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**VALUE FOR MONEY ANALYSIS OF GEF INTERVENTIONS IN SUPPORT OF
SUSTAINABLE FOREST MANAGEMENT**

(Prepared by the Independent Evaluation Office of the GEF)

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ABBREVIATIONS AND ACRONYMS

CBD	Convention on Biological Diversity
GEF	Global Environment Facility
LSMS	Living Standards Measurement Survey
STAP	Scientific and Technical Advisory Panel
NDVI	Normalized Difference Vegetation Index
UNCCD	United Nations Convention to Combat Desertification

Notes

GEF replenishment periods

GEF-1	1995–1998
GEF-2	1999–2002
GEF-3	2003–2006
GEF-4	2006–2010
GEF-5	2010–2014
GEF-6	2014–2018

All monetary amounts are US\$

1 INTRODUCTION

1.1 Objectives

1. This study is the first Value for Money analysis undertaken by the IEO to assess the impact and global environmental benefits of GEF investments and technical support through SFM interventions. This study assessed the impacts of SFM interventions on environmental and biophysical variables, co-benefits measured in terms of socio-economic indicators, and the estimation of monetary values of ecosystem services based on the principle of natural capital accounting. Five hundred and six (506) projects¹ were examined, some of which were implemented in earlier replenishment periods before GEF had initiated a dedicated SFM program in GEF-5.

2. GEF's contribution to generating environmental and socio-economic benefits, including global environmental benefits (GEBs), through sustainable forest management (SFM) interventions, has not been independently evaluated in the past, reflecting a gap in understanding the relevance, effectiveness, efficiency and impact of GEF support. Previous studies on SFM within the GEF partnership includes an advisory document on SFM, and a report which synthesizes the effectiveness of Community Forest Management initiatives in generating environmental benefits, both produced by STAP.

3. This study had three objectives. The first was to estimate the portfolio-scale impact of GEF interventions in Sustainable Forest Management (SFM) on land cover and associated above-ground carbon storage. The second objective was to use the calculated impacts on land cover to estimate the monetary value of tons of carbon sequestered. The third objective was to examine the socioeconomic effects using a portfolio-wide approach (based on night light activity²), as well as focusing on a single-country case study, Uganda, by leveraging in-country household survey information.

2 BACKGROUND

4. Since its inception, the GEF has provided support to its partner countries to improve the sustainability of their forestry resources. Although SFM is not a focal area, forest-based interventions have been supported through GEF focal area interventions, multifocal projects, integrated approach pilots (IAPs), and, more recently, designed through the impact programs. While projects prior to GEF-5 addressed forest issues through several focal area objectives, the GEF initiated a dedicated SFM program in GEF 5. SFM interventions from GEF-5 onwards were funded through an additional incentive, with SFM specific objectives, even though SFM is not a separate focal area per se. With a

¹ List of projects with title, GEF ID, grant amount is available on the GEF IEO website.

² Night light are used as a proxy for socio-economic growth as studies have demonstrated that night time lights is highly correlated with economic activity, population, and establishment density (Mellander et al. 2015).

total investment of approximately \$2.8 billion in grants and an additional \$14 billion in co-financing, SFM interventions have evolved over the GEF phases, with the objective of increasing environmental benefits and delivering socio-economic co-benefits. The environmental and socioeconomic co-benefits that may accrue from these SFM related investments have not been assessed so far.

5. In this study, the IEO expanded on the satellite-based approach applied in the value for money analysis of GEF land degradation projects (IEO, 2016) to examine the environmental effectiveness, efficiency and impact of GEF interventions in SFM. Data used included the geographic locations within which GEF SFM projects are located, and measurements on environmental outcomes based on indicators suggested by the United Nations Convention to Combat Desertification (UNCCD 2015) and Convention on Biological Diversity (CBD 2016). Satellite-based measurements of nighttime lights intensity over time, which has been frequently used as a proxy for socioeconomic outcomes, was used in this study. A quasi-experimental approach was applied to analyze the effectiveness of GEF projects and programs along both environmental and socio-economic dimensions, and valuations were estimated based on attributable carbon sequestered by GEF projects.

6. A total of 506 SFM project³ were examined including projects from earlier replenishment periods before GEF initiated a dedicated SFM program in GEF-5; of these, 347 met the two criteria for inclusion: (1) availability of precise geospatial information (less than 10 square kilometers), and (2) a period of implementation that began no later than 2013 (approximately 70% of projects). Within these 347 projects, 1,924 project implementation sites were identified with high precision (~5.5 sites per project, Figure 1)

3 SUMMARY OF FINDINGS

3.1 Regional Focus

7. **The majority of GEF SFM project implementation sites are located in Sub-Saharan Africa, Latin America and the Caribbean.** This trend may not be analogous to funding, as it focuses on identified locations at which projects are implemented. Madagascar, Colombia, and Brazil are the three countries with the largest number of GEF SFM project locations.

