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IEEM Integrated Economic-Environmental Modeling

The IEEM + ESM Approach: An Application to the SDGs in Guatemala.

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THE IEEM PLATFORM AND ITS MOTIVATION

- Economy-wide computable general equilibrium (CGE) models are widely used for public policy and investment analysis.
- Kenneth J. Arrow, Nobel laureate in economics, affirmed, "…in all cases where the repercussions of proposed policies are widespread, there is no real alternative to CGE" (Arrow, 2005, p.13).
- Ministries of Finance/Central Banks/Planning Depts, IDB et al. undertake or purchase CGE analysis.
- Little consideration of natural capital and ecosystem services.

THE IEEM PLATFORM VALUE-ADDED

1. Integrates **SEEA (System of Environmental-Economic Accounting CF)** data in dynamic economy-wide framework.

2. Natural resource modules with policy relevant features.

3. Standard economic indicators (Min Fin), and; natural capital and wealth metrics.

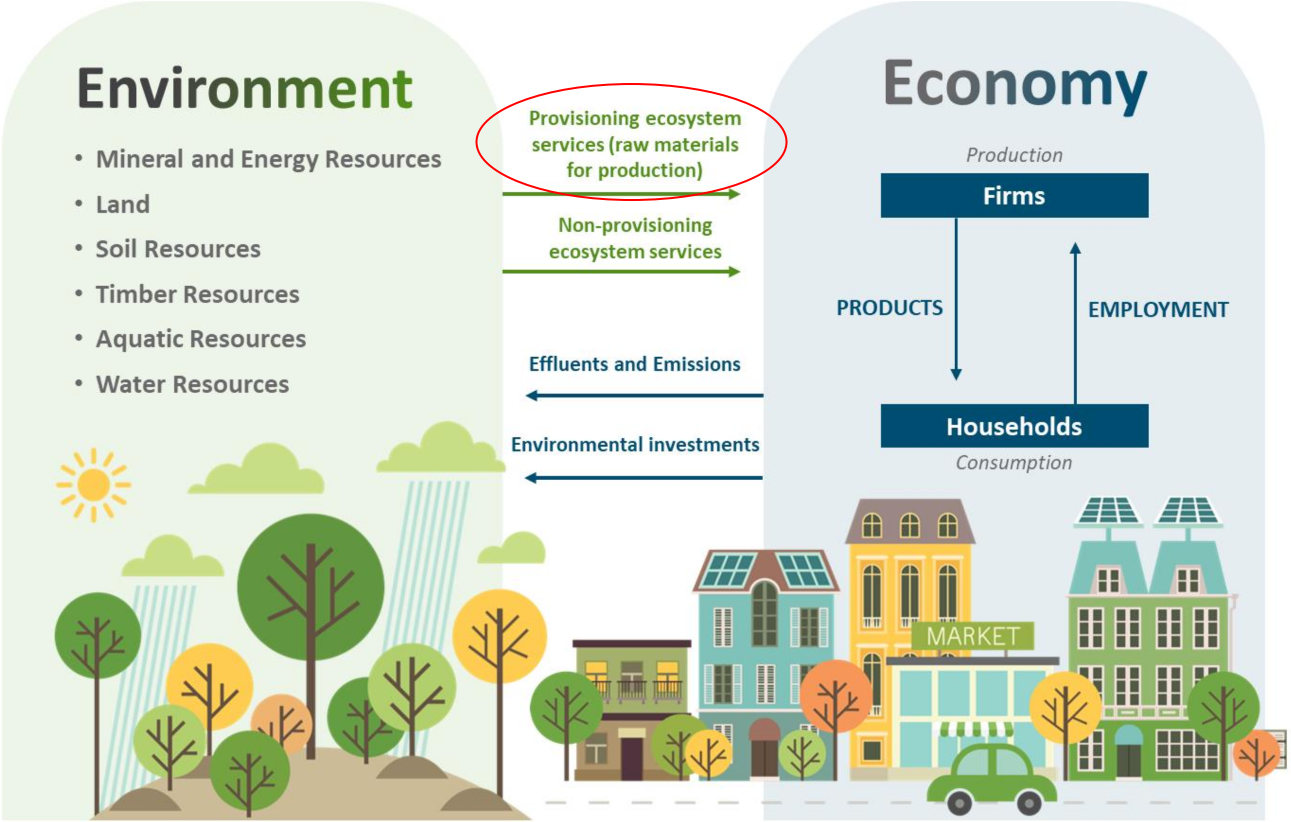
4. IEEM + ESM: spatial land use/ecosystem service impacts.

NATURAL CAPITAL

MANUFACTURED CAPITAL

HUMAN CAPITAL

ENVIRONMENT - ECONOMY INTERACTIONS



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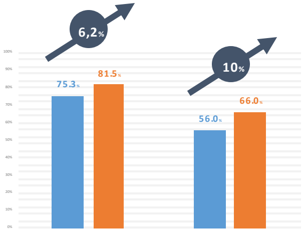
GUATEMALA APPLICATION TO SDG 2: ZERO HUNGER AND SDG 6: WATER AND SANITATION

Increase of irrigated area:
112,798 ha.

