

Heart of Borneo

Investing in Nature for a Green Economy

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Technical Background Material

Kalimantan InVEST and LCM Modeling

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For

WWF Heart of Borneo Global Initiative

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HoB Scenario Development and InVEST Modeling

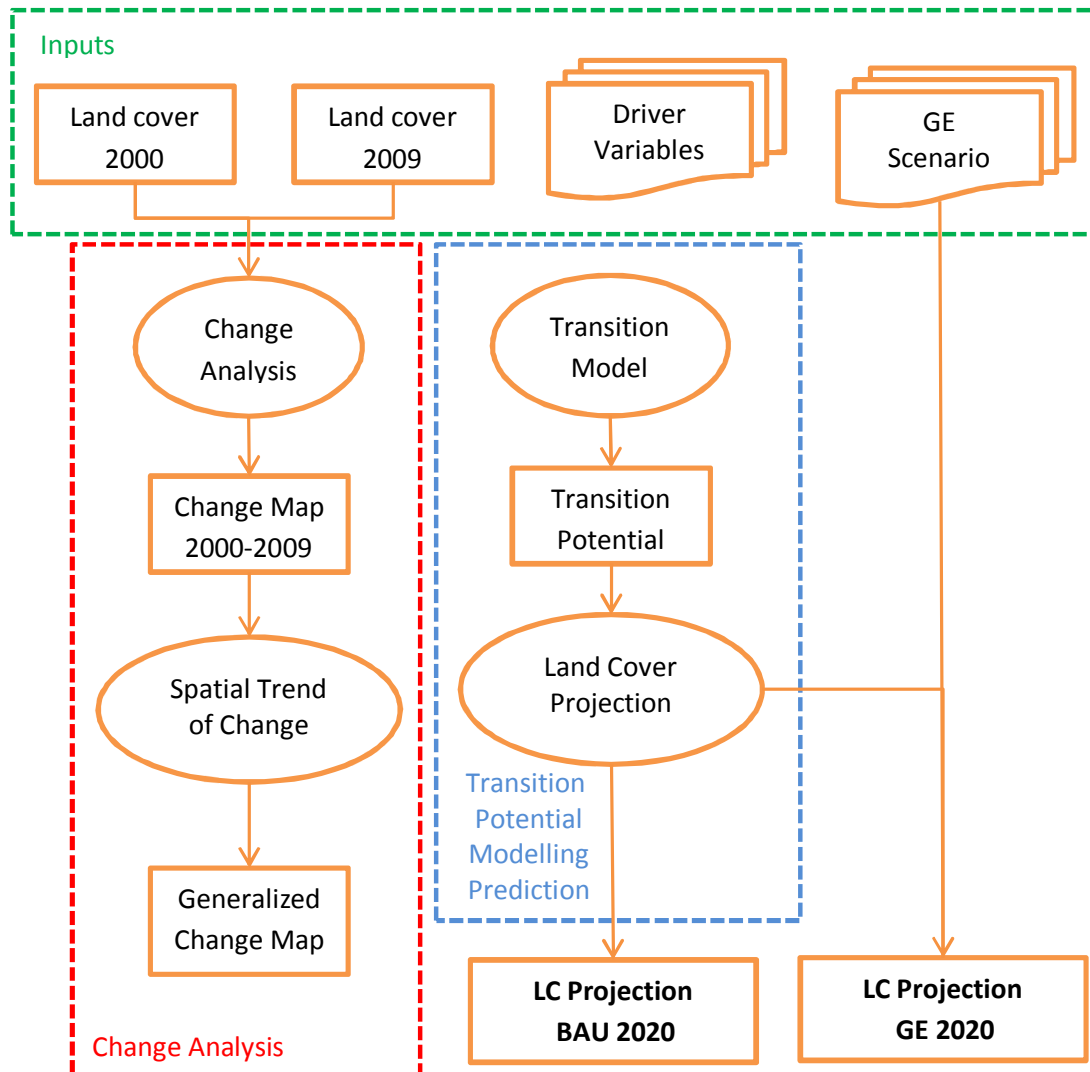
This document describes the application of IDRISI Land Change Modeler (LCM) and the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) models to support the development of *The Heart of Borneo: Investing in Nature for a Green Economy report*.

