**Introducción.**

Para la selección de las áreas a intervenir se consideró como unidad de análisis la subcuenca, empleando la división en subcuencas realizada en el estudio de balance hídrico para Honduras (CEDEX, 2002), dado que para estas subcuencas se cuenta con información detallada a nivel de oferta y demanda hídrica. Según esta división en Honduras existen 464 subcuencas.

A fin de priorizar las subcuencas afectadas por gorgojo que serán restauradas a través del programa de HO-L1179, se consideraron los siguientes pasos:

1. Paso 1. Identificar las sub-cuencas de Honduras más importantes para la producción de agua superficial. Estas subcuencas serían en las que el servicio de regulación hídrica de los bosques tiene mayor valor.
2. Paso 2. Dentro de las subcuencas identificadas en (1) seleccionar las que presentan mayor afectación por gorgojo y que están territorialmente agrupadas.
3. Paso 3. Agrupar las subcuencas por zonas.
4. Paso 4. Aplicar el índice Conservation Forest Targeting Tool (CFTT) en las subcuencas del área de influencia del programa (ver anexo 1 describiendo la metodología).
5. Paso 5. Seleccionar las subzonas que presentan un valor más alto del índice y analizar cuanta es el área en estas sub-zonas afectada por gorgojo que cuentan con el uso forestal definido hasta cubrir la meta de 34,000 Ha a restaurar del programa.

**Paso 1. Identificar las sub-cuencas de Honduras más importantes para la producción de agua superficial.**

Se combinaron tres criterios:

Criterio 1. Subcuencas donde se proyecta un balance hídrico negativo. Por medio de este criterio se seleccionaron las sub-cuencas que presentan un balance de cero o negativo en los meses de estiaje para el escenario a 2025, porque se trata de las subcuencas donde el servicio ecosistémico de regulación hídrica que proveen los bosques tiene mayor valor. Para esto se usaron los valores del Balance Hídrico para 2025 (Balairon et al, 2003)[1]. Este estudio analiza el balance hídrico para 2025 para cada una de las subcuencas como la diferencia entre las demandas consuntivas a nivel de la subcuenca (urbana, agraria, industrial, acuícola, usos recreativos) y no consuntivas (principalmente energética) y la disponibilidad potencial del recurso hídrico.

Además de este criterio se consideraron dos criterios más:

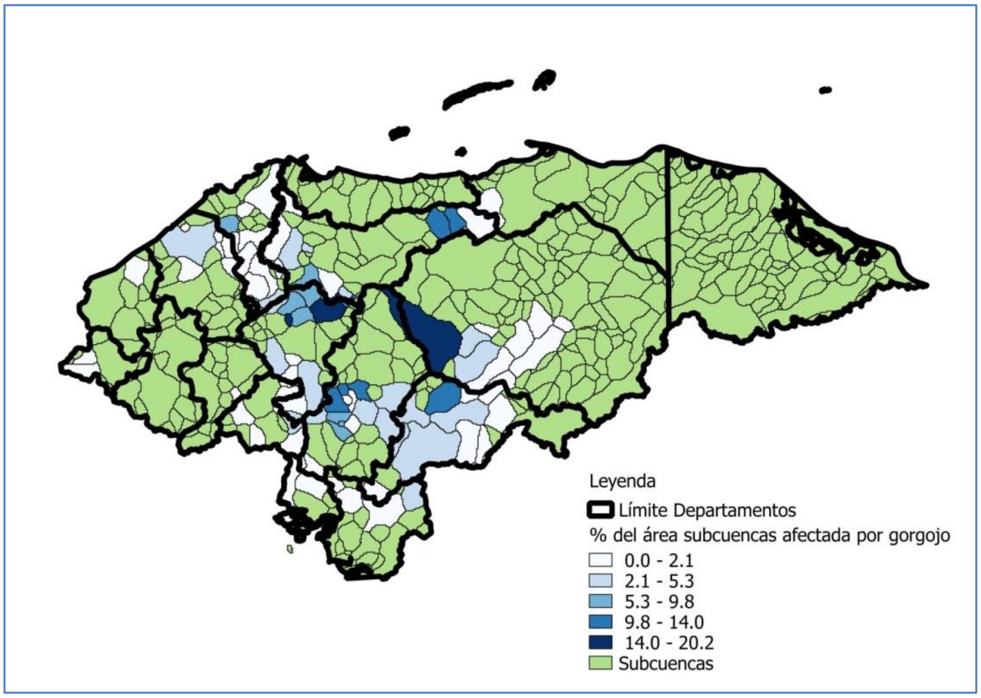
Criterios 2. Subcuencas que se proyectan para el suministro de agua futuro para la capital de Honduras. Actualmente la ciudad de Tegucigalpa muestra un escenario crítico de suministro de agua pues en promedio un 32% de la población no recibe la dotación mínima que se considera limitante para el desarrollo (BID, 2016). En el corto plazo subcuencas adicionales deberán ser incluidas en el sistema de

[1] El balance hídrico se calculó como la diferencia entre la oferta y la demanda para todas las sub-cuencas en Honduras y mes para los dos escenarios, 2005 y 2025.

suministro de agua (BID, 2016). En base a este criterio se incluyeron tres sub-cuenca más (Guacerique, Río Grande y Río del Hombre) como algunas de los más importantes para las aguas superficiales.