Investment:
US$6.045 million



Increase water and sanitation coverage by 6.2% and 10% to **81.5% and 66%, respectively**

Investment:
US$1.607 billion

Time horizon:
5 years

SDG

SDG 2, Target 2.3

Time horizon:
13 years

SDG

SDG 6, Target 6.1 and 6.2

SDG 15: LIFE ON LAND

Increase in forest management and conservation:
81,200 ha.

Investment:
US$8.35 million

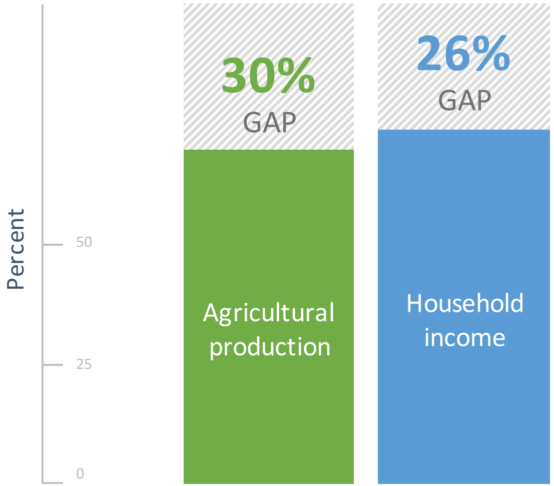
Time horizon:
6 years

SDG

SDG 15, Target 15.2

ECONOMIC IMPACTS

SDG 2



Difference from base in 2035 in millions of USD.

	SDG 2 AND 6	SDG 15
GDP	261	71
Private consumption	212	61