This document focuses on the sources of data, their analysis and processing – it is intended to allow technically-minded individuals to understand the approaches undertaken in the Heart of Borneo and to help them to further develop them in the Heart of Borneo, or elsewhere.

Readers are encouraged to review the InVEST User Guide and the wealth of material available through the Natural Capital Project Website (<http://www.naturalcapitalproject.org/>). Readers are also encouraged to review material on IDRISI LCM available from Clark Labs (<http://www.clarklabs.org/>).

Scenario development

The conceptual overview for the LCM Modeling is provided below for the land cover prediction for Green Economy (GE) and Business as Usual (BAU).



LCM and standard GIS analysis techniques were used to create ‘spatially-explicit scenarios’, which map and quantify land cover in the BAU and GE scenarios. The analysis was limited to Kalimantan because of data availability.

LCM allows prediction of future land cover based on historical, observed land cover change and other potential drivers of change. LCM provides tools to model land cover transition potentials that express the likelihood that land will transition in the future using, for the HoB analysis, logistic regression. LCM also allows maps of variables that might drive or explain change to be incorporated into the prediction model. LCM was used to develop the BAU and GE scenarios, based on land-cover change observed in Kalimantan between 2000 and 2009. Because of the complexity of land cover change, modeling was limited to predicting change in natural forest extent (i.e. forest classes primary forest and secondary forest were modeled). Biophysical factors and human drivers of land cover change were included in LCM modeling:

- Existing roads – dataset provided by WWF showing roads extract from Landsat Mosaics 2000
- Fire distribution – ATSR World Fire Atlas 1995 -2010, European Space Agency
- Elevation – SRTM v4
- Slope – derived from SRTM v4
- Settlements – specific class extracted from the land cover / land use dataset from the year 2009

After completing the LCM modeling of natural forest cover, the scenarios were finalized using standard GIS techniques. Firstly, the scenario forest cover extent dataset was merged with the 2009 non-forest land cover / land use classes. Then, the scenario land cover was further updated using the most reliable land use information available for mining, palm oil, and forestry development plans:

- Mining – the mining concession dataset was provided by WWF based on data from the Ministry of Energy and Mineral Resources. Under both scenarios, a mining concession located in primary forest results in the primary forest being changed to secondary forest. A mining concession located in secondary forest results in the secondary forest being changed to bush/shrub. It would be preferable to know more information about the plan for mine development – i.e. which locations within the concession will be mined and when. However, limited public information is available for the mining concessions. While simplistic, it is reasonable to assume that mining development, including exploration stages, will cause forest degradation and forest loss.
- Palm oil – the palm oil plantation concessions (issued permit areas) dataset was provided by WWF. Under the BAU scenario, the palm oil concessions are all implemented and the land cover (including natural forest) is changed to plantation. The exception is land settlement areas or mining concessions that are in the construction or production phase – it is unlikely that plantation will change these land uses. Under the GE scenario, plantation is also restricted in areas of natural forest.
- Forestry – active forest concessions mean that primary forest is converted to secondary forest. Inactive forest concessions resulted in secondary forest being converted to bush/shrub because a lack of active management puts them at high risk. Note, in several cases, forest concessions are not forest covered, and contain bush/shrub, agriculture, plantation or mining.

InVEST Input Data

The InVEST data cover the whole island of Borneo or are limited to Kalimantan, depending on the data sources. The InVEST freshwater models are run on a catchment basis, i.e. Mahakam, Kapuas, and Kapuas Barito. The inputs for different models are described in the sub-sections below.

Soils (Depth)

- Source: RePPPProt (1990. The Land Resources of Indonesia: a national overview. Government of the Republic of Indonesia: Ministry of Transmigration, Directorate General of Settlement Preparation, and BAKOSURTANAL. Land Resources Department NRI, Overseas Development Administration, Foreign and Commonwealth Office UK.)
- Input Filename: RePPPProt-soildepth.shp

- **Input Field: DEPTHMNR1**
- Known issues: there are some issues with the RePPPProt data because of the quality of digitizing
 - No category 11 to 25 cm in the RePPPProt data
 - Category no facet1 – depth unknown
 - Nodata values and how to handle in InVEST?
- Output: Grid 1km resolution
- Projection: converted to UTM 49s, WGS84 datum

Field: DEPTHMNR1	Reclass: Soil Depth (mm)	Comments
none, very shallow (0-10cm)	50	
moderately shallow (26-50cm)	380	
mod deep (51-75cm) moderate/deep	630	
deep (76-100cm)	880	
very deep (101-150cm)	1260	
extremely deep >150cm)	1500	
no facet1, 2 etc.	1260	
No Data	0	Small islands in rivers allocated value "0"

Soils (Plant Available Water Content Fraction)

The amount of soil water that can be extracted by the plant - it is defined as the difference in soil moisture content between the field capacity and the wilting point. It is expressed as millimetres of plant-available water within the root zone.

