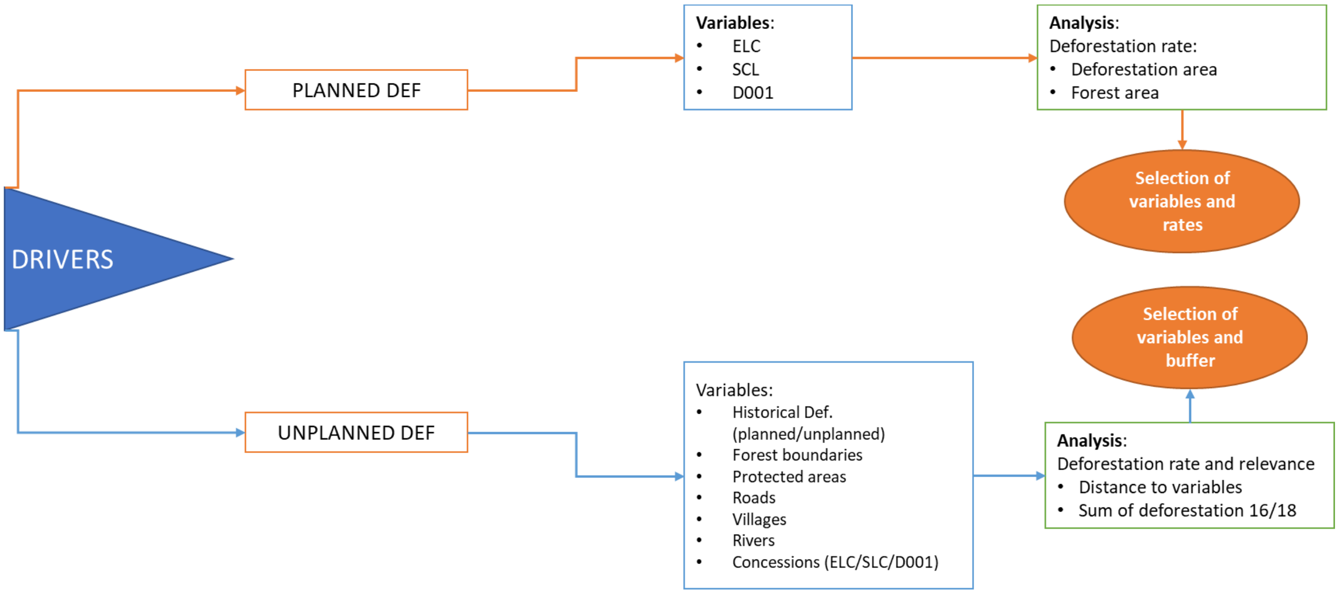


Figure 10. Workflow to evaluate the importance of variables related to deforestation drivers.

Planned Deforestation data analysis

The total area of Planned deforestation was estimated as the sum of deforestation (calculated by the FCC maps) within the concession areas, considering ELC, SLC, and D001. For each concession type, the annual deforestation rate (deforested area/forest area/year) was estimated for the period 2014-2018.

Within the boundaries of concession lands, the annual deforestation rate is 3.3%, while the rate outside those boundaries is 1.4%. The general national rate is 1.6%.

Table 4. Annual deforestation rate within concessioned lands.

	Inside ELC – SLC – D001	Outside ELC – SLC – D001	Total National
Deforestation (ha/year)	35,230	103,483	148,713
Forest Area (ha)	1,080,685	7,391,650	8,472,335
Annual Deforestation Rate	3.3%	1.4%	1.6%

Analyzing the deforestation rate by type of concession, the results show that the annual rate is higher in the SLC and D001 (both with a 4.6% rate) than in ELC (3.2%).

As a result of the analysis, the following parameters and deforestation rates were selected:

Table 5. Deforestation rates estimated inside Dir 001, ELC and SLC.

Variable	D001	ELC	SLC
Annual Deforestation Rate	4.6%	3.2%	4.6%
Forest Area 2014 (ha)	51,521	1,089,543	23,817

The analysis also included the Community Forestry (CFo), Community Fisheries (CFi), and Mining Concession. However, Deforestation rates were close to the areas outside these types of concession. Hence, CFo, CFi and Mining concessions were not considered in the following steps.

Table 6. Deforestation rates estimated inside CFi, CFo and Mining concessions.

Variable	CFI	CFO	Mining
Annual Deforestation Rate	1.9%	1.5%	1.8%
Forest Area 2014 (ha)	23,751	230,560	1,934,711

Unplanned Deforestation

Unplanned deforestation is considered as forest loss areas outside ELC, SLC, and D001 concessions. Hence, all the processes were carried out, masking the Non-Forest area and concessions.

The initial hypothesis is that recent deforestation is more likely to occure closer to the risk variables. The risk variables included in the analysis were selected considering the availbality of spatial information related to the variables identified in Figure 8 above.

In order to confirm the hypothesis, the relation between recent deforestation in absolute and relative terms (total deforestation and deforestation rates) for each of variable at 500-meter intervals up to 5 km has been analyzed. Figure 11 shows the Euclidean distance to variables in a color ramp from closer in red, to farther in green.

The relation between recent deforestation as the independent variable (considered as the deforestation during the period 2016-2018) and the following dependent variables were analyzed, considering each "buffer" by itself and the accumulated results:

- Deforestation in the period 2014-2016:
- Forest boundaries in the period 2014-2016
- Concession areas
- Villages
- Water bodies
- Roads