3.2 Relevance

8. **GEF SFM projects in Brazil, East Asia and Madagascar were implemented in geographic locations with very high initial conditions of deforestation.** GEF projects were not targeted towards areas that might maximize socioeconomic co-benefits, instead preferencing areas that were more

³ List of projects with title, GEF ID, grant amount is available on the GEF IEO website.

likely to improve environmental outcomes.

3.3 Effectiveness & Valuation

9. **The GEF SFM interventions⁴ were estimated to have avoided approximately 4,875 square kilometers of deforestation over their respective implementation periods** (an average of 2.5 square kilometers per intervention location). Combined with improvements in vegetation density, this project cohort contributed additional sequestered above-ground carbon of 1.33 tonnes / hectare / year, worth \$727,990 annually on average (under a conservative valuation of carbon at \$12.90/MT), compared to locations with no GEF interventions. This estimate is conservative given the fact that not all GEF intervention locations are known, representing only the 1,924 for which more precise geographic information was available. If valuation is extrapolated to cases for which exact geospatial information was not available, but a known site of implementation exists (3,585 intervention locations), the estimate is \$1.36 million/ year, providing a slightly less conservative estimate of impacts. This contrasts to an average implementation cost of \$5.9 million, resulting in a break-even point of 4.5 years if only above-ground biomass is considered in valuation.

3.4 Socioeconomic Co-benefits

10. **Positive impact on socioeconomic benefits.** A portfolio level global-scope analysis of economic and social co-benefits of GEF SFM projects suggest a small, positive impact on socioeconomic benefits indicated by nighttime light intensity. It should be noted that a majority of SFM interventions were designed to address multiple focal area objectives, especially after GEF-5. In addition to the carbon sequestered, there is evidence that projects implemented since GEF-5 demonstrated a positive effect on nighttime lights (+0.24), a proxy for economic development, which was not discernible in preceding periods. In the absence of precise geographic information, it is possible that these findings represent an under-estimate of the true impacts across the GEF SFM portfolio since locations without any recorded high precision geographic data in project descriptions are not included.

11. **GEF SFM projects are associated with an increase in household assets.** The local-scope case study of Uganda provided more direct estimates of economic impacts, leveraging the World Bank Living Standards Measurement Survey (LSMS) to detect the impact of GEF projects on proximate (within 50km) households. By matching LSMS locations proximate to GEF interventions to those far away from GEF interventions, the local analysis indicates that GEF SFM projects are associated with an increase in household assets between \$163 and \$353 (within 40-60 km respectively). The Uganda case study show that households proximate to a GEF implementation site tended to experience improvements in assets approximately \$310 (within 50 km) higher than those not proximate to a GEF implementation site.

⁴ Subset of project implementation sites that met the inclusion criteria.

12. The findings for this value for money analysis in Uganda are in-line with a study by Jayachandran et al. 2017 that implemented a randomized control trial for a GEF payment for ecosystem services (PES) project. Households received payments to contribute to the protection of forests on their lands and were paid based on the success in avoiding deforestation and degradation as measured by satellite imagery. While Jayachandran et al. do not explicitly examine the impacts of this intervention on socioeconomic outcomes, they note that the benefits of averted CO₂ emissions over relatively short time frames (i.e., a 2-year delay in deforestation) can result in a positive value for money even if deforestation occurs at a future date after project implementation. Compared to the Jayachandran's PES study, this study uses a more modest valuation for carbon sequestration (\$12.90 per MT, as contrasted to \$39 per MT in Jayachandran et al. [2017]). This study also explicitly considers the benefits of permanently averting emissions (while Jayachandran et al. 2017 instead employ a baseline 4-year aversion valuation strategy).

13. In summary, the analysis of socio-economic co-benefits of GEF interventions has not been evaluated, and this study is a first attempt at estimating the global and local level contributions. The global scope study suggested a generally neutral impact, with some exceptions; however, the coarse nature of the nighttime lights data used to approximate economic productivity limits the conclusions to areas which experienced large degrees of change. Further, in the cases where exceptional increases in nighttime lights were observed, projects tended to underperform in terms of environmental outcomes – representing a challenging tradeoff between co-benefits and primary benefits and how they are measured. Leveraging local household survey data provided a more direct way to measure how the GEF may be impacting local socioeconomic conditions, and the results demonstrate the positive income effects associated with GEF interventions. Taken together, these findings clearly demonstrate the need for clear location information, baseline and monitoring information on environmental and socioeconomic outcomes.

4 DATA

4.1 The Portfolio Analyzed

14. This analysis examined 506 projects supported based on the protocol adopted by the GEF Secretariat to identify SFM projects in the GEF portfolio. This protocol has two elements: the first considers the project's contribution to SFM and if it addresses one or more of the seven elements⁵ which are considered key aspects of SFM adopted from the UNFF's 2007 non-legally binding instrument on all types of forests. The second element of the protocol establishes that at least \$1 million of funding (GEF grants and co-finance) must be allocated towards one or more of the seven SFM elements.