Criterio 3. Subcuencas que rodean la presa del Cajón. La represa hidroeléctrica Francisco Morazán (El Cajón) proporciona aproximadamente un 25% de la energía eléctrica total que consume Honduras y es la mayor fuente de energía renovable. Las subcuencas alrededor del área protegida de las presas se incluyeron como parte de la subcuencas más importantes para las aguas superficiales a nivel nacional.

**MAPA N°1. SUBCUENCAS CON BALANCE HIDRICO MENSUAL NEGATIVO Y AFECTACION POR GORGOJO.**



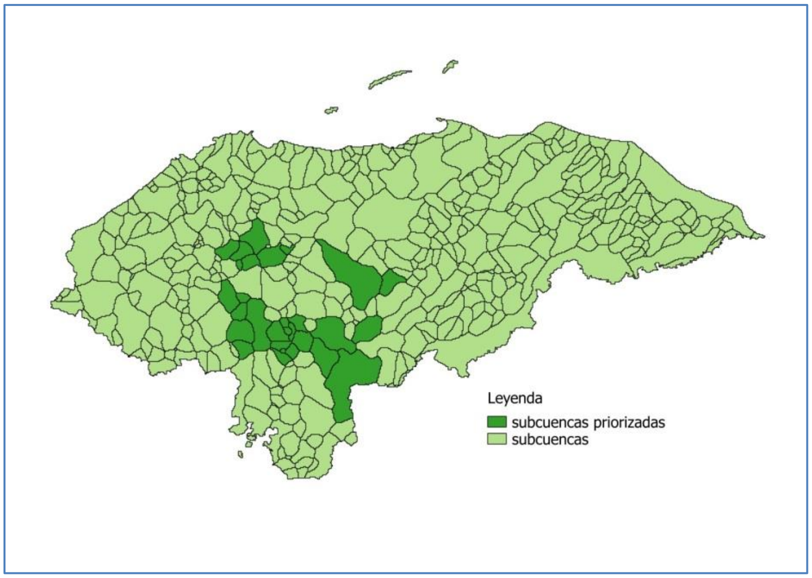

*Fuente: análisis propio a partir de datos de subcuencas del balance hídrico nacional (Balairon et al, 2003) y mapas del ICF (2016) de afectación de la plaga.*

En el mapa 1 se muestran las 74 subcuencas seleccionadas aplicando los criterios 1, 2 y 3 y el % de afectación por gorgojo.

**Paso 2. Dentro de las subcuencas identificadas en (1) seleccionar las que presentan mayor afectación por gorgojo y que están territorialmente agrupadas.**

En función de la afectación del gorgojo (seleccionado las que tienen mayores % de afectación) y considerando subcuencas que estén agrupadas territorialmente (seleccionando cluster de subcuencas) de estas 74 subcuencas se seleccionaron 29. Está quedó definida como la zona de influencia del programa (ver mapa 2).

## MAPA N°2. ÁREA DE INFLUENCIA DEL PROGRAMA.

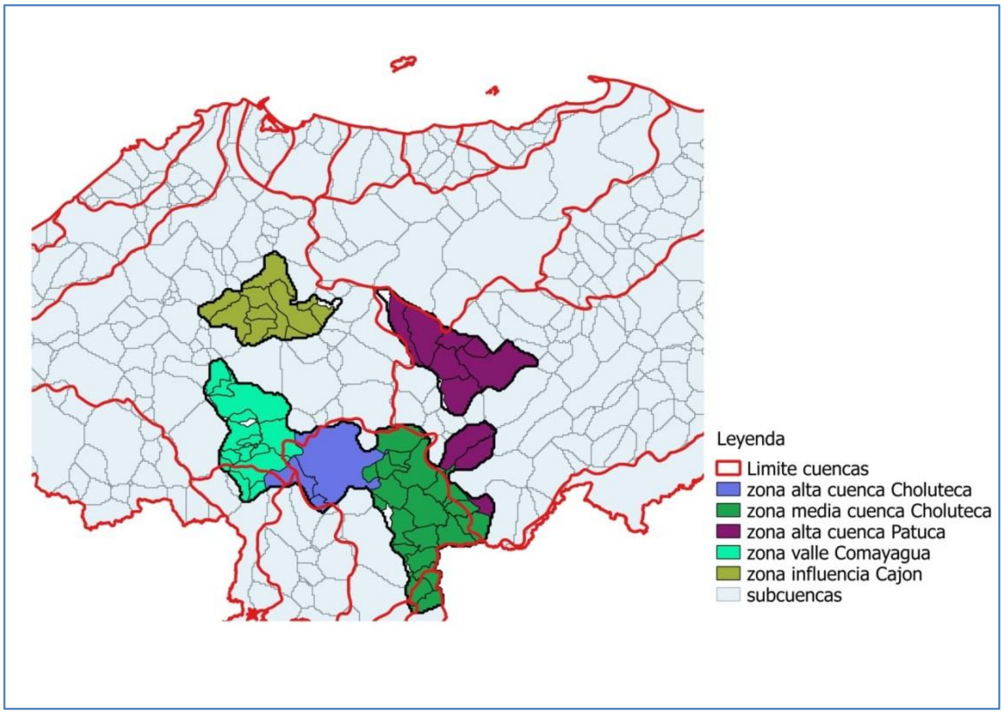



**Paso 3. Agrupar las subcuencas por zonas**

Considerando las zonas que abastecen, las 29 subcuencas del área de influencia del programa se pueden agrupar en 4 sub-zonas (mapa 3):