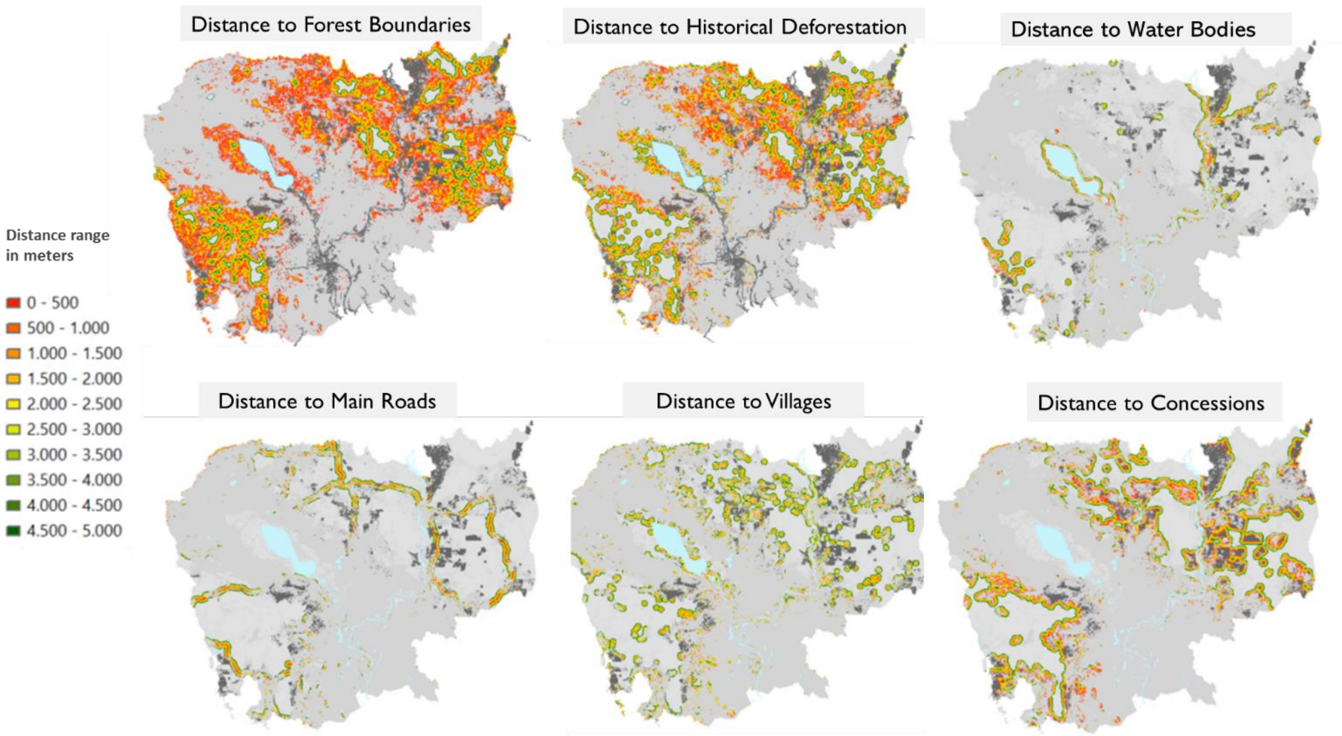


Figure 11. Euclidean distance to selected variables

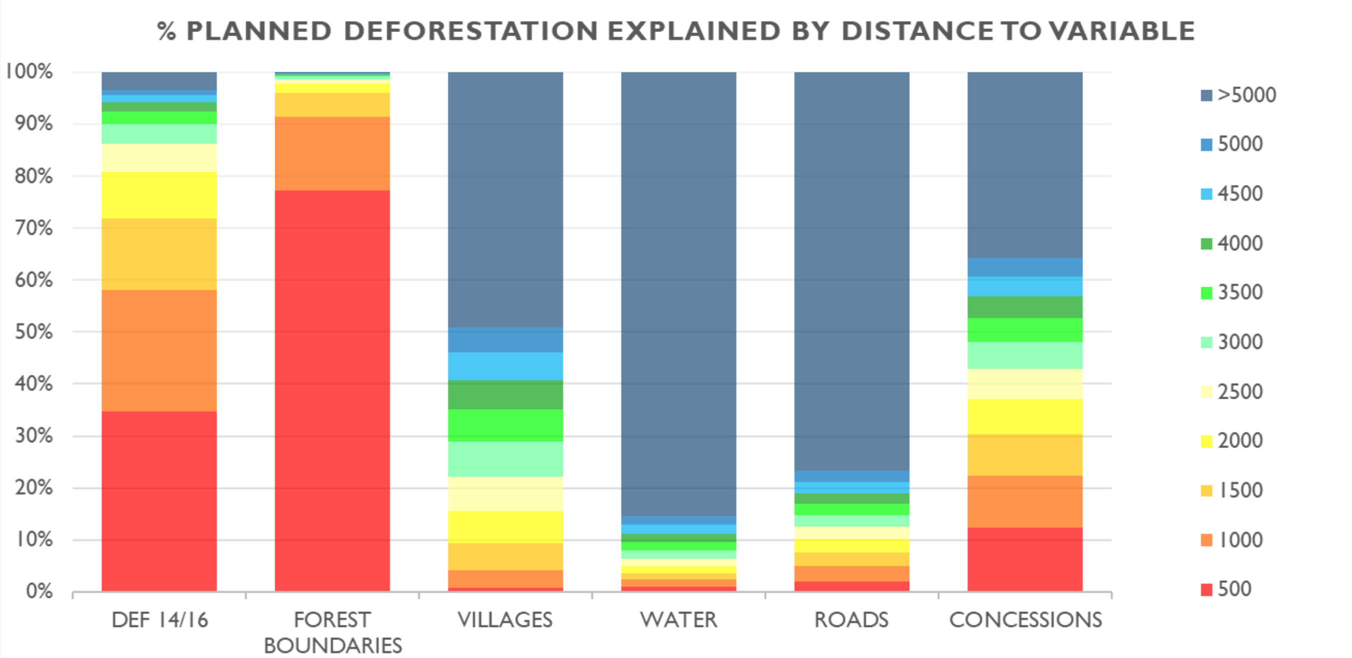


Figure 12. Proportion of deforestation explained by distance to analyzed variables