⁵ a) Extent of Forest Resources; b) Biological Diversity; c) Forest Health and Vitality; d) Productive Functions of Forest Resources; e) Protective Functions of Forest Resources; f) Socio-economic Functions; g) Legal, policy and institutional framework.

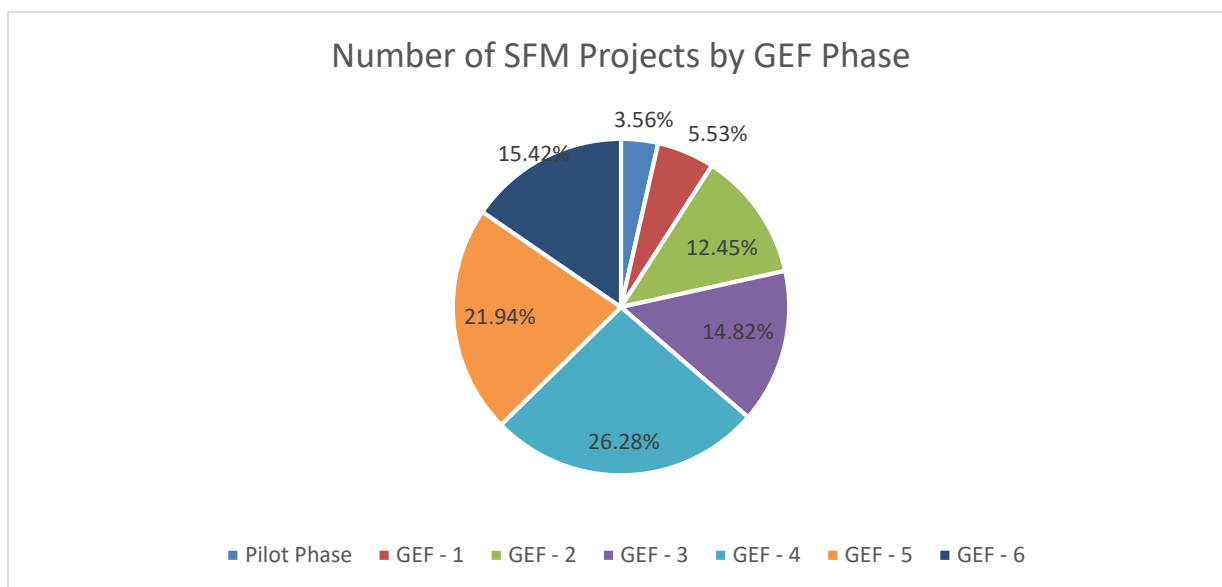


Figure 1: Number of SFM projects by GEF phase.

15. Of the 506 SFM projects examined, 26.2 percent were approved during GEF 4 and 22 percent were approved during GEF 5. Ten percent belonged to the pilot phase and the GEF 1 phase (Figure 1). Funding for these SFM interventions is mainly drawn from the GEF's biodiversity and multifocal focal area allocations (including SFM incentive since GEF 5). Biodiversity focal area projects constitute half of the SFM portfolio, followed by multifocal projects which constitute 44 percent of the portfolio (Figure 2).