Private fixed investment	39	1
Exports	99	217
Imports	90	208

ENVIRONMENTAL IMPACTS

SDG 15 increased total greenhouse gas emissions by **121,584 tons of CO_2** while SDGs 2 and 6 reduced emissions by **368 tons of CO_2** by 2035.

SDG 15 reduced water consumption per capita in agriculture by **1,971 m^3** while SDGs 2 and 6 increased consumption by **5,164 m^3** by 2035.

SDG 15 reduced deforestation by **35,391 ha** by 2035.

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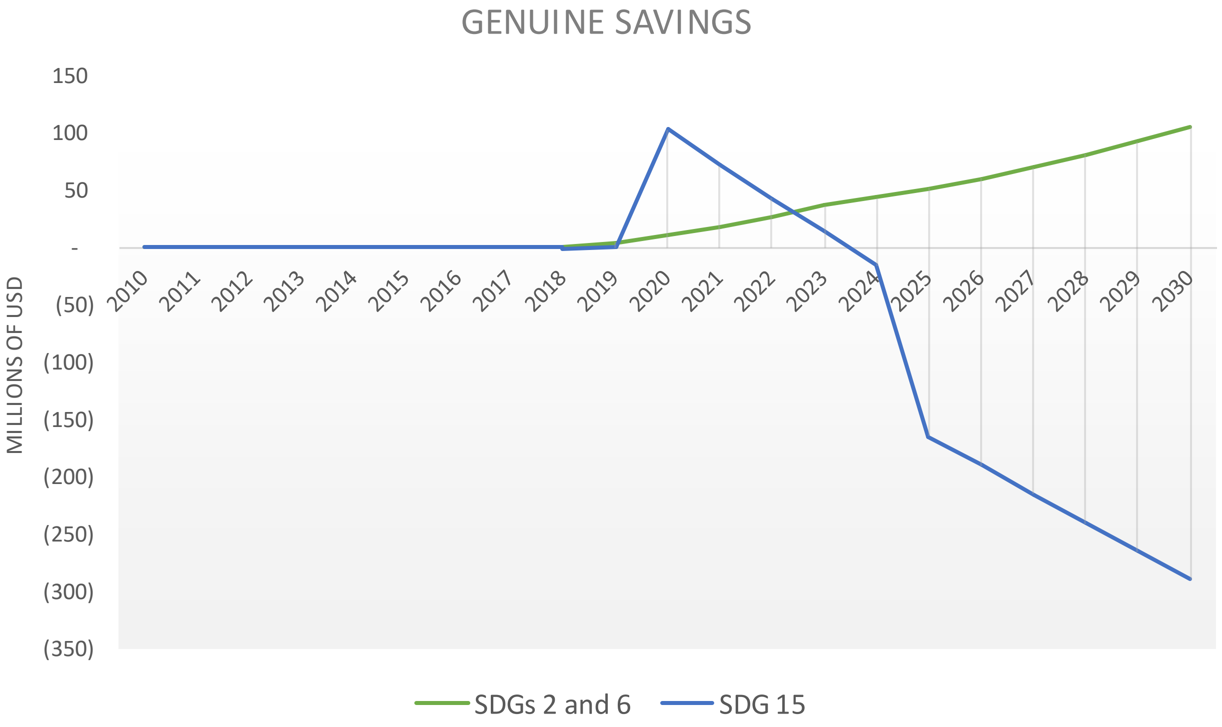
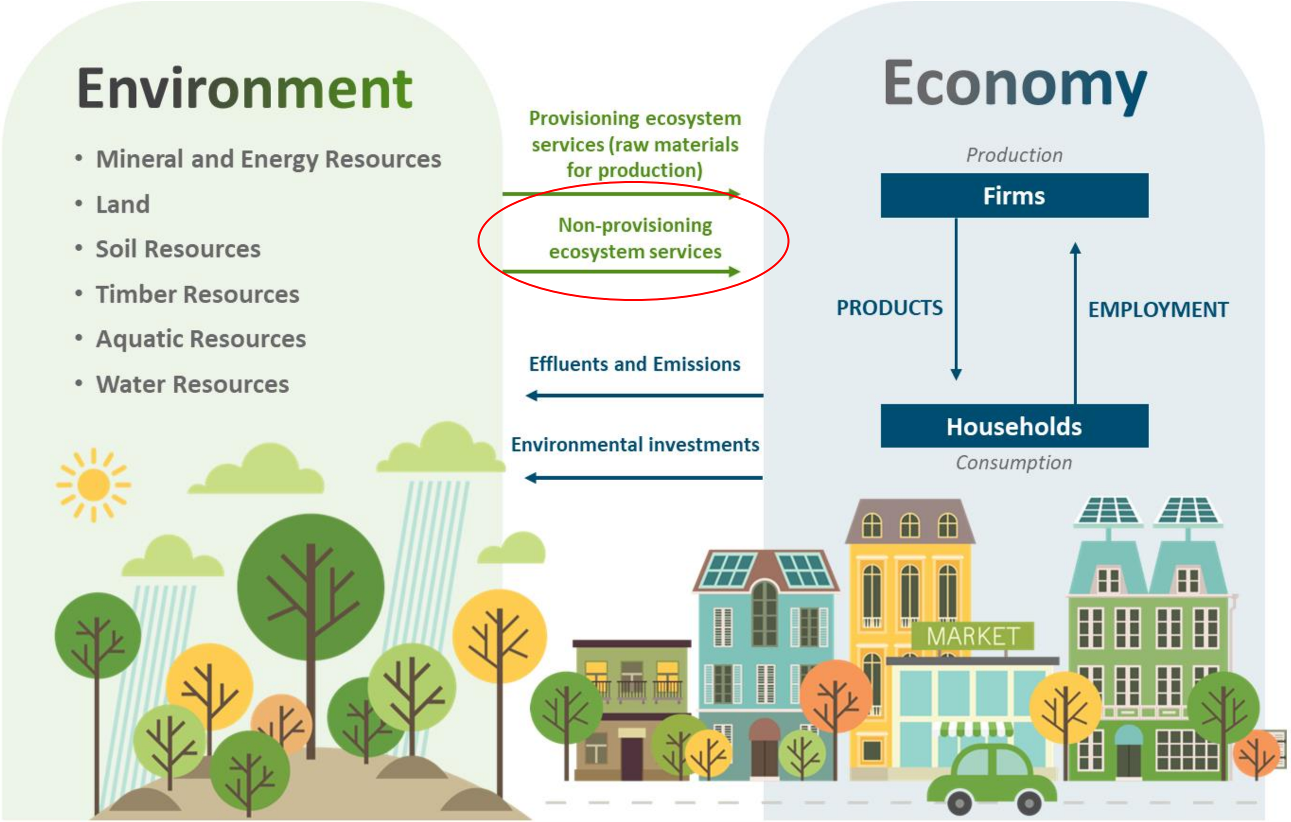
WHY GREEN INDICATORS ARE NOT ENOUGH