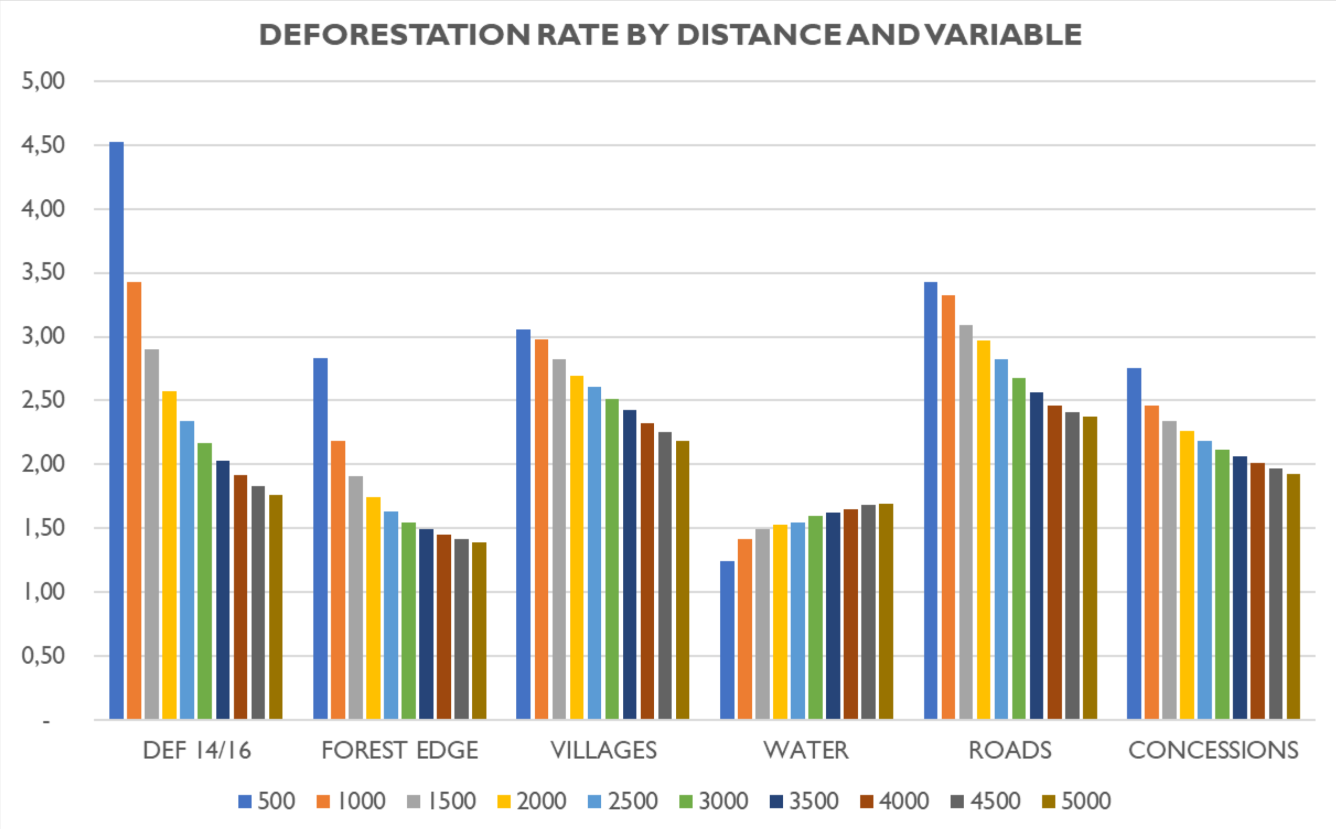


Figure 13. Annual deforestation rate by distance to analyzed variables

The average annual unplanned deforestation rate in the period 2016-18 was 1.5%. Among the criteria tested, most of the estimated deforestation (4.53%) occurred within a distance of 500 meters to the previous deforestation area (Def 14/16).

It is also important to note that around the 77% of the accumulated deforestation occur at 500m from forest boundaries, and the deforestation rate in this range is close to 3%. The 29% of deforestation also is located at 3000m from Villages, and the 17% at 3500m from Roads respectively.

The only parameter which does not have a clear relation with deforestation is distance to water bodies.

As a result of the analysis and based on the combination of deforestation explanation and deforestation rate by parameter and buffer, the following variables and buffers were selected for the following procedures. However, different settings could be selected and analyzed:

Table 7. Variables and parameters selected

Variables	Distance range	Deforestation rate	Deforestation explained
Historical Deforestation	2000m	2.6%	83.5%
Forest boundaries	500m	2.8%	77.1%
Villages	3000m	2.5%	28.9%
Roads	3500m	2.6%	16.9%
Concession areas	500m	2.8%	12.4%

DATA EXPLORATORY ANALYSIS

The following workflow describes the methodology used to refine the previous step, aiming to select the best combination of variables to explain the current deforestation:

Figure 14. Data exploratory analysis procedure.

Akaike information criterion (AIC) (Akaike, 1974) selection method was used as a robust statistical procedure to select the best explanatory variables. AIC is a fined technique based on in-sample fit to estimate the likelihood of a model to predict/estimate future values. A good model is the one that has minimum AIC among all the other models (Mohammed, E.; et al. 2015).

The AIC results allow the user to select the best combination of independent variables to explain the dependent variable. The proposed approach to choose the best combination of variables is the Forward approach.

In the first step, the user should review the AIC results for the single variables. The lower AIC value is the best explanatory variable, and therefore, this variable should be selected.

In the following step, the user should review the combination of the variable selected in the previous step with the rest of the variables and determine the lower AIC value. The variables combination will be chosen if the AIC is lower than the one obtained previously. The process iteratively including a higher number of variables until the selection of the best combination.

AIC selection method was applied over the selected variables plus the Population Density information at a district level. The Independent variable was set as the sum of deforestation area outside concessions during 2016/2018. The rest of the variables were included as dependent variables.

For each district, the following calculations were made (displayed in Figure 15):

- Sum of deforestation area 2016/2018
- Sum of forest area in 2016
- Sum of forest area outside concessions within a distance of:
    - 2000m to the deforestation in the period 2014-2016
    - 500m to the Forest boundaries in 2016
    - 3000m to Villages
    - 3500m to Roads
    - 500m to Concessions
- Average Population Density