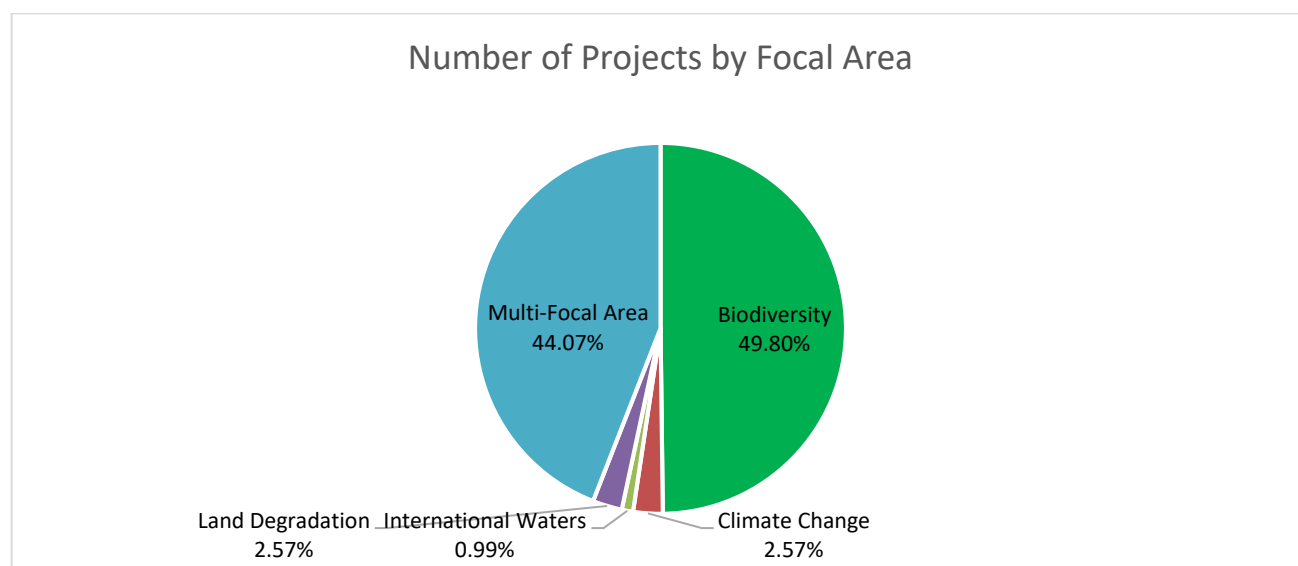


Figure 2: Number of projects by GEF focal area.

16. All SFM projects were manually assessed by trained geocoders to determine if there was adequate information in the project documentation which would enable the mapping of where interventions occurred. Through this process, 3,585 implementation sites were identified. A subset of 1,924 of these sites representing 347 projects, met the inclusion criteria of high geographic precision and year of implementation, and therefore were used in this analysis. These 347 projects were demarcated by polygons representing the area of project implementation. An example of a small number of such projects can be seen in Figure 3 (inset map).

17. After all locations were identified, a round of data quality assurance was performed, including de-duplication of projects and locations, correcting data and field type mismatches, correcting and aligning project locations with relevant administrative zones, and a semantic versioning to track relevant changes to datasets if updates were made. The spatial distribution of all projects mapped to exact locations can be seen in Figure 3.

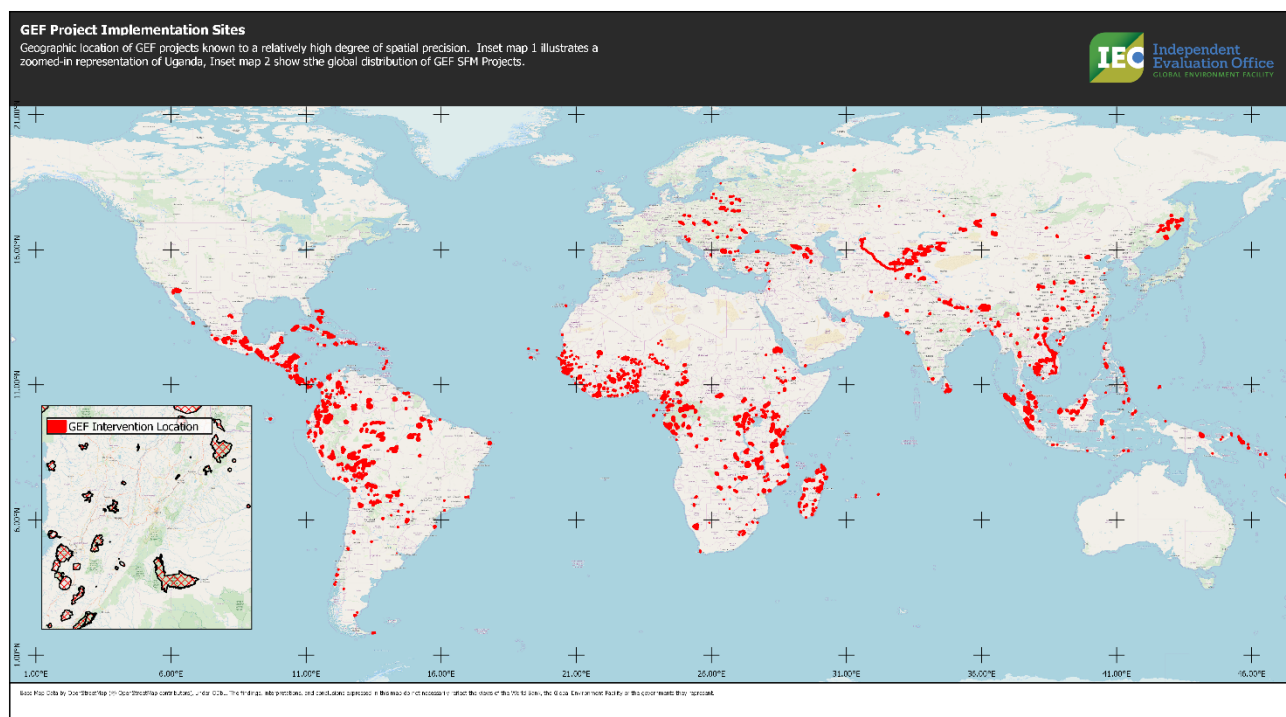


Figure 3: Example of geocoded location information for GEF Project Implementation Areas. Inset Map 1 (top) illustrates a zoomed-in representation of Uganda. Inset Map 2 (bottom) shows the global distribution of GEF SFM projects.