(i) La sub-zona de la cuenca alta del rio Choluteca que incluye las subcuencas que abastecen a la ciudad de Tegucigalpa,
(ii) La sub-zona de la cuenca media del rio Choluteca.
(iii) La sub-zona del valle de Comayagua, que abastece uno de los valles más fértiles de Honduras.
(iv) La sub-zona en torno a la represa del Cajón, que incluye las subcuencas que rodean la represa.
(v) La sub-zona parte alta de la cuenca del rio Patuca.

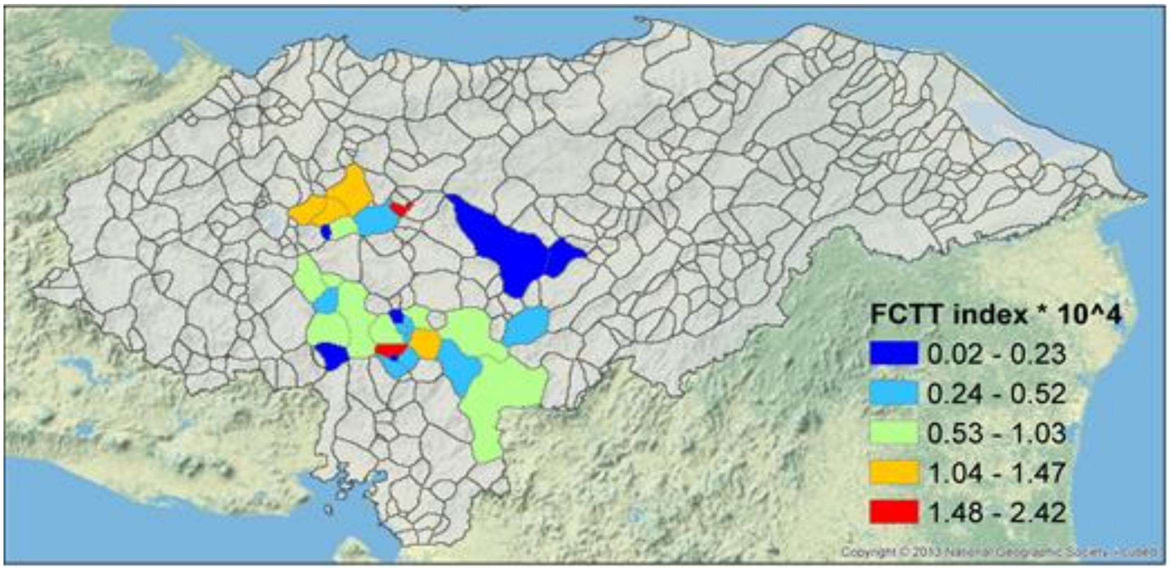
**MAPA N°3 IDENTIFICACION DE SUB-ZONAS EN EL ÁREA DE INFLUENCIA DEL PROGRAMA.**




**Paso 4. Aplicar el índice Conservation Forest Targeting Tool (CFTT) en las subcuencas del área de influencia del programa.**

En estas 29 subcuencas que constituyen el área de influencia del programa se aplicó índice conservation forest targeting tool (CFTT). Esta herramienta generó un índice de clasificación de las 29 subcuencas en función de la importancia del bosque para proveer servicios ecosistémicos. Los valores del índice se agruparon en 4 rangos (mapa 4): muy bajo (0.02-0.23), bajo (0.24-0.52), medio (0.53-1.03), alto (1.04-1.47) y muy alto (1.48-2.42).

**MAPA N°4 RESULTADOS CFTT EN EL ÁREA DE INFLUENCIA DEL PROGRAMA.**




**Paso 5. Seleccionar las subzonas que presentan un valor más alto del índice y analizar cuanta es el área en estas sub-zonas afectada por gorgojo que cuentan con el uso forestal definido hasta cubrir la meta de 34,000 Ha a restaurar del programa.**

Esta distinción en rangos del CFTT permite apreciar visualmente que los mayores valores del índice se encuentran en las subzona que rodea la presa del Cajón. A continuación las subzona de la parte alta de la cuenca del rio Choluteca, las subzona de la zona del valle de Comayagua y las subzona de la cuenca media del rio Choluteca (ambas con valores semejantes) y finalmente las subzona de la zona alta del rio Patuca.