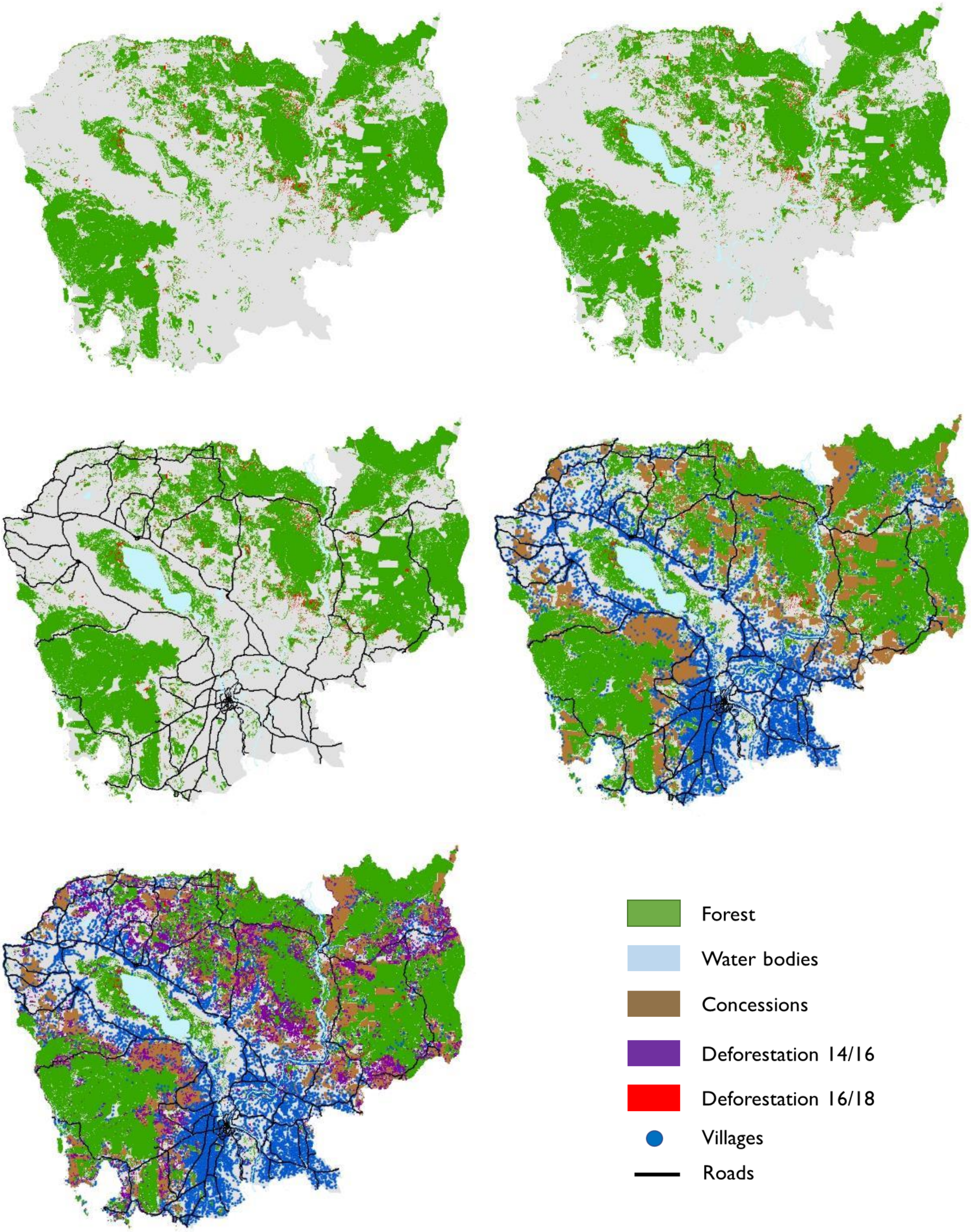


Figure 15. Variables included in the AIC analysis to select the best explanatory variables.

The application of the forward approach to select the variables to be included in the final model indicates that the most relevant variable was the historical deforestation in the period 2014-2016.

	1 Variable	AIC Value
1	rg_Concessions_500	1.965,65
2	rg_Def_14_16_2000	1.893,86
3	rg_No_Forest_16_500	1.909,53
4	rg_Roads_3500	2.049,42
5	rg_Villages2_3000	2.053,08
6	populationDensity	2.084,56

Figure 16. AIC value for each variable

The AIC value is lower when historical deforestation variable was combined with the forest boundaries in 2016.

	2 Variables		AIC Value
1	rg_Concessions_500	rg_Def_14_16_2000	1.895,68
2	rg_Concessions_500	rg_No_Forest_16_500	1.906,14
3	rg_Concessions_500	rg_Roads_3500	1.967,21
4	rg_Concessions_500	rg_Villages2_3000	1.965,48
5	rg_Concessions_500	populationDensity	1.967,64
6	**rg_Def_14_16_2000**	**rg_No_Forest_16_500**	**1.890,48**
7	rg_Def_14_16_2000	rg_Roads_3500	1.895,72
8	rg_Def_14_16_2000	rg_Villages2_3000	1.895,86
9	rg_Def_14_16_2000	populationDensity	1.895,40
10	rg_No_Forest_16_500	rg_Roads_3500	1.909,26
11	rg_No_Forest_16_500	rg_Villages2_3000	1.905,79
12	rg_No_Forest_16_500	populationDensity	1.911,49
13	rg_Roads_3500	rg_Villages2_3000	2.041,90
14	rg_Roads_3500	populationDensity	2.051,40
15	rg_Villages2_3000	populationDensity	2.054,90

Figure 17. AIC values for the combination of two variables

If additional variables are included in the combination, the AIC value does not improve.

	3 Variables			AIC Value
1	rg_Concessions_500	rg_Def_14_16_2000	rg_No_Forest_16_500	1.892,41
2	rg_Concessions_500	rg_Def_14_16_2000	rg_Roads_3500	1.897,61
3	rg_Concessions_500	rg_Def_14_16_2000	rg_Villages2_3000	1.897,67
4	rg_Concessions_500	rg_Def_14_16_2000	populationDensity	1.897,21
5	rg_Concessions_500	rg_No_Forest_16_500	rg_Roads_3500	1.907,66
6	rg_Concessions_500	rg_No_Forest_16_500	rg_Villages2_3000	1.905,02
7	rg_Concessions_500	rg_No_Forest_16_500	populationDensity	1.908,02
8	rg_Concessions_500	rg_Roads_3500	rg_Villages2_3000	1.967,47
9	rg_Concessions_500	rg_Roads_3500	populationDensity	1.969,17
10	rg_Concessions_500	rg_Villages2_3000	populationDensity	1.967,23
11	rg_Def_14_16_2000	rg_No_Forest_16_500	rg_Roads_3500	1.892,27
12	rg_Def_14_16_2000	rg_No_Forest_16_500	rg_Villages2_3000	1.892,16
13	rg_Def_14_16_2000	rg_No_Forest_16_500	populationDensity	1.892,10
14	rg_Def_14_16_2000	rg_Roads_3500	rg_Villages2_3000	1.897,67
15	rg_Def_14_16_2000	rg_Roads_3500	populationDensity	1.897,17
16	rg_Def_14_16_2000	rg_Villages2_3000	populationDensity	1.897,38
17	rg_No_Forest_16_500	rg_Roads_3500	rg_Villages2_3000	1.907,58
18	rg_No_Forest_16_500	rg_Roads_3500	populationDensity	1.911,07
19	rg_No_Forest_16_500	rg_Villages2_3000	populationDensity	1.907,03
20	rg_Roads_3500	rg_Villages2_3000	populationDensity	2.043,53

Figure 18. AIC values for the combination of three variables

Therefore, **Historical deforestation** and **Forest boundaries** were selected to create the regression model.