4.2 Outcome Measures

18. This study relies on four outcome measures that we explicitly sought to model the impact of GEF SFM projects. These include measurements of (1) vegetation density; (2) deforestation; (3) night lights as a proxy for socio-economic measures; and (4) in-country based survey metrics of household assets. Measures (1) and (2) are further used to estimate above-ground carbon stocks using the approach outlined in the Value for Money Analysis for Land Degradation Projects of GEF (IEO, 2016)

which leverages Ecofloristic Zone Carbon Fractions dataset derived by the Oak Ridge National Laboratory in conjunction with global carbon stock estimates (Saatchi et al. 2011). Each of these measurements were calculated with the following procedures for each geocoded GEF project:

19. *Vegetation density* - The yearly maximum vegetation density for each GEF project was calculated on an annual basis from 1985 to 2015 using the Long-Term Data Record Normalized Difference Vegetation Index (NDVI) product. Periods prior to GEF projects were used to calculate baseline trends and levels, whereas contemporary data was used to establish impacts.

20. *Forest Cover Change* - The Hansen et al. (2013) tree cover product from the University of Maryland was employed to detect deforestation. These products are available at 30-meter resolution for 2000, and on a yearly basis for years 2001 to 2018. The absolute annual change in tree cover is calculated post-2000, whereas a baseline is calculated using the data from years prior to 2000. Additionally, data available from the Global Land Cover Facility at the University of Maryland for forest change data for 1990 (Kim et al. 2014) were used.

21. *Night Lights and In-Country Survey Data* - The Defense Meteorological Satellite Program Operational Linescan System (DMSP-OLS) and Visible Infrared Imaging Radiometer Suite (VIIRS) nighttime lights satellite products were employed to detect changes in the intensity of lights. Night lights are used as a proxy for socio-economic growth as several studies have demonstrated that night time lights is highly correlated with economic activity, population, and establishment density (Mellander et al. 2015). These data are available at resolutions of 1 kilometer and approximately 500 meters, respectively. The trend in nighttime lights for a pre- and post-period was calculated for each GEF project, and the difference in trends was explored. As a second, localized step, the World Bank Living Standards Measurement Survey (LSMS) was used to explore the impacts of GEF project implementations on household assets for a single case study country (Uganda).

4.3 Other Correlated Variables and Data Integration

22. In addition to the outcome measures being used, we employed a wide range of other measures to control for potentially confounding factors that may drive changes in the outcomes other than GEF interventions. These variables that include population, temperature, access to roads, precipitation, nighttime lights, slope, elevation etc. are summarized in Annex Table A1. Each of these data sources were joined into a common data frame (Goodman et al. 2019).

4.4 Generating Comparison Cases: Counterfactuals

In this analysis, we compared GEF projects locations to locations at which no known GEF intervention occurred (“counterfactuals”, or control locations). For comparison we generated, 10,000 counterfactual locations. As illustrated in Figure 4, those locations were identified within a minimum distance of 25 kms from GEF projects and within 50 kms (illustrated by the light-green band; details on this procedure can be found in the annex). This was done to facilitate matching of each known GEF intervention location to a location that was similar along all measurable variables collected but did not have a GEF intervention.