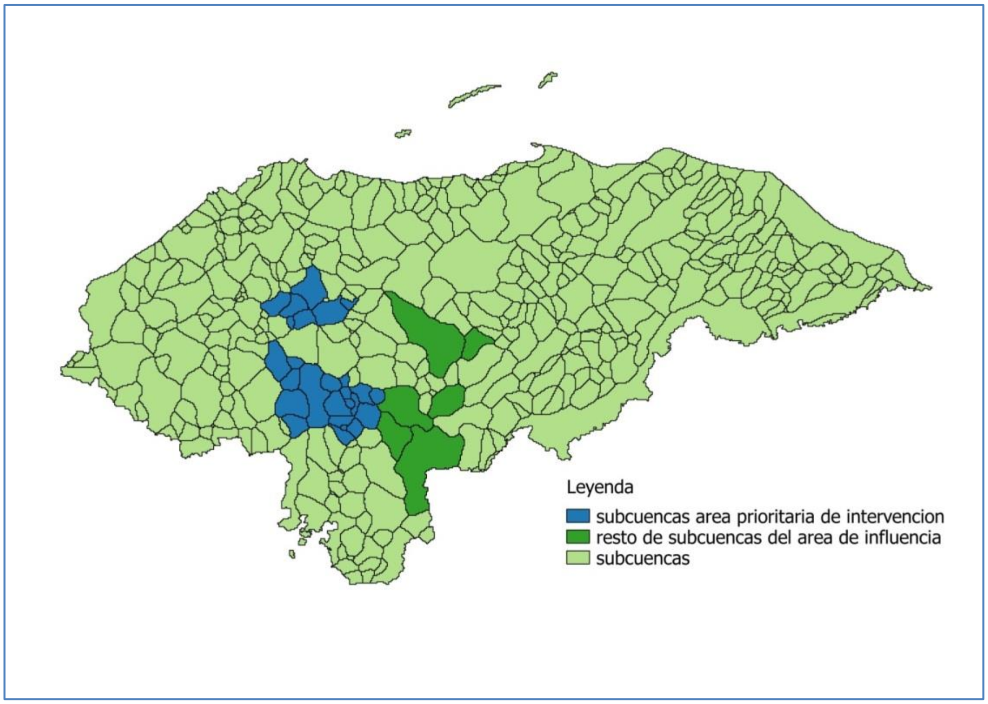
En base a esta información y de forma participativa con las contrapartes del Gobierno de Honduras, el Instituto de Conservación Forestal, la Secretaria de Finanzas y la Presidencia de la República, se decidió iniciar la intervención por las sub-zonas que presentan mayores valores del CFTT, tomando todas las sub-cuencas de cada sub-zona (no se hizo una priorización de subcuencas a nivel de cada sub-zona en base a los valores del CFTT).

Dado que el programa sólo intervendrá en zonas donde el uso forestal este definido (áreas protegidas, microcuencas abastecedoras de agua, bosques nacionales y ejidales concesionados a grupos forestales y bosques privados) se fueron sumando las áreas afectadas por gorgojo que se encuentran en las sub-zonas hasta completar aproximadamente las 34,000 Ha que es la meta del programa (ver mapa 5).

Esta quedó definida como el área prioritaria de intervención del programa, que es el área donde se iniciará la intervención del programa. Dado que la inscripción al programa es voluntaria en caso de que tras la promoción en esta área y la inscripción y validación de los beneficiarios/as no se lograra completar la meta de 34,000 Ha previstas para la restauración se continuará la promoción en el

siguiente subzona del área de la influencia definida en base al valor del índice de servicios ecosistémicos y evitando la dispersión territorial.

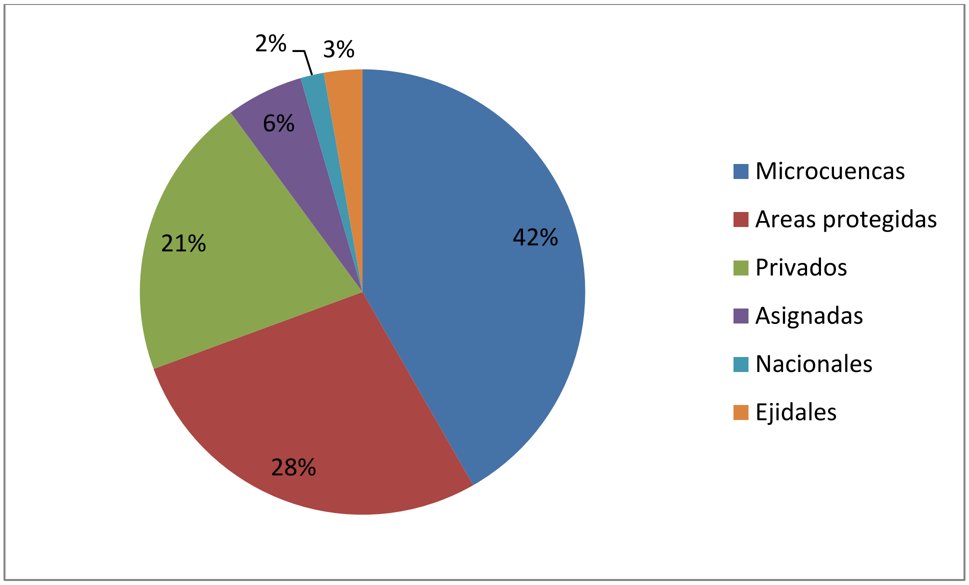
### MAPA N°5. ÁREA PRIORITARIA DE INTERVENCIÓN.