DEFORESTATION MODEL/RISK MAP DEVELOPING

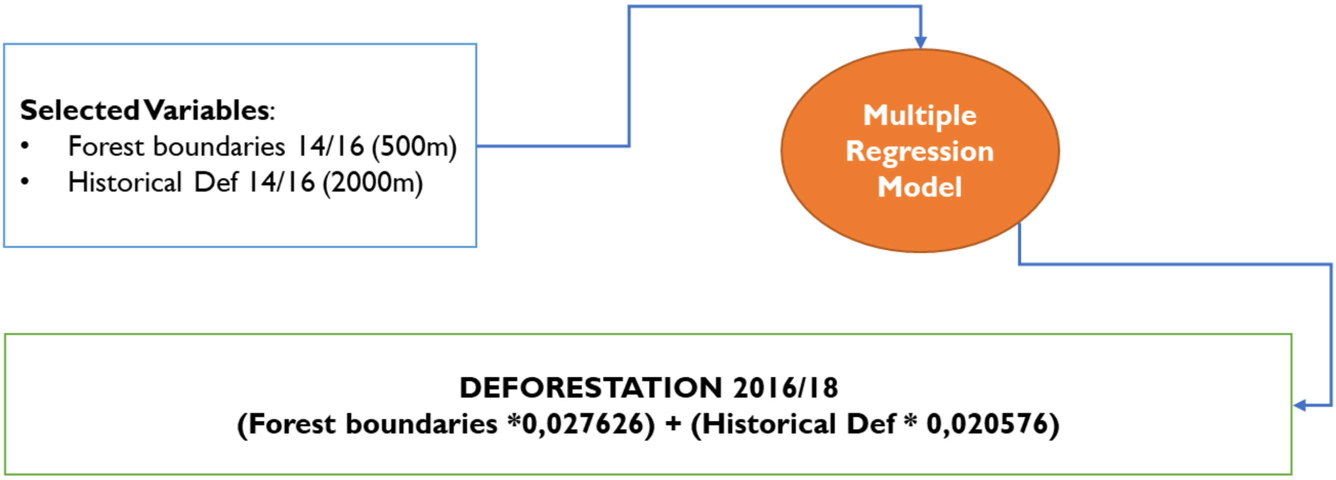


Figure 19. Workflow to integrate the information into a Deforestation Risk Map.

Using the selected variables, a Multiple Regression Model[3] is estimated, the model result is a prediction of the deforested area in hectares every two years.

The interception value was established as "0". Thus to avoid, in the one hand, a potential negative intercept, which will deliver negative values for the areas do not include within the distance selected for the variables; or, in the other hand, a minimum risk value for all the forest area.

The following regression statistics and coefficients were obtained:

Regression Statisticals			
Multiple R squared	0.6838		
R^2 Adjusted	0.6806		
Residual standard error:	122 on 195 degrees of freedom		
N	168		
Variables	*Coefficients*	*Std. Error*	*t Value*
2000 m to the Deforestation	0.020576	0.005142	4.001
500 m to Forest Boundaries	0.027626	0.010381	2.661

[3] Further information about Multiple Regression Model in the following link: https://towardsdatascience.com/understanding-multiple-regression-249b16bde83e

Before to apply the multiple regression model, it was necessary to process variables aiming to include information corresponding to the period 2014/18.

This modification is made to use the most representative existing data. Further, to fit the final result to deforestation per year:

- the area within 2000m to the deforestation, were estimated by the period 2014/2018 and values divided by two

- the forest boundaries area was updated to use the information from 2018 land use map.

The final equation, further applied at a 100 m pixel level, to run the model was:

$$U - Def_i = (\left(\left(Def_{14-18_i}\right) * 0.020576\right) + (ForBound_{2018_i} * 0.027626))/2$$

Were:

$U - Def_i$ = Estimated unplanned deforested area by year (ha/year) by pixel.

Def_{14-18_i}=Forest area (ha) within a distance of 2000m from the deforested area in 2014/18 by pixel.

$ForBound_{2018_i}$= Forest area (ha) within a distance of 500m from forest boundaries in 2018 by pixel

In the case of the area considered as Planned deforestation, the following parameters were used for each type of concession:

Variable	D001	ELC	SLC	Overlapped Area
AnnualDeforestation Rate	4.5%	3.2%	4.6%	12.5%
Area		1,058,103		77

The equation applied to estimate the predicted deforestation by year was the following:

$$P - Def_i = Forest_{i,j} * Def\_rate_{i,j}$$

Were:

$P - Def_i$ = Estimated planned deforested area by year (ha/year) by pixel.

$Forest_{i,j}$=Forest area in 2018 (ha) by concession type "j" by pixel.

$Def\_rate_{i,j}$= Annual deforestation rate by concession type "j" by pixel.

Finally, both results are aggregated to obtain a prediction of future deforestation area in hectares by year (Figure 20). The total area of deforestation estimated was 89.237 ha/year.