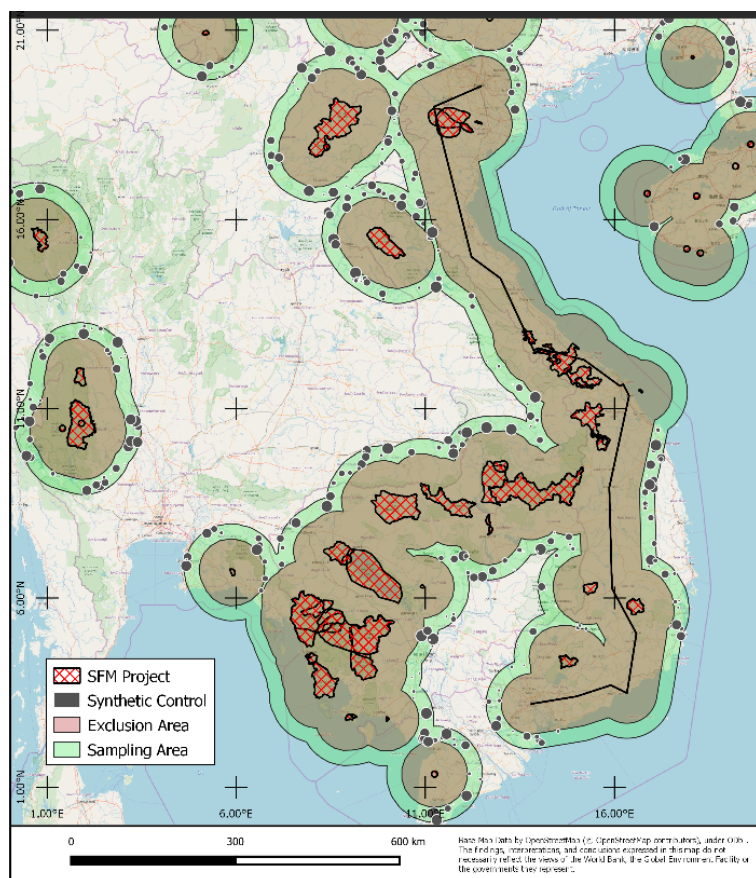


Figure 4: Creation of counterfactual sites (synthetic control). All selected control sites are at a minimum distance of 25 kms (illustrated by the light-green band)

4.5 Data for the Uganda Case Study

23. For a single country case study in Uganda, a secondary analysis was performed to examine the impact of GEF SFM projects on household assets, measured using local household surveys. This analysis was conducted using two unique data sources, in addition to the variables used in the global analysis (Annex Table A1). The first data source was generated at a scale of 10 square kilometers, to which all satellite and survey information was generalized for analysis. The second data source was the World Bank Living Standards Measurement Survey, which was used to estimate household assets.

24. Collected in 2009 and 2011 within Uganda, the LSMS data source provides geographic latitude and longitude information on where household clusters were surveyed, accurate to within 5 kilometers. In both surveys, an identical question was asked which is used in this analysis – “What is the total estimated value of all the assets owned by your household?” In 2009, the LSMS surveyed 2,960 households with an instrument designed to measure household assets. Of these households, 2,926 provided a response to this question along with geographic location information. In 2011, the LSMS surveyed 2,497 households; with a total of 2,316 households that provided information on

assets along with geographic information. These two data sets were used in this analysis. The household assets were calculated for both the time period within every 10 sq km.

5 METHODS

5.1 Portfolio Analysis

A casual tree approach was applied to understand the factors which have an important influence on vegetation density, deforestation and nighttime lights to estimate the above-ground carbon sequestration attributable to each GEF SFM project location. Some of the variables considered included air temperature, precipitation, population, road networks etc. The approach compared geospatial regions with near-identical characteristics at which a GEF project was and was not implemented – and the differences in outcome was used to estimate the impact of an intervention. Details of this approach is in the annex A, as well as in the land degradation VfM study by the IEO (IEO, 2016).

5.2 Local-Scale Analytic Approach

25. A model was run to explore the relationship between household assets and the presence of GEF interventions. To further explore the impacts of GEF SFM projects on socioeconomic outcomes, a single country – Uganda was selected for a local-scale analysis on the basis of available data. The country was divided into smaller multiple units of 10 square kilometers, to which all satellite and survey information was generalized for analysis (see Figure 5, where grey shade indicates areas with no LSMS data, hashed areas with red boundary indicate GEF SFM projects and green indicate areas where LSMS data was available). For each 10 square kilometer area seen in Figure 5, the distance to the nearest GEF SFM project is calculated. Further, in certain areas which the World Bank's LSMS conducted household surveys, total household assets in 2009 and 2011 are calculated. Finally, all of the datasets are calculated for each 10 square kilometers. Factors that were accounted for included air temperature, population, distance to coast, conflict incidents, road networks, precipitation, slope, elevation etc. More information on the details of this approach is in Annex Table A1.

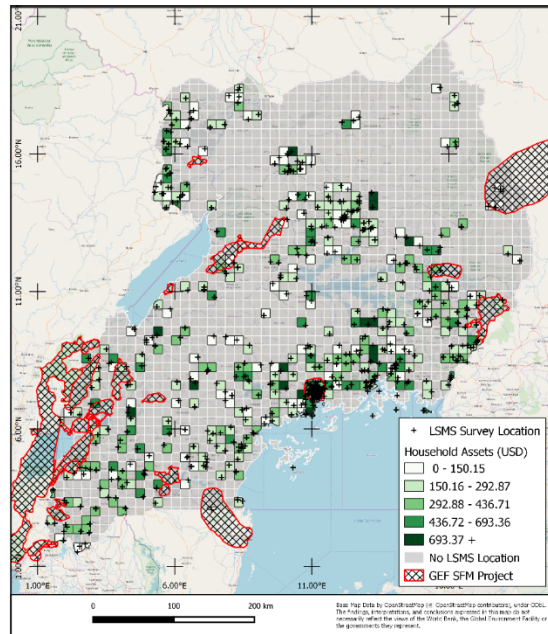


Figure 5: Data used in Uganda case study. Grey shade indicates areas with no LSMS data, hashed areas with red boundary indicates GEF SFM projects and green indicate areas where LSMS data was available.