- WWF consultant provides a PAWC value for each RePPPProt land system **Symbol** – it is not clear how the PAWC values were created and they cannot be re-created.

SPAW Software (<http://hrsl.arsusda.gov/SPAW/index.htm>) was used to calculate a value of PAWC. According to the SPAW software documentation, PAWC fraction is the quantity of water (in/ft; cm/m) that a plant is able to extract from a soil at field capacity, calculated as

$$FC (\%v) - WP (\%v) \times \text{depth of soil}$$

Where

Field Capacity (FC): The water content, (%v), of the soil matrix approximating the water content of a saturated soil that has been allowed to freely drain. Estimated as a hydraulic tension of 33 kPa (.33 Bar) and dependant only on the soil texture and unaffected by salinity or gravel.

Wilting Point (WP): The water content, (%v), below which plants are generally unable to extract water from the soil. Estimated as a hydraulic tension of 1500 kPa (15 Bar) and dependant only on the soil texture and unaffected by salinity or gravel.

The SPAW documentation does not specify the units for soil depth, but it is centimeters.

The fraction of plant available water is therefore:

$$(FC - WP) / \text{depth of soil}$$

The table below cross references RePPProt soil texture values and texture classes in SPAW software and provides an example PAWC value for a soil depth of 100cm.

RePPProt Grade	SPAW Texture Class	WP	FC	PAWC Fraction (example 100 cm depth)
Coarse	Sand	5	9.4	0.05
Coarse	Loamy Sand	5.1	12.1	0.051
Medium	Silt	6.3	31.6	0.063
Moderately Coarse	Sandy Loam	8.1	17.9	0.081
Moderately Fine	Loam	12.6	26.7	0.126
Medium	Silty Loam	13.7	32.1	0.137
Moderately Fine	Sandy Clay Loam	18.3	28.3	0.183
Fine	Silty Clay Loam	21	37.9	0.21
Fine	Clay Loam	21.3	35	0.213
Moderately Coarse	Sandy Clay	26	37.1	0.26
Fine	Silty Clay	27.8	41.6	0.278
Fine	Clay	29.9	42	0.299

Average Annual Potential Evapo-transpiration

If no measured data on pan evaporation are available, the Blaney-Criddle method can be used to calculate ETo. The Blaney-Criddle Method (<http://www.fao.org/docrep/u3160e/u3160e04.htm>)

This method is straightforward and requires only data on **mean temperatures**.

The Blaney-Criddle formula is:

$$ETo = p(0.46T_{\text{mean}} + 8) \text{ where:}$$

ETo = reference crop evapotranspiration (mm/day)

T_{mean} = mean daily temperature (° C)

p = mean daily percentage of annual daytime hours.

The value of p selected for Borneo is 0.27 (<http://www.fao.org/docrep/u3160e/u3160e04.htm>).

Mean temperature was obtained from WorldClim (mean temperature, 2.5 arc-minutes) (<http://www.worldclim.org/current>).

Precipitation

Mean precipitation was obtained from WorldClim (mean precipitation, 2.5 arc-minutes) (<http://www.worldclim.org/current>). The monthly data were summed and converted to mm.

Landuse/Land cover

Ministry of Forestry data for 2000 and 2009 were provided by WWF. Data were converted to raster at a resolution of 1km. The European Space Agency (ESA) GlobCover data from 2005 and 2009 were also downloaded (<http://ionia1.esrin.esa.int/>). The Ministry of Forestry data, supported by the GlobCover data, were cleaned by Hatfield to improve the consistency between dates for land cover change modeling.