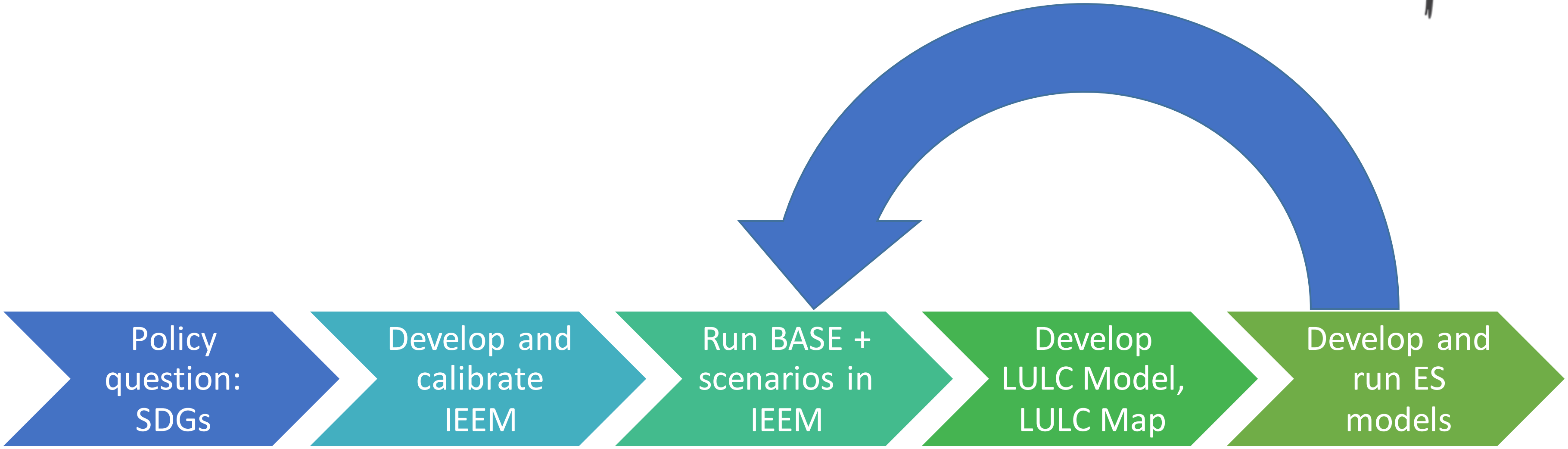


IEEM + ESM
Proof of concept

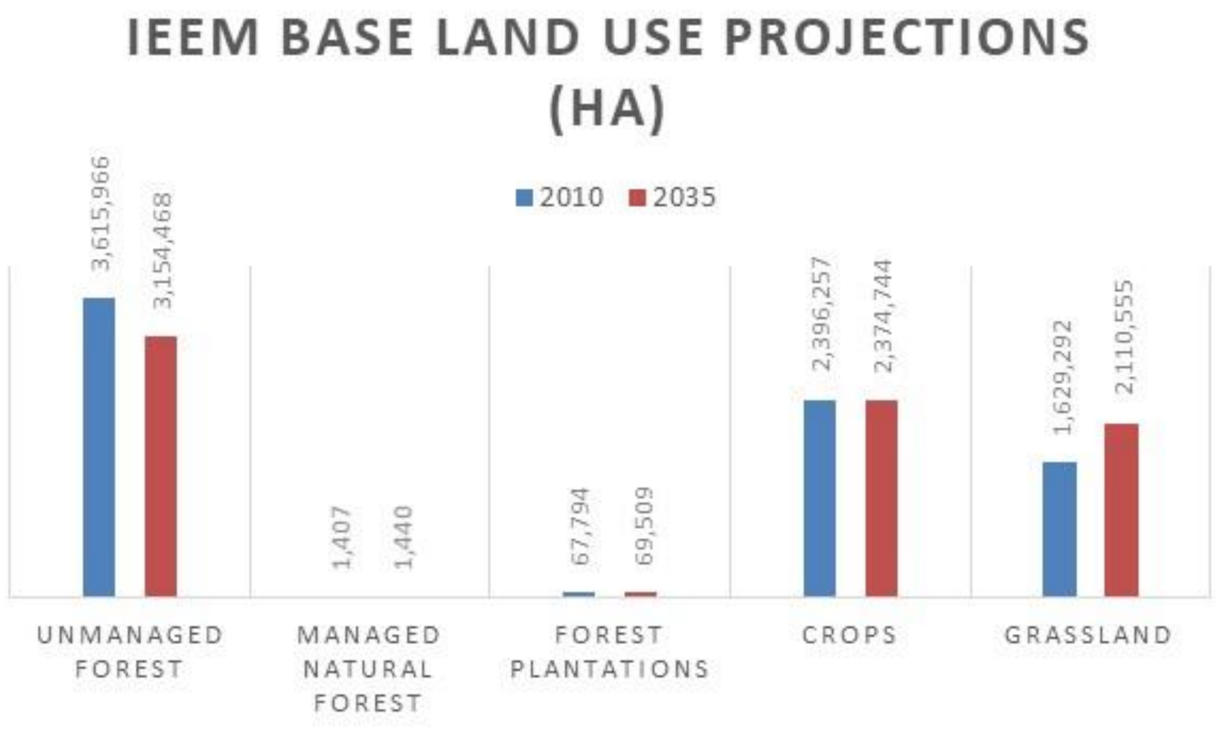
ENVIRONMENT - ECONOMY INTERACTIONS



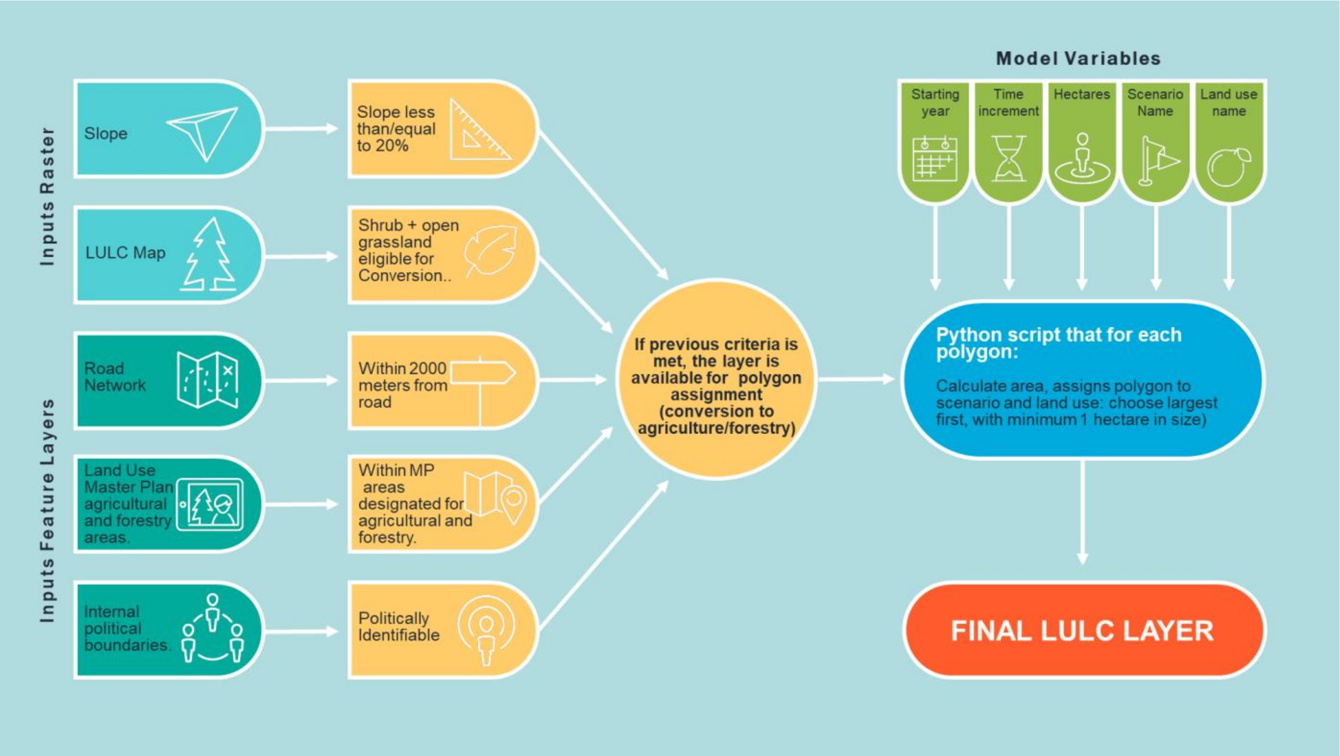
IEEM + ESM WORKFLOW



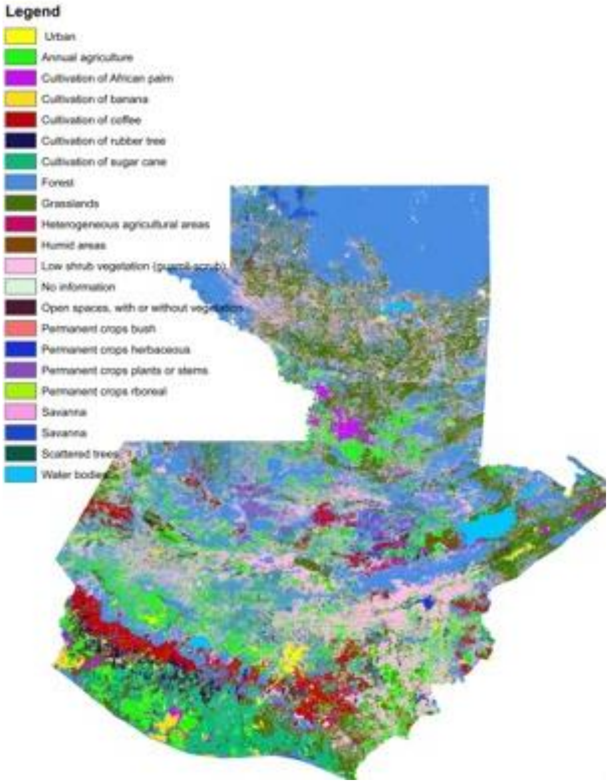
STEP 1: RUN IEEM TO GENERATE BASELINE PROJECTION

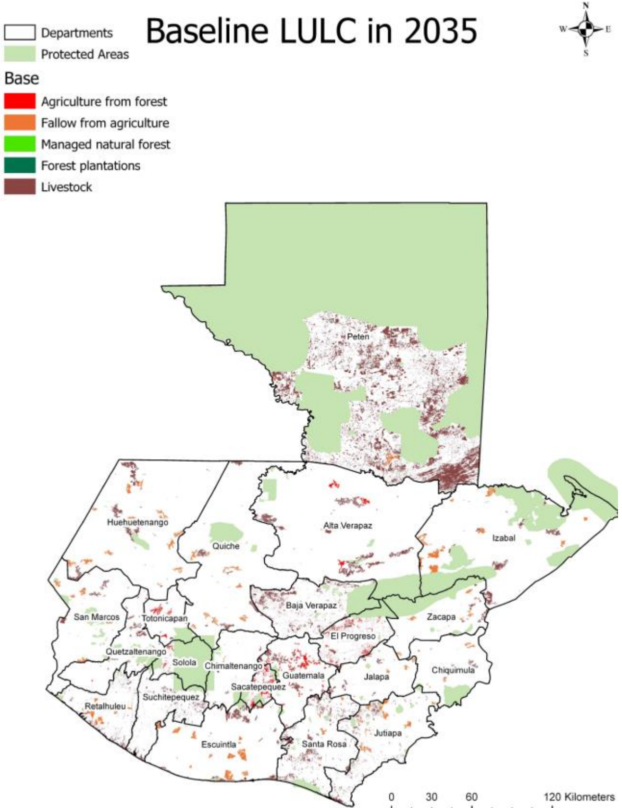


STEP 2: DEVELOP LULC CHANGE MODEL



STEP 3: MAP LULC CHANGE PROJECTIONS BASE AND SCENARIOS





STEP 4: PARAMETERIZE AND RUN ES MODELS

InVEST Sediment Delivery Ratio Model

$USLE_i = R_i \cdot K_i \cdot LS_i \cdot C_i \cdot P_i$

Where:

- R_i is rainfall erosivity (units: $MJ \cdot mm(ha \cdot hr)^{-1}$)$MJ \cdot mm(ha \cdot hr)^{-1)}$,
- K_i is soil erodibility (units: $ton \cdot ha \cdot hr(MJ \cdot ha \cdot mm)^{-1}ton \cdot ha \cdot hr(MJ \cdot ha \cdot mm)^{-1}$),
- LS_i is a slope length-gradient factor (unitless)
- C_i is a crop-management factor (unitless), and;
- P_i is a support practice factor.