26. A threshold of 50 kilometers is used to approximate the distance at which we expect household assets might be impacted by GEF SFM projects – i.e., if the area is within 50 kilometers of a GEF SFM project, it is considered impacted. These impacted areas close to GEF SFM projects are matched to untreated locations (far away from GEF SFM sites), and are compared to estimate the impact of GEF SFM projects. The model describing this estimate can be seen in the Annex Table A3.

6 RESULTS

6.1 Regional Focus

27. There is considerable geographic variance in the GEF SFM portfolio (Figure 6). Of unique focus in this analysis is the number of project implementation locations – not simply the number of projects – which may be more indicative of the on-the-ground complexity and scope of logistics, as well as the geographic scope of the population impacted by activities.

28. Of all identified implementation locations, the majority are located in Sub-Saharan Africa, Latin America and the Caribbean. The highest number of project locations is in Sub-Saharan Africa with Madagascar having the highest overall density of project locations with 202 discrete project implementation sites. Colombia has the second most identified locations (81), and Brazil the third (79). Of note, as figure 3 illustrates with higher granularity, is a general lack of investment in drylands areas through GEF-6.

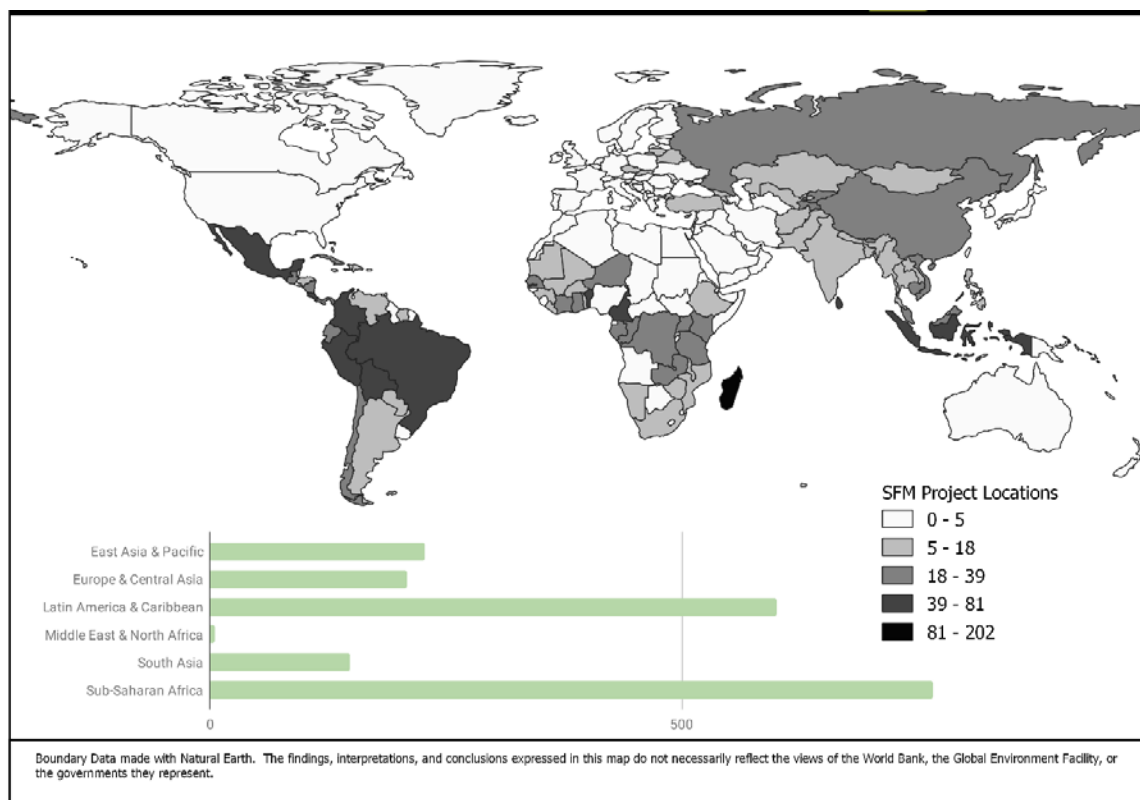


Figure 6: Global distribution of SFM Project implementation locations (including all 3,585 identified project location sites).

29. In addition to spatial variation in the locations of GEF interventions, there is considerable variation in the initial conditions that GEF projects were exposed to. Initial conditions are defined as the satellite-observed measurement the year before the start of the project's implementation. Figure 7 shows how challenging initial conditions were for each GEF project, averaged across all projects within a country. Table 1 contains the definitions and global summary statistics for each variable to serve as a point of comparison.