Elevation and Catchments

Initially, HydroShEDS and Hydro1k were investigated, but the quality of the data and the size and hierarchical structure of the catchments was not satisfactory:

- HydroSHEDS watersheds have holes / missing watersheds
- Hydro1k is relatively coarse, but has reasonable sub-watersheds for large basins
- Other InVEST modules require a hydrologically-correct DEM. Ideally, ability to create watersheds from hydrologically correct DEM.

STRM v4 data were used with the Watershed Delineation Tools toolbox to process the STRM data and product flow direction, flow accumulation, rivers:

1. STRM was mosaicked for the island of Borneo (tiles)
2. SRTM was degraded from 90 to 250m resolution
3. Watershed Delineation Tools were run with a flow accumulation threshold of 7500 cells for river starting points (~468 sq km).
4. Output is sink-filled DEM, catchments, rivers and derived elevation layers (flow direction and flow accumulation)

The catchments were converted from raster to shapefile. The watersheds for the Mahakam, Kapuas Barito and Barito catchments were selected and a Catchments dataset created by dissolving the sub-catchment boundaries for each catchment. The result is a hierarchical catchment dataset.

Some manual edits were made to remove very small sub-catchments since these can cause problems with InVEST. The hydrologically-correct STRM dataset was ultimately converted to 1km for use with InVEST since higher resolution data means that model runs take too long, or fail.

Erodibility (K)

Erodability data were generated from verified RePPPProt data by Junaedy Syamsudin (2008).

NO	RePPPProt_SYMBOL	SOIL_USDA	K_EROD
1	AKU	Tropudults, Dystropepts	0.3400
2	BKN	Tropaquepts,Fluvaquents, Tropofluvents	0.3400
3	BLI	Fluvaquents, Tropaquepts	0.3200
4	BPD	Dystropepts, Paleudults, Tropudults	0.3000
5	BRH	Trpopsamments, Tropohemists, Placaquod	0.2300
6	BRW	Tropudults, Dysropepts, Troporthods	0.2300
7	BTA	Tropudults	0.0800
8	BTK	Tropudults	0.2600
9	BWN	Tropudults	0.3400
10	GBJ	Rendolls, Eutropepts	0.1900
11	GBT	Tropohemist, Tropofibrist	0.2300
12	GDG	Tropudults, Dysropepts, Haplorthoxs	0.3100
13	HJA	Rendolls, Eutropepts	0.1100
14	JLH	Dystropepts, Tropudults	0.3400
15	KHY	Tropaquepts, Fluvaquents, Tropohemist	0.3400
16	KJP	Sulfaquents, Hydraquents	0.2300
17	KLG	Rendolls	0.3000
18	KLR	Tropaquepts,Fluvaquents	0.1900
19	KPR	Tropudults, TropudalFs, Eutropepts	0.2300
20	KRU	Tropudults, troporthods. dystropepts	0.2300
21	LHI	Tropudults, Dystropepts	0.1500
22	LNG	Tropudults, Dystropepts	0.1500
23	LPN	Tropudults	0.3400
24	LWW	Tropudults, Tropaquepts	0.3400
25	MDW	Troposaprists,Trpohemists,Tropaquents	0.1500
26	MGH	Tropaquepts, Tropaquents, Tropudults	0.3400
27	MPT	Tropudults, Dystropepts	0.3000
28	MTL	Tropudults, Dystropepts	0.3000
29	OKI	Rendolls, Eutropepts, Tropofolist	0.1500
30	PDH	Tropudults, Dystropepts	0.2300
31	PKU	Placaquods, Tropopsamments, Dystropept	0.2300
32	PLN	Dystropepts, Tropudults	0.2600
33	PMG	Fluvaquents, Tropaquepts	0.2300
34	PST	Tropohumods, Paleudults,Tropudults	0.1500
35	PTG	Pasmaquents, Tropaquents, Tropopsamme	0.2300
36	RGK	Tropudults, Dystropepts, Tropaquepts	0.2300
37	SBG	Tropaquepts,Fluvaquents, Tropofluvents	0.3400
38	SGT	Placaquods, tropopsamments	0.2300
39	SHD	Ustipsamments, tropofibrists, troposaprists	0.1200
40	SMD	Tropudults	0.2300
41	SMI	Dystropepts, tropudults	0.2600