Source: Sharp et al., 2016.

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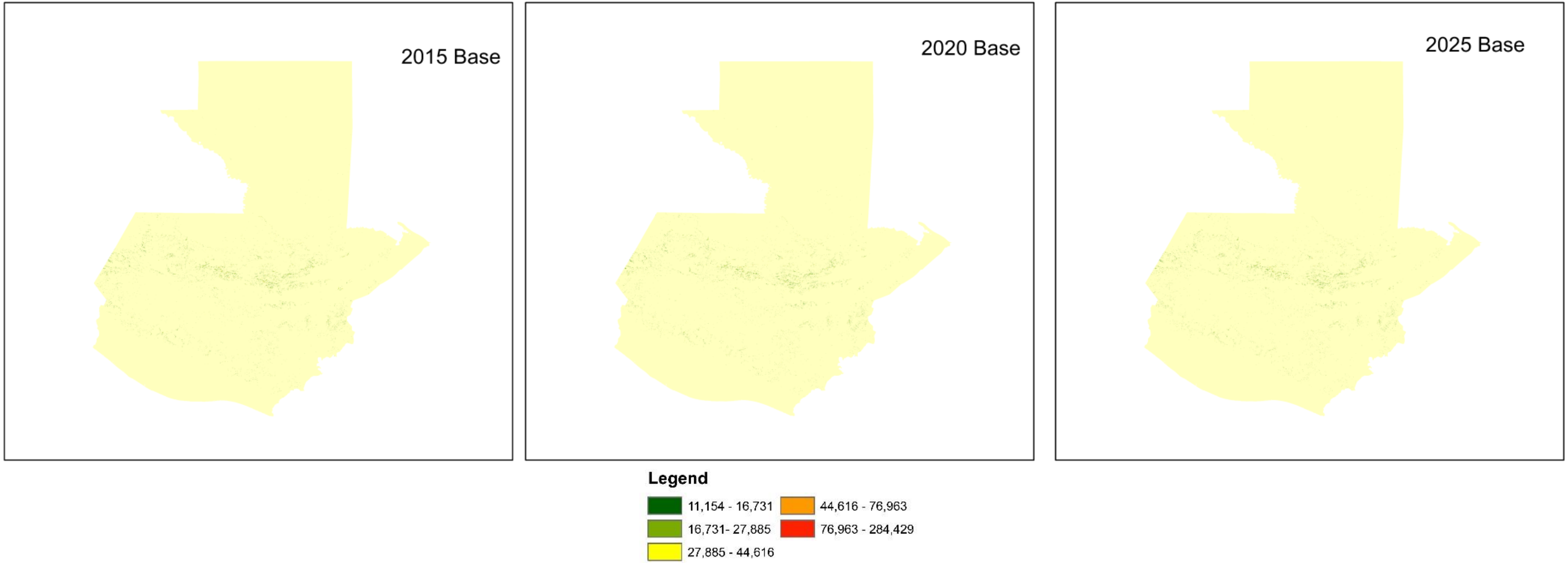
STEP 5: GENERATE ESM RESULTS, SCENARIO MINUS BASE

Severe Erosion: USLE > 11 tons/ha/yr.



STEP 6: RELATE ES CHANGE TO IEEM VARIABLES

- Considering erosion mitigation ES, one potential impact pathway of changes in ES supply is through agricultural productivity (there are others!).

- Quantitatively describe pathway: 8% productivity loss for severe erosion (Panagos et al., 2018).

$$LPL_d = \frac{SER_d}{TAA_d} \cdot 0.04$$

Where:

- LPL_d is the land productivity loss by subscript *d* Department;
- SER_d is the agricultural land area (hectares) subject to severe erosion of >11t/ha/year in each Department, and;
- TAA_d is the total agricultural area, both crop and livestock, by Department.

TABLE 2 Literature review of studies estimating the agricultural productivity loss due to soil erosion by water