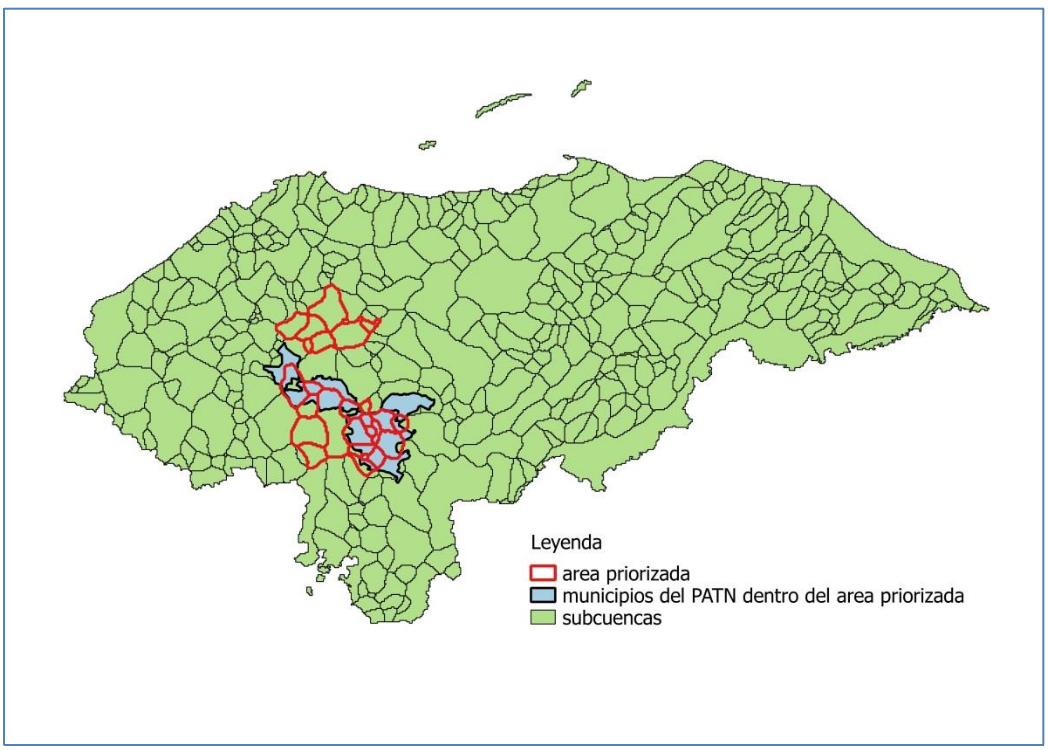

El área total afectada por el gorgojo en el área prioritaria de intervención es de 52,000 Ha, de las que 34,909 Ha cuentan con un uso del bosque definido. La distribución por uso sería la siguiente (análisis realizado a partir de datos del ICF, 2016):

### TABLA Y GRÁFICO N°1. AREAS FORESTALES POR TIPO DE USO EN EL AREA PRIORITARIA DE INTERVENCIÓN.

| | Ha | % |
|---|---|---|
| **Microcuencas** | 14562 | 42% |
| **Areas protegidas** | 9660 | 28% |
| **Privados con plan de manejo** | 7165 | 21% |
| **Asignadas** | 1957 | 6% |
| **Nacionales** | 591 | 2% |
| **Ejidales** | 974 | 3% |
| **TOTAL** | **34909** | |




## MAPA N°6. ÁREA PRIORITARIA DEL PROGRAMA Y MUNICIPIOS PATN




En el mapa se incluye el área prioritaria y la ubicación de municipios priorizados por la Plan de la Alianza para la Prosperidad del Triángulo Norte (PATN) que se encuentran dentro del área prioritaria.

**Anexo 1. Report on high-level (sub-watershed-level) spatial prioritization for project on "Prioritization of Areas of Program (HO-L1179) Intervention using the Forest Conservation Targeting Tool (ATN/OC-15620-HO).**

**Memo**

From: Allen Blackman

To: Gines Suarez

Re: Report on high-level (sub-watershed-level) spatial prioritization for project on "Prioritization of Areas of Program (HO-L1179) Intervention using the Forest Conservation Targeting Tool (ATN/OC-15620-HO)

Date: June 19, 2016

## 1. OBJECTIVE

The main objective of the project is to perform a quantitative spatial prioritization to select the locations in which Government of Honduras will promote forest conservation via various interventions including natural forest rehabilitation and agroforestry as part of the Forest Sustainable Management Project (the project). The prioritization will be conducted at two levels: high and low. The high-level prioritization will be at the sub-watershed-level as part of the project design phase. The low-level prioritization will be at the1km square cell-level and will be restricted to the sub-watersheds selected in the high-level prioritization, as part of the project implementation phase. This memo focuses on the high-level prioritization only.