42	SPG	Tropopsamments,tropaquepts	0.3400
43	SRM	Tropopsamments,tropaquepts	0.2300
44	SST	Tropudults, Dysropepts, Troporthods	0.3400
45	STB	Tropudults	0.3400
46	TBA	Tropudults, Tropohumults, Dystropepts	0.3400
47	TDR	Tropudults, Dysropepts, Troporthods	0.3400
48	TNJ	Tropaquepts,Fluvaquents	0.2600
49	TWB	Tropudults, Dystropepts	0.2600
50	TWH	Tropudults, Dystropepts	0.3400
51	TWI	Tropudults, Dystropepts	0.3400
52	NODA	Nodata, Waterbodies	0.0000

Erosivity (R)

Rainfall erosivity is a climatic factor, which can be determined from rainfall data. Rainfall erosivity is highly related to soil loss. Increased rain erosivity indicates greater erosive capacity of the overland water flow. The source of rainfall data is taken from: <http://www.worldclim.org/> and its calculated by following formula:

$$R = 2.21 * P^{1.36}$$

R: Erosivity index

P: Monthly Rainfall (cm)

Reference: Lenvain (1989) in Asdak 1995, Hidrologi dan Pengelolaan DAS, UGM Press.

InVEST Model Parameters

InVEST models require a set of parameter files, which were storied in Microsoft Access tables. The following .

- Nutrient_biophysical.mdb
- Nutrient_threshold.mdb
- Sediment_biophysical.mdb
- Sediment_threshold.mdb
- Water_yield.mdb

Other Datasets used for Mapping

Water Supply Companies (PDAM)

W+B obtained data on the location and characteristics of the water utility supply companies in Kalimantan. The file contained the coordinates of the supply intakes and Hatfield created a shapefile for use with water related InVEST maps.

HPH Concessions and Rating

A shapefile of HPH concessions for 2009 was provided by WWF (source from MoF). Hatfield cleaned the dataset to remove “sliver polygons”. Some specific attributes of interest for the HoB study were:

HPH activity status – the active or inactive status and area (ha) of forest management units (HPH).

HPH GFTN Rating – the performance status for the HPH according to the GFTN

The performance and activity status of HPH can be used to identify the area (ha) of forest at risk or potentially available for restoration.

Biomass

SARVISION above ground biomass data were analysed by WWF Germany – a SARVISION readme file and documentation is provided. SARVISION data are provided as biomass ranges, but the mid-point of the range can be used when an absolute quantitative value is required.

ArcGIS zonal statistics can be used to extract the MEAN (average) biomass, for example for each HPH forest concessions polygon. Other biomass attributes can be obtained from the zonal statistics, such as variance.

Natural Forest on APL/Development Land Status

There are two approaches to determine the natural forest that is at risk of conversion:

1. MoF 2009 data and APL land (limited to Kalimantan only)
2. GlobCover 2009 and APL land and “development land” for Malaysia and Brunei (using Forest Status HoB provided by WWF, and obviously limited to the HoB)

Note: GlobCover natural forest classes are:

- 40, Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (> 5m)
- 50, Closed (>40%) broadleaved deciduous forest (>5m)
- 60, Open (15-40%) broadleaved deciduous forest/woodland (>5m)
- 70, Closed (>40%) needleleaved evergreen forest (>5m)
- 90, Open (15-40%) needleleaved deciduous or evergreen forest (>5m)
- 100, Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)
- 110, Mosaic forest or shrubland (50-70%) / grassland (20-50%)
- 160, Closed to open broadleaved forest regularly flooded (fresh-brackish water)
- 170, Closed broadleaved forest permanently flooded (saline-brackish water)

InVEST Outputs

All outputs had a suffix **y0**, **y9**, **bu**, or **ge** to designate year 2000, year 2009, BAU, and Green Economy land cover was used.

InVEST provides a number of different formats for output files, for example the sediment retention model outputs:

- usle_mn (tons/ha): Mean potential soil loss per sub-watershed
- sret_mn (tons/ha): mean sediment retained per cell on each sub-watershed, including sediment retained that originates upstream as well as sediment that originates on the cell itself.
- sexp_mn (tons/ha): the mean sediment export per cell on each sub-watershed

Percentage change from 2009 was calculated according to the following formula:

$$100 * \frac{[\text{Scenario value}] - [\text{2009 value}]}{[\text{2009 value}]}$$