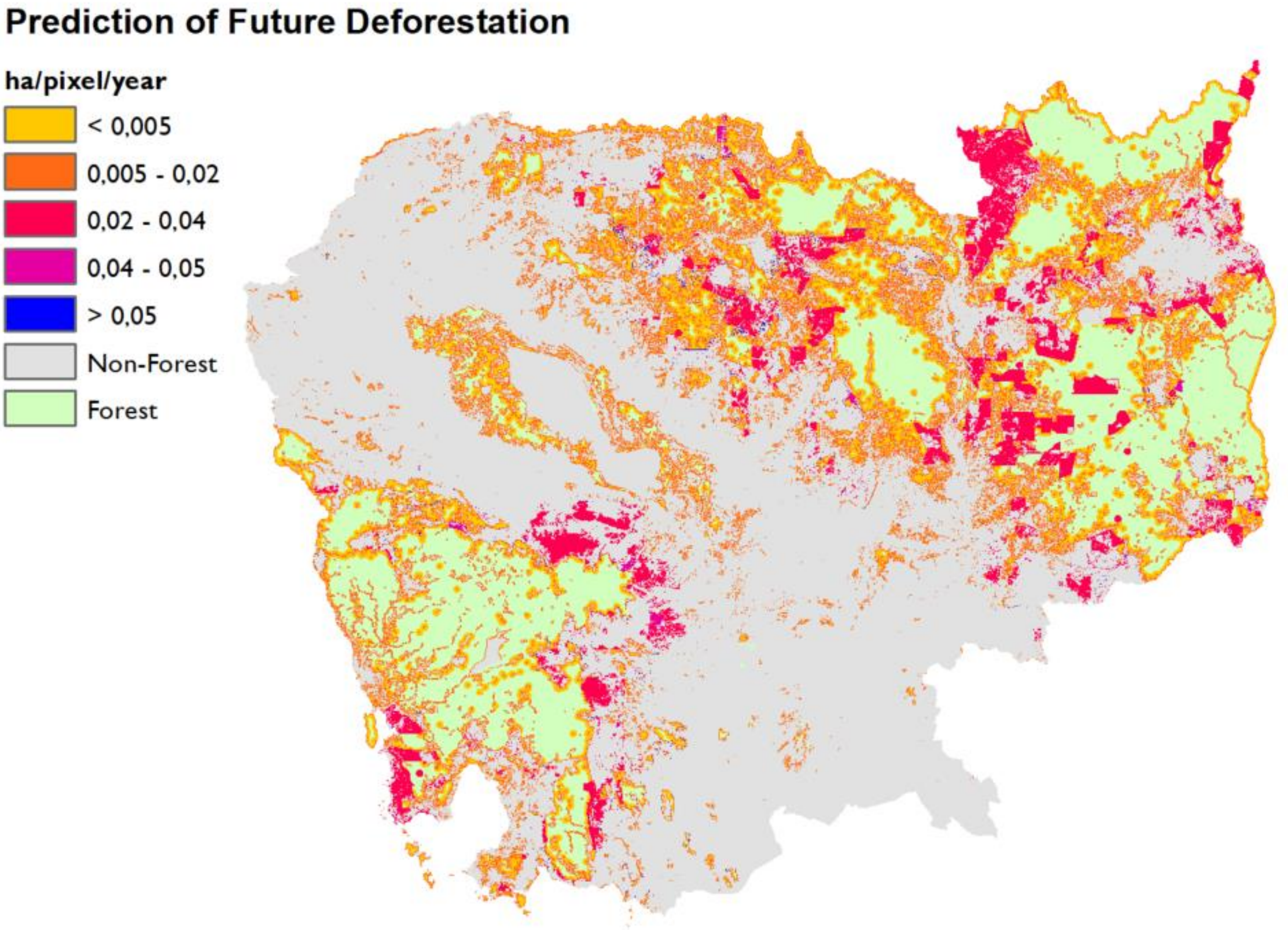


Figure 20. Deforestation model/risk map result.

ALLOCATION METHOD

To be consistent with the FREL, the data sources used to develop the allocation method include the results and the information used in the updated FREL:

- The Updated FREL result is 44.695.152 t CO_2e/year[4].
- It was develop using stratification by forest types: Evergreen forest, Semi-evergreen forest, Deciduous forest, and Other forests.

The method proposed to allocate the FREL, combine the information from:

- the deforestation model/risk map described in the previous section,
- the national emission factor (EF) by forest type, as used in the updated FREL (Table 8),
- the most recent Land use map (2018) to identify the spatial distribution of forest types.

The corresponding EFs were assigned to each forest type area, obtaining a spatial representation of EFs (Figure 21). This information is further combined with the Deforestation model/risk map to provide an estimation of emissions by cell per year (Figure *22.* Estimated emissions by cell per year.Figure 22).

Table 8. Forest Types Deforestation National EF.

Forest type 'mix.'	Number of plots	AGB	BGB	Total Biomass	Total Carbon	Total CO_2	CI (%)
Evergreen	446	133.12	49.26	182.38	85.72	314.30	5
Semi-evergreen	49	165.23	33.05	198.28	93.19	341.70	19
Deciduous	132	70.87	14.17	85.04	39.97	146.55	10
Other Forest	54	45.39	21.72	67.11	31.54	115.66	25

[4] As estimated in the First Draft Updated FREL.