## 2. METHODS

### A. The Forest Conservation Targeting Tool (FCTT) overview

To conduct the high-level spatial prioritization, a modified version of the Forest Conservation Targeting Tool (FCTT) was used. This tool was developed for the National Aeronautics and Space Administration (NASA) by Resources for the Future (RFF), a non-profit nonpartisan environmental economics research institute in Washington, DC (www.rff.org). The FCTT is a web-based decision tool that provides the data and analysis policy makers need to geographically target conservation investments so as to maximize their bang-for-the-buck, or more technically, the expected conservation benefit per dollar spent. To do that, the FCTT takes into account spatial data on deforestation risk, conservation costs, and three different types of forest ecosystem services: carbon storage, provision of biodiversity habitat, and provision of hydrological services. Unlike other computational spatial prioritization tools, all of the data

the FCTT uses are on-board. However, users are able to substitute their own data for the onboard data if they wish.

For this IADB project, the RFF project team modified the FCTT in two ways. The first concerns the spatial unit of analysis. The FCTT default choices for Honduras are administrative units and 1km square cells. For this project, the FCTT was modified to use sub-watersheds as a spatial unit of analysis. There are 464 sub-watersheds in Honduras. Second, as described below, the default data on the provision of hydrological services was replaced with newly generated data on change in annual runoff.

**B. FCTT structure**

The FCTT calculates the expected conservation benefit per dollar spent in a given sub-watershed as the risk of deforestation in the sub-watershed times the ratio of the total benefit of conservation in the sub-watershed to the cost of conservation there. That is,

$$EBC_p = R_p * \frac{B_p}{C_p} \qquad (1)$$

where

| | |
|---|---|
| *p* | indexes sub-watershed |
| *EBC* | is expected benefit per dollar |
| *R* | is deforestation risk |
| *B* | is total conservation benefit |
| *C* | is conservation cost. |

Total benefit, $B_p$, is the weighted sum of median-normalized indices of three separate types of ecosystem benefit that forests provide, which were listed above: carbon storage, provision of biodiversity habitat, and provision of hydrological services. More formally,

$$B_p = \sum_j w^j \frac{B_p^j}{B^j} \qquad (2)$$

where

| | |
|---|---|
| $j$ | = (c, b, h) indexes the type of ecological benefits: carbon storage (c), provision of biodiversity habitat (b), and provision of hydrological services (h) |
| $w^j$ | is a weight for benefit type |
| $B_p^j$ | is benefit type j in unit p |
| $B^j$ | is the median values of the benefit j across all sub-watersheds within an study area |

Note that the three weights sum to one. They reflect an inherently subjective judgment about the relative importance of the three benefit types. For example one policy maker might care only about carbon storage and not at all about biodiversity or hydrological benefits, in which case their weights would be ($w^c$ = 1, $w^b$ = 0, $w^h$ = 0 ). FCTT users themselves must determine the weights for each benefit type, and input that information into the webtool.

As discussed below, the three indices of ecological benefits are denominated in different units: carbon storage is measured in tons, provision of biodiversity habitat in numbers of species, and hydrological services in cubic meters squared. We normalize each index by its median value to make the magnitudes of the indices comparable.

Given these different units, measure of expected conservation benefit per dollar spent in a given sub-watershed, $EBC_p$, does not by itself provide meaningful information. Rather, $EBC_p$ for a given watershed is only meaningful when compared to those for other watersheds. In that case, it gives an indication of the ranking of expected conservation benefit per dollar spent across watersheds. In other words, $EBC_p$ is a 'ordinal' measure, not a 'cardinal' one.

Having calculated an index of expected benefit per dollar spent for each sub-watershed in a study area, the FCTT uses a simple 'knapsack' algorithm to select them. It ranks all sub-watersheds from highest expected benefit per dollar spent to the lowest. Then, starting at the top of the list it selects sub-watersheds until a user-defined conservation budget is exhausted. The default budget is arbitrarily set at 10% of the conservation costs of all spatial units in a user-defined study area.

**C. FCTT data**

This section briefly describes the data the FCTT used to estimate deforestation risk, conservation cost, and benefits. Table 1 summarizes the discussion.

Table 1. Data and methods used to parameterize FCTT

| Parameter | Key data/model | Description of key data/model | Methods |
|---|---|---|---|
| Deforestation risk | Hansen et al. (2013) | $30m^2$ annual data on land cover change 2001-2012 | Along other with geospatial data on land characteristics, used to econometrically estimate unit-level risk of deforestation on forested land |
| Carbon benefits | Deutsche Gesellschaft für Internationale (2014) | $30m^2$ above-ground and below-ground carbon stock in woody vegetation | Averaged over forest area of predio |
| Biodiversity benefits | IUCN (2013), Birdlife Int. (2012) | Species ranges for mammals, amphibians, reptiles and birds | Used to calculate a rarity weighted richness index for each unit: weighted count of threatened species where weights reflect rarity of each species globally. |
| Hydrological benefits | Mulligan (2013) | Integrated land-use/hydrological model | Used to generate measure of total annual runoff in each unit. |
| Conservation cost | Naidoo and Iwamura (2007) | 5 min grid (9 km2) data on potential annual gross revenue from agriculture. | Used to calculate unit-level gross revenue from agriculture. |