Reference	Estimation of crop yield loss due to soil erosion	Comments on estimation method
Lyles (1975)	Productivity loss ~6% per 2.5 cm of soil loss	Experiments in the United States
Pierce, Larson, Dowdy, and Graham (1983)	2–4% productivity loss in case of severe erosion (>25 t ha^{-1} year^{-1})	U.S. croplands; NRI survey
Battiston, Miller, and Shelton (1987)	8% productivity loss due to soil erosion	Corn yield experiments in Ontario
Magrath and Arens (1989)	0–12% annual productivity loss in case of severe erosion	Analysis of three comparable studies in Java, Indonesia
Schumacher, Lindstrom, Mokma, and Nelson (1994)	8% yield reduction in cornfields with severe erosion	North Central United States experiments
Pimentel et al. (1995)	Severe soil erosion by water (rates of higher than 17 t ha^{-1} year^{-1}) can cause a crop productivity loss of 8% annually.	Review article
Crosson (1995)	Productivity loss to only 0.4% per year (8% productivity loss after 20 years).	Review study based on Pimentel et al. (1995) article
Lal (1995)	Yield reductions due to severe erosion may range from 2% to 40%, with a mean of 8.2% for the continent.	A review of available data in African plots
Oyedele and Aina (1998)	Maize yield reduction of 10–17% on severely eroded	Plot experiments in Africa
Van den Born, de Haan, Pearce, and Howarth (2000)	9% productivity loss for maize and other grains under high erosion risk	European Union 15 countries based on ICONA 1991
De La Rosa, Moreno, Mayol, and Bonsón (2000)	12% reduction on crop productivity will be reached in 2100 with erosion rates of 16 t ha^{-1} year^{-1}.	Based on results in Andalusia region (Spain)
Bakker, Govers, and Rounsevell (2004)	2.7% yield decrease per decade according to findings in de-surfacing experiments; yield reductions due to soil erosion are around 4.3% per 10 cm of soil lost.	Based on data analysis (field data collection) in Europe
den Biggelaar, Lal, Wiebe, and Breneman (2001)	Crop productivity based on past plot studies for different crops in all continents, showing negligible effects for erosion rates <2 t ha^{-1} year^{-1}.	Analysis of soil erosion–productivity experiments
Bakker, Govers, Jones, and Rounsevell (2007)	4.9% yield loss in case of 10 cm soil erosion	Based on available water capacity analysis
Montgomery (2007)	Soil loss rates less than 12 t ha^{-1} year^{-1} as tolerable for maintain the crop productivity	Based on the U.S. Department of Agriculture values
Larney, Janzen, Olson, and Olson (2009)	Grain yields may fall by 2.1% annually per cm of soil removal	Experiments in Alberta, Canada

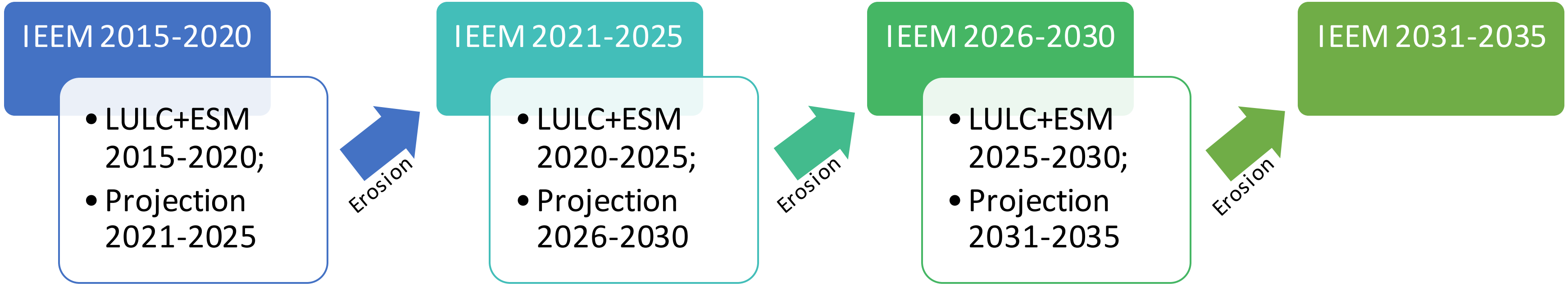
Note. NRI = National Resources Inventory.

Source: Panagos et al., 2018.