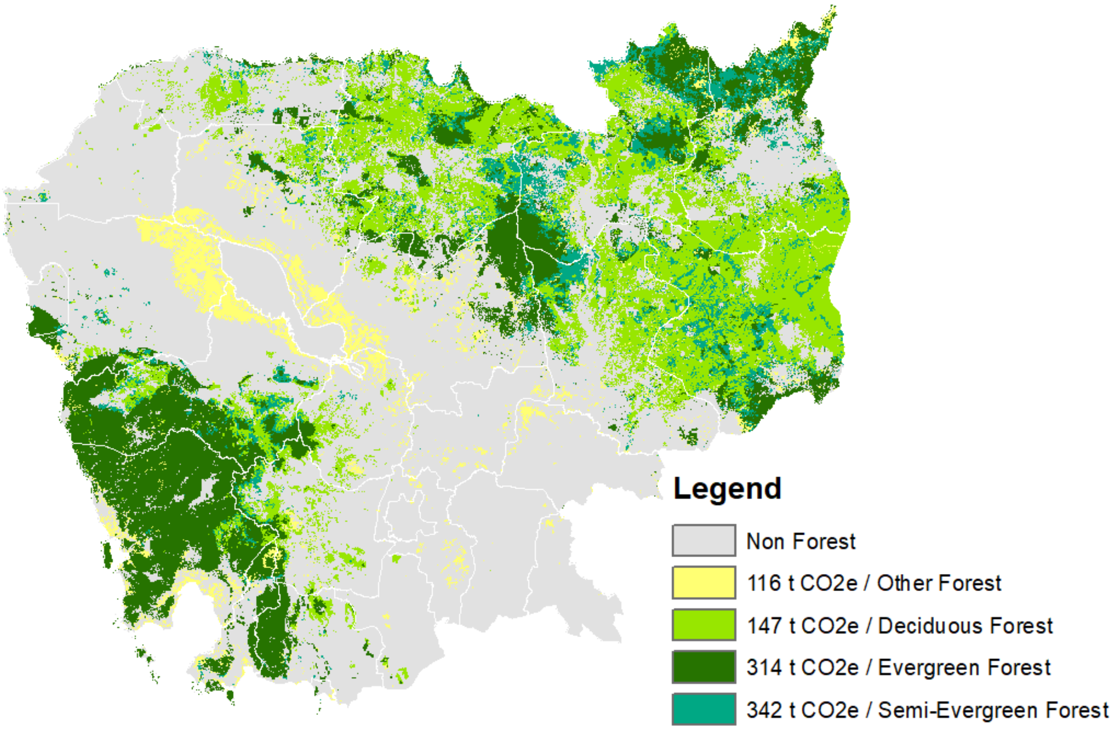


Figure 21. Spatial distribution of forest types and EF used

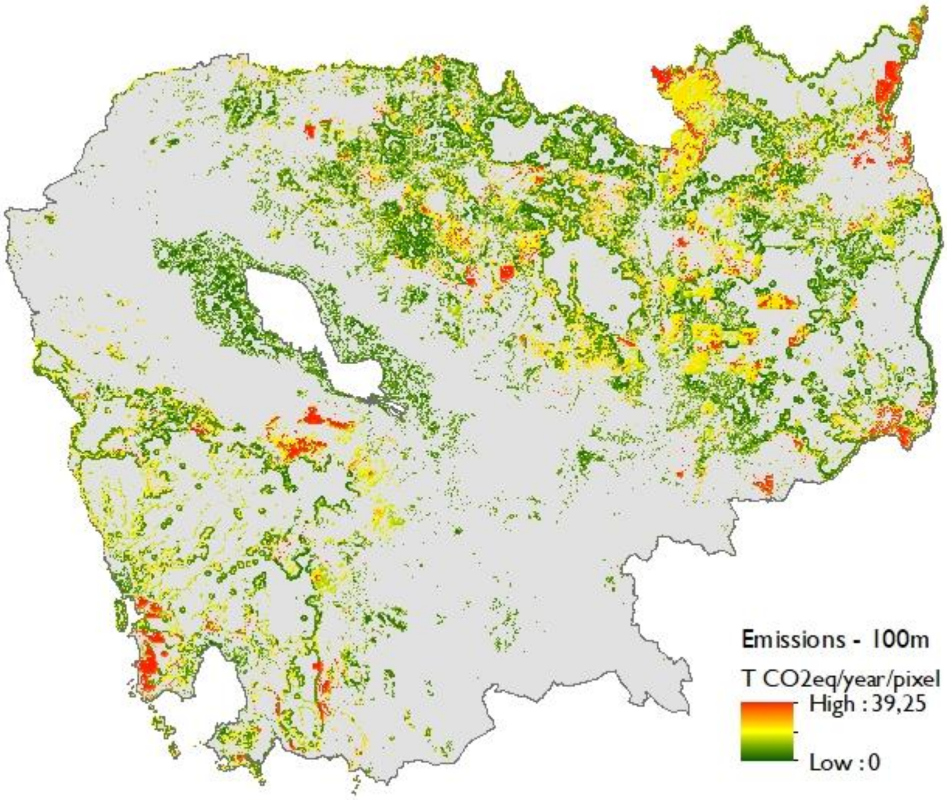


Figure 22. Estimated emissions by cell per year.

ALLOCATION TEST AND ANALYSIS

To allocate, the following equation is applied:

Equation 1. Allocation equation.

$$\mathrm{tCO2\ Allocated_{Project}} = \mathrm{FREL}\ \frac{\mathrm{DefRate_i} \times \mathrm{Forest\_area_i} \times \mathrm{EF_{FT}}}{\sum \mathrm{Def\_area_J} \times \mathrm{EF_{FT}}}$$

Where:

$\mathrm{DefRate_i}$= Annual deforestation rate risk of a project area

$\mathrm{Forest\_area_i}$= Total forest area within the project

$\mathrm{Def\_area_J}$= Total deforested area estimated at the national level by forest type per year

$\mathrm{EF_{FT}}$= Emission Factor weighted by forest type

The equation multiplies the FREL by the percentage of total emissions, considering a range from 0 to 100%, ensuring that the proportion of the FREL allocated will never be oversized the total national FREL.

The model was tested over four made-up projects with similar extension, 129,600 ha, but different locations (Figure 23).

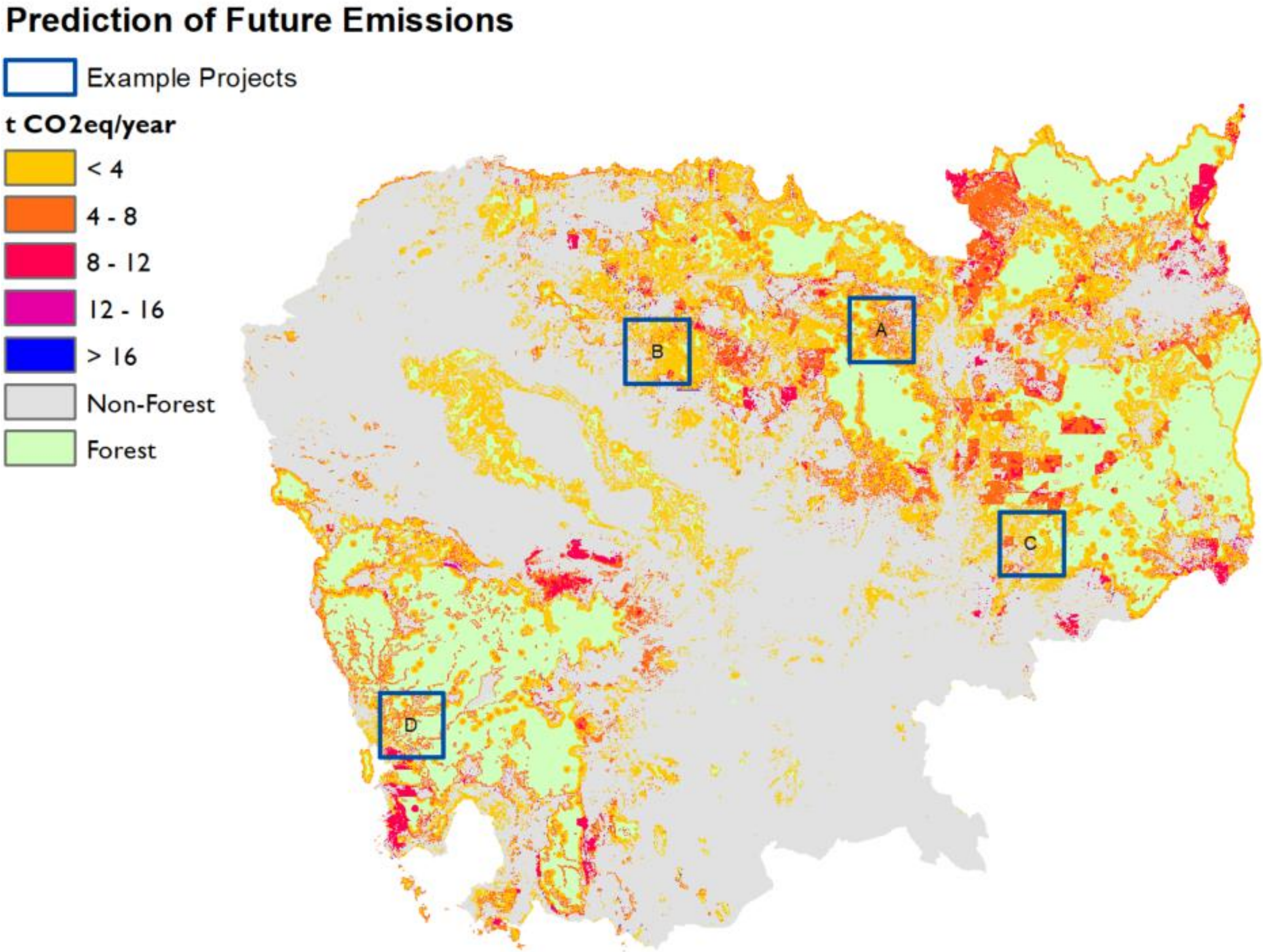


Figure 23. Made-up projects location

The example reflects the variability of results depending on the risk level and the carbon stock in the project area.