1. Deforestation risk (*R*)

For each sub-watershed, deforestation risk is econometrically estimated as the annual probability that existing forests in the sub-watershed will be cleared. The econometric model purports to capture the *past* relationship between deforestation and land characteristics that drive deforestation, including both: (i) time-invariant characteristics such as distance to population centers, soil quality, slope, altitude, opportunity cost of forest conservation and demography; and (ii) time-varying characteristics such as annual rainfall, average temperature, and population density. Estimated parameters from this econometric model are used to predict *future* clearing on forested land as a function of its characteristics. The most important data in the econometric model are those on deforestation: fine-scale ($30m^2$ resolution) 2000-2012 annual land-cover change data (Hansen et al. 2013).

3. Carbon benefits ($B^c$)

The carbon benefit of forest conservation is average per-hectare carbon content of above-ground and below-ground woody vegetation in each sub-watershed from a $30m^2$ data set developed for GIZ (2014). Units are tons per hectare.

4. Biodiversity benefits ($B^b$)

A rarity weighted richness index (RWRI) is used to measure the biodiversity benefit of forest conservation. An RWRI is a weighted count of all threatened species in a specific location, where the weight for each species is inversely related to the total area of its range in a larger geographic unit such as a country. Hence, a RWRI gives species with a larger share of their total range in a specific location more weight than species with a smaller share of their range in that location. The data used to calculate RWRI for each sub-watershed are digitized species ranges for mammals, reptiles, and amphibians compiled by the International Union for the Conservation of Nature (IUCN 2013) and digitized species ranges for birds compiled by Birdlife International (Birdlife International 2012). Threated species include those that are endangered, vulnerable, and critical.

5. Hydrological benefits ($B^h$)

Hydrological benefits are estimated using WaterWorld, an off-the-shelf integrated land-use/hydrological model (Mulligan 2013). The model is used to simulate the effects of deforestation on hydrological services at the 1-km level. Deforestation effects are directly related to the provision of forest hydrological services. That is, the analysis is based on the rationale that if the loss of forests in a watershed produces large changes in hydrological services, then those forests provide relatively high levels of hydrological services.

The default version of the FCTT uses two WaterWorld outputs—changes in water balance from a baseline scenario and changes water quality from a baseline—to generate a single index of hydrological services. Water balance is simply the difference between transpiration and precipitation and is measured in millimeters per year. It proxies for the change in ground water as well as the change in surface water since aquifer recharge depends critically on water balance. Water quality is measured as the mean percentage of water polluted when forest is cleared for agriculture or ranching.

For this project, however, at the request of IADB, a third WaterWorld output—change in runoff (m3/yr), calculated as water balance cumulated downstream—is used to capture the provision of forest hydrological services. To generate estimates of the effect of deforestation on change in runoff, the RFF team ran new WaterWorld simulations. At the suggestion of IADB, they assumed a 5% deforestation rate. In addition, they assumed forests were converted to the dominant rural cleared-land use in the watershed (pasture or agriculture) as defined by a land use map provided by IADB (Jimenez 2014).

6. Opportunity cost (C)

As a proxy for conservation costs, the FCTT uses average per-hectare opportunity cost due to forgone agricultural revenues in each sub-watershed. These estimates are derived from Naidoo and Iwamura's (2007) 5 min grid (9 km2) data set.

**D. Weights**

At the suggestion of IADB, the following weights for the three forest ecosystem services were used: 15% carbon storage , 15% provision of biodiversity habitat, and 70% provision of hydrological services.