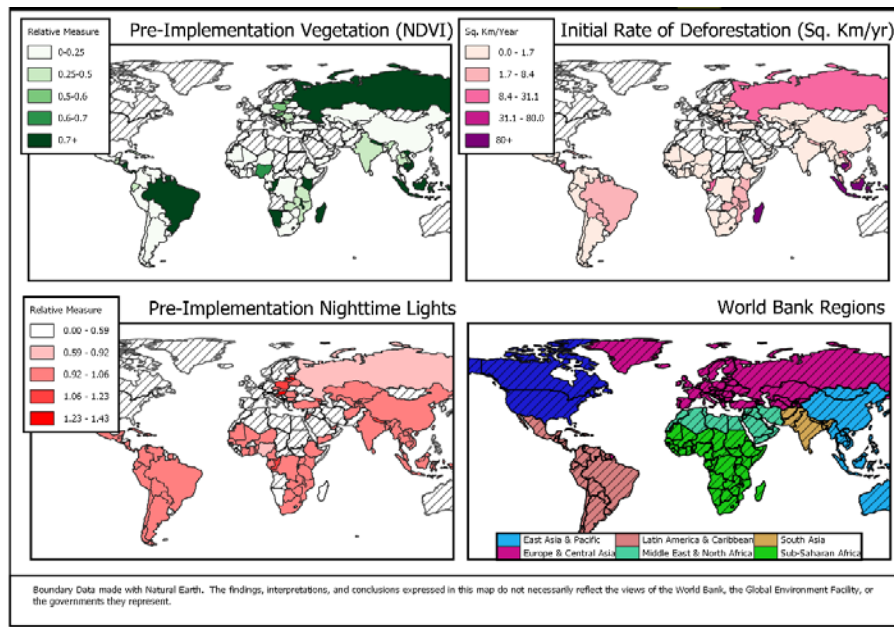


Figure 7: Global pre-trends for pre-implementation status of outcome metrics for the precise GEF project locations.

30. Figure 7 (top left) shows how the initial value of vegetation density (NDVI) at GEF implementation sites largely follow expected biological trends – GEF SFM projects in countries with vegetation that tends to grow densely (such as the Brazilian Amazon) also tend to have higher levels of initial vegetation density. This contrasts to lower levels of vegetation density in the baseline condition at GEF SFM projects in areas with vegetation regimes that tend to be less dense, such as those in Africa. Figure 7, (top right) demonstrates the spatial variation in deforestation – projects in Madagascar and East Asia were implemented in areas with very high initial conditions of deforestation. In South America, GEF SFM projects sites in Brazil had many of the highest initial areas of high deforestation. In terms of initial socioeconomic conditions at GEF sites (Figure 7, bottom left), we observe relatively little variation in initial light intensity – most GEF projects are implemented in areas with exceptionally little light proximate to them (i.e., access to electricity).

Table 1: Baseline Conditions and Estimated Impacts at GEF Project Intervention Locations

Variable	Definition		Min	Mean	Max
Nighttime Lights	Relative values ranging from 0 to 63, in which larger values indicate more light received by the satellite sensor.	Baseline	0.0	3.7	63.0
		Impact Estimate (Annual)	-1.44	.91	12.2
Vegetation Density (NDVI)	Relative values ranging from 0 to 1, in which smaller values indicate less vegetation density.	Baseline	.004	.532	.830
		Impact Estimate (Annual)	-.04	0.016	0.07
Deforestation	The percent of land covered by a GEF intervention that was subjected to deforestation within a given year (smaller values indicate less deforestation; negative values indicate avoided deforestation).	Baseline	0%	0.2%	19%
		Impact Estimate (Annual)	-2.3%	-.27%	2.5%

6.2 SFM Project Site Selection

31. A necessary precursor to analyzing the outcomes of GEF interventions is to develop a propensity model which identifies dimensions along which GEF projects sites were selected - for example, whether GEF projects were intentionally located in protected areas. The results of the model are used in the Causal Tree to mitigate bias due to non-random selection, but also provide insights into the rationale for site selection or the relevance of GEF projects.

32. The propensity model⁶ highlights a number of biases in GEF project locations. Projects are more likely to be in:

- (a) Areas with higher rates of absolute deforestation.
- (b) Areas slightly closer to the coast, water bodies, roads, cities and country borders.
- (c) Protected areas.
- (d) Areas with higher slope and elevation.

GEF project locations are significantly correlated with both deforestation and vegetation (NDVI), but are not significantly correlated with nighttime lights, suggesting that the GEF has appropriately focused its interventions in areas of environmental concern.

6.3 Portfolio-scale Impacts of GEF SFM Projects on Deforestation and Vegetation

33. The results of the Causal Tree analysis for the full GEF SFM portfolio's impact on annual rates of deforestation (measured in the percent of land subject to deforestation annually) is seen in Figure 8 and Table 1. Green boxes indicate factors that were statistically significant, and the red boxes indicate factors that were not significant. Across all areas with GEF SFM projects the model estimates a mean