Table 9. Application of allocation method.

Project	DefRate*For (ha/year)	DefRate*For*EF (tCO_2eq/year))	EF_tot *Def_tot (tCO_2eq/year)	FREL (tCO_2eq/year)	ALLOCATION (tCO_2eq/year)
A	1.061	302.583	16.627.224	45.002.590	818.959
B	1.163	209.604			567.306
C	1.177	179.444			485.676
D	830	226.992			614.367
TOTAL	**4.231**	**918.623**			**2.486.309**

The allocated proportion of the FREL to Project "A" is 32% over the average between the four projects (621.577 t CO2eq/year). In the other hand, the proportion allocated to Project "C" is 22% below the average.

Table 10. Variance form the average emissions allocated by project

Project	Variance from average emission (%)
A	+32%
B	-9%
C	-22%
D	-1%
Average emisión allocated	621.577 t CO_2eq/year

The different forest types distribution within each project area, and therefore its carbon stock, has a substantial impact over the results. Project "A" represent 25% of the projected deforestation over the four projects; however, the volume of emission represents 33%. In the opposite situation, Project "C" represent 28% of the projected deforestation but 20% of the emission. 5,5% of the total FREL was allocated to the projects used in this example.

Table 11. Comparison between predicted deforestation area and emissions by project

Project	Projected Deforestation (ha)	Projected Emissions (%)	Proportion of the FREL allocated (%)
			1,82%
A	25%	33%	1,26%
B	27%	23%	1,08%
C	28%	20%	1,37%
D	20%	25%	5,52%

It should be noted that all forest inside concessions has been considered under a specific level of risk of deforestation. In contrast, 45% of the forest outside the concession, corresponding to 3.126.786 ha, has been classified as "zero risks" areas.

Further, the average predicted emission per hectare estimated inside the concession (6,67 t CO_2eq/ha/year) were 2,5 times higher than in the forest under risk outside concessions (2.76 t CO_2eq/ha/year).

Table 12. Comparison between Planned and Unplanned Deforestation estimations

Forest Class	Emissions allocated (tCO_2eq/year)	Total Area(Ha)	Emissions by hectare by year (tCO_2eq/ha/year)
Planned	6.027.436	904.294	6,67
Unplanned	10.599.788	3.845.350	2,76
Zero Risk	0	3.126.786	0
TOTAL FOREST AREA	16.627.224	7.876.430	2,11

CONSULTATION

The consultancy to develop the allocation methodology has relied on a stakeholder consultation process to create a shared space that allows to collect feedback, address the main concerns from the involved actors and identify improvements to solve potential issues in the final implementation of the methodology.

Several consultations activities were carried out during the process to develop the allocation methodology; however, the more relevant was carried out during October 2020, once the draft method was refined and applied.

It is worth noting that, the methodology was presented in July 2020 to the stakeholder's consultation group, and several improvements were carried out, such as:

- To use of the AIC method to select the variables, replacing the previous method proposed based on the Exploratory Regression Analysis.
- To generate the results on a higher spatial resolution. From 6km cell grid, used in the previous drafts, to 1 ha resolution in the latest version.

Since July, the focus of the consultancy was the development of an automatic tool to create Deforestation Risk maps, aiming to run the procedures described in the previous sections, allowing quick and unbiases modifications and adjustments.

Besides, the tool allows to address, and different test options and new variables proposed and collected during the consultation process.

Due to the potential improvements of the official data to be used on the Updated FREL and the FREL Allocation method, no real examples were presented during the consultation. However, stakeholders were able to identify the main concerns relevant to the possible results.

The main concern across the stakeholders is related to the large areas considered as "Zero Risk", in which there the allocation is "0". As describes above the "Zero Risk" area covers 3.126.786 ha of forest. This forest is mainly located inside Protected Areas and, in several cases over existing REDD+ projects accounting areas.

Projects have identified the reduction of its baselines, because of this methodological issue, like a significant risk to operationalize its forest protection activities in the future. Therefore, the following options were proposed to be analyzed before the official implementation of the allocation methodology:

- Improve the spatial datasets used: Stakeholders´ has primarily focused its concern about the "roads" layer used. New dataset developed by the JICA is available, this layer includes more detailed information on existing roads and pathways, many of which pass through protected areas and forests, which increases the risk of deforestation in those areas. There are two different options to use this data:
    - Include the JICA Roads dataset as a new variable in the analysis
    - Update the Forest Boundaries variables by merging the last Land-use Map and the JICA Roads layer.

- Apply a default risk value for all forest area: Current results indicate that only the 55% of the forest in Cambodia is under deforestation risk, corresponding to forest inside concessions, a forest within a distance of 500 meters to the forest boundaries, and forest within a distance of 2000 meters from the previous deforestation. However, 20% of unplanned deforestation happen far from these criteria. In this regard, the proposed option to be adopted is to:

    - Estimate the historical deforestation occurring beyond the criteria selected
    - Estimate the forest area categorized as “Zero Risk.”
    - Calculate a deforestation risk, dividing both estimations, and
    - Apply this risk over the “Zero Risk”.

- Pertinent of Planned Deforestation: There is a shared conviction of the relevant that the methodology includes both planned and unplanned deforestation. However, as detailed in the previous section, the proportion of the FREL allocated to areas considered as planned deforestation is significantly much higher at the hectare level than the allocated to the rest of the forest area. Besides, there is no detailed information about future activities to be carried out inside the different concessions. Thus, while detailed management plans were not available, it is proposed to apply the methodology for unplanned deforestation across the whole country, without different treatments for the forest located inside or outside the concessions.

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OPTIONS TO ALLOCATE THE FREL FIRST DRAFT REPORT

Support to the development of an updated Forest Reference Level and develop options to allocate the FRL at multiple spatial scales for REDD+ implementation in Cambodia.

7 JULY 2020

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