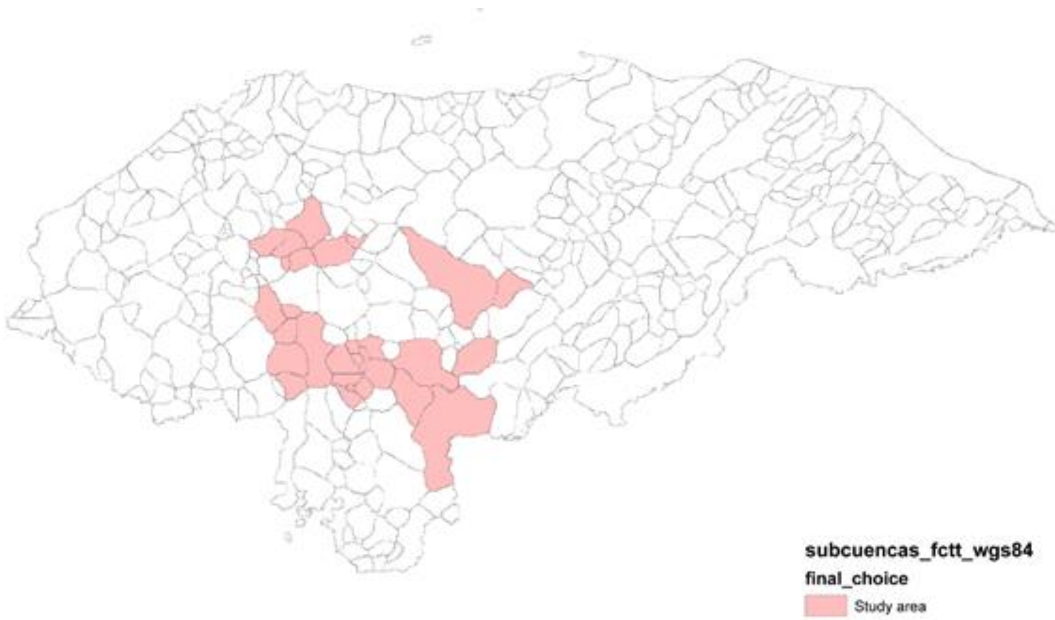
**E. Budget and total target area**

As noted above, the FCTT identifies sub-watersheds that generate the greatest expected return on conservation investment per dollar spent by first ranking sub-watersheds from highest to lowest expected return, and then selecting the highest ranked sub-watersheds until a user-defined budget is exhausted. The default budget is arbitrarily set at 10% of the total opportunity cost of all spatial units in a user-defined study area. The combined area of the spatial units the FCTT selects varies and depends on their size. However, for this project, IADB determined that the goal of the high-level spatial prioritization would be to identify sub-watersheds with a combined area of roughly 300,000 hectare of forest. Therefore, we adjusted the budget used by the FCTT until the model selected sub-watersheds with a combined total area of roughly 300,000 hectares.

**F. Study area**

We defined the study area for the spatial prioritization as follows. The FCTT identifies sub-watersheds generating the greatest expected return on conservation per dollar spent from among a subset of the country's 464 sub-watersheds meeting the following three criteria: (a) active or inactive pine beetle infestation; (b) exhibit water deficits, and (c) are more or less contiguous. Spatial data (shape files) provided by IADB was used to enforce the first two criteria. (The pine beetle data was contained in shape files named "shape plagas" and the water deficit data in shape files named "masc3."). IADB enforced the third criteria based on visual inspection. This resulted in a constrained study area comprising 29 sub-watersheds (Figure 1).

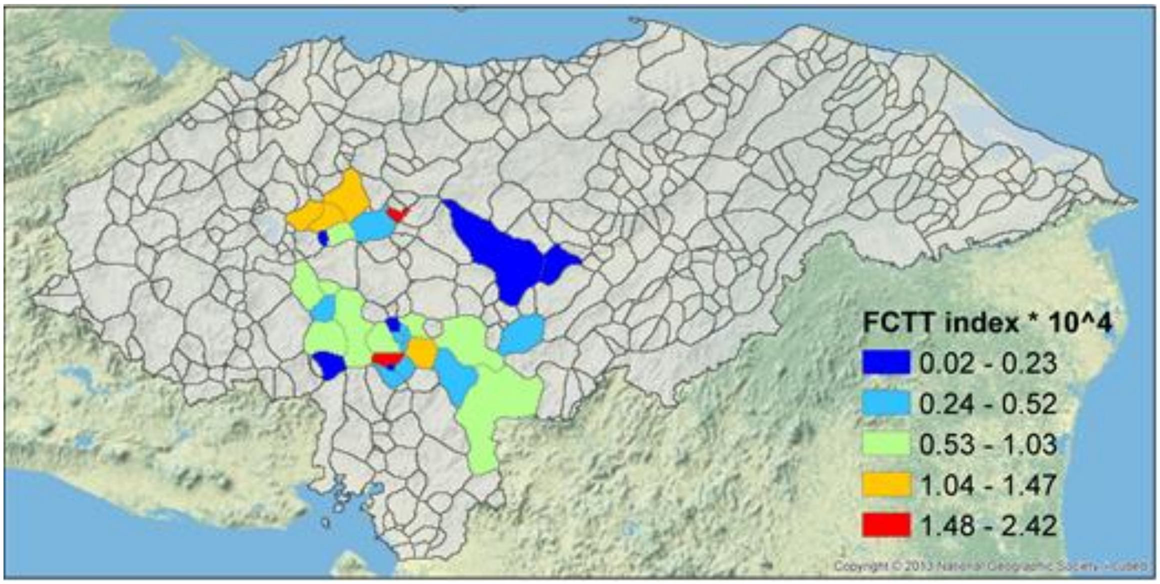
Figure 1. 29 sub-watershed that comprise constrained study area (criteria = active or inactive pine beetle infestation; water deficit, and contiguity)




**3. RESULTS**

Identifying information and other data on these sub-watersheds is included in "fctt_results_highlevel_constrined.REV1.xls." As noted above, the value of the index that the FCTT uses to select watersheds with the highest expected conservation benefit per dollar spent in a given sub-watershed, $EBC_p$, is not meaningful in itself. Rather, it is only meaningful when compared to indices for other watersheds. In that case, it gives an indication of the ranking of expected conservation benefit per dollar spent across watersheds. In Figure 2, highest ranking sub-watersheds are colored in beige and the lowest ranking ones are colored in blue.

Figure 2. Results of constrained high-level spatial prioritization;



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