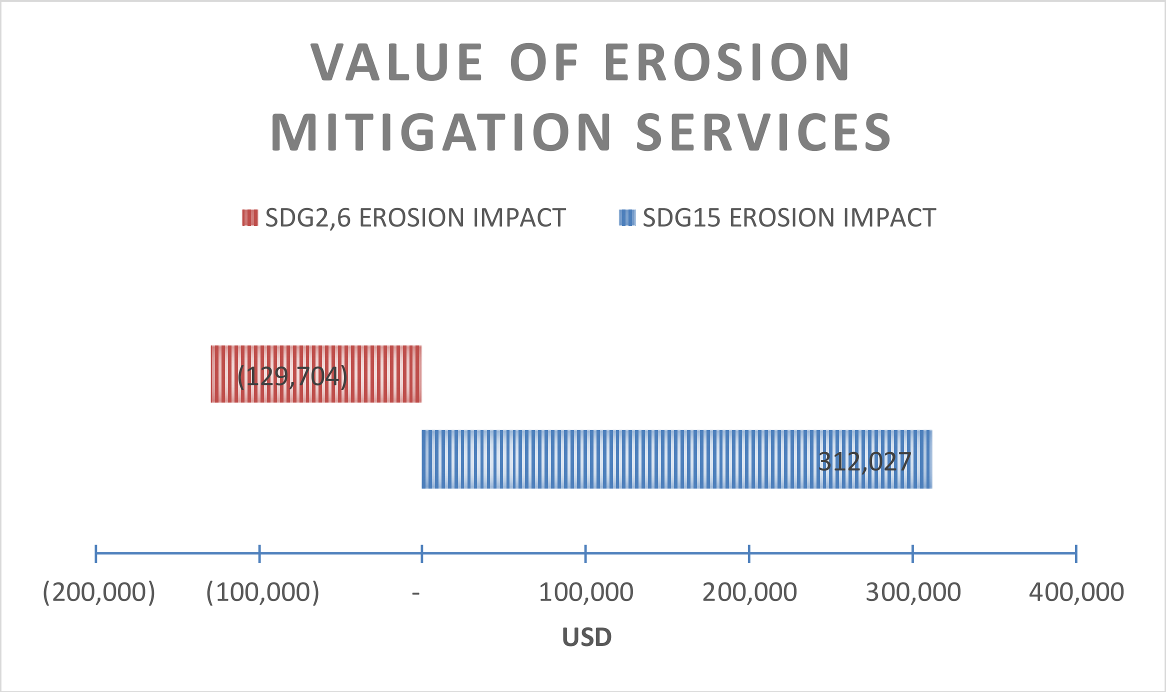
STEP 7: FEED ESM IMPACT BACK TO IEEM AND ITERATE

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
DEPARTMENT	LPL_d (%)	LPL_d (%)	LPL_d (%)	LPL_d (%)	LPL_d (%)	LPL_d (%)	LPL_d (%)	LPL_d (%)	LPL_d (%)	LPL_d (%)	LPL_d (%)
Guatemala	0.0398680	0.0406616	0.0414551	0.0422487	0.0430423	0.043836	0.044512	0.045188	0.045864	0.046540	0.0472155
El Progreso	0.2267094	0.2266053	0.2265012	0.2263971	0.2262930	0.226189	0.229351	0.232512	0.235674	0.238836	0.2419978
Sacatepequez	0.0717616	0.0778290	0.0838964	0.0899637	0.0960311	0.102098	0.103986	0.105874	0.107761	0.109649	0.1115361
Chimaltenango	0.0345597	0.0345598	0.0345599	0.0345600	0.0345601	0.034560	0.034583	0.034605	0.034628	0.034651	0.0346731
Escuintla	0.0035007	0.0035008	0.0035010	0.0035011	0.0035013	0.003501	0.003501	0.003501	0.003501	0.003501	0.0035014
Santa Rosa	0.0275717	0.0274066	0.0272415	0.0270764	0.0269112	0.026746	0.026648	0.026550	0.026451	0.026353	0.0262550
Solola	0.1653336	0.1667672	0.1682008	0.1696344	0.1710680	0.172502	0.173747	0.174993	0.176239	0.177484	0.1787298
Totonicapan	0.0099412	0.0102026	0.0104640	0.0107254	0.0109867	0.011248	0.011248	0.011248	0.011248	0.011248	0.0112481
Quetzaltenango	0.0308880	0.0308037	0.0307195	0.0306352	0.0305509	0.030467	0.030467	0.030467	0.030467	0.030467	0.0304666
Suchitepequez	0.0090420	0.0090216	0.0090012	0.0089808	0.0089604	0.008940	0.008940	0.008940	0.008940	0.008940	0.0089399
Retalhuleu	0.0012203	0.0012199	0.0012194	0.0012189	0.0012184	0.001218	0.001218	0.001218	0.001218	0.001218	0.0012180
San Marcos	0.0709679	0.0705838	0.0701997	0.0698155	0.0694314	0.069047	0.068866	0.068684	0.068503	0.068321	0.0681399
Huehuetenango	0.2205299	0.2194926	0.2184552	0.2174179	0.2163806	0.215343	0.214260	0.213177	0.212094	0.211011	0.2099280
Quiche	0.2488614	0.2483546	0.2478479	0.2473412	0.2468344	0.246328	0.246319	0.246311	0.246303	0.246294	0.2462861
Baja Verapaz	0.2291479	0.2267817	0.2244156	0.2220494	0.2196833	0.217317	0.217297	0.217277	0.217257	0.217237	0.2172176
Alta Verapaz	0.2588638	0.2579392	0.2570147	0.2560901	0.2551656	0.254241	0.254449	0.254657	0.254865	0.255073	0.2552806
Peten	0.0011371	0.0011235	0.0011098	0.0010962	0.0010826	0.001069	0.001069	0.001069	0.001069	0.001069	0.0010689
Izabal	0.0456172	0.0451324	0.0446476	0.0441628	0.0436779	0.043193	0.043080	0.042967	0.042853	0.042740	0.0426266
Zacapa	0.1405783	0.1386212	0.1366640	0.1347069	0.1327497	0.130793	0.130642	0.130490	0.130339	0.130188	0.1300373
Chiquimula	0.1700176	0.1691836	0.1683496	0.1675155	0.1666815	0.165847	0.165759	0.165671	0.165583	0.165495	0.1654066
Jalapa	0.0715681	0.0714808	0.0713935	0.0713062	0.0712189	0.071132	0.070538	0.069944	0.069351	0.068757	0.0681635
Jutiapa	0.0156843	0.0155951	0.0155059	0.0154167	0.0153275	0.015238	0.015166	0.015094	0.015022	0.014950	0.0148777

INTERACTION IEEM+ESM



RECALCULATE INDICATORS



FINAL THOUGHTS

- Integrate the IEEM+ESM work flow (LULC+ESM).
- Consider a range of magnitudes for erosion impacts and shocks.
- Other ecosystem services or goods: soil fertility, potable water, crop pollination.

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FOR MORE INFORMATION ON IEEM:

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IEEM AND NATURAL CAPITAL ACCOUNTING

IEEM VIDEO

English: https://vimeo.com/240348050
Spanish: https://vimeo.com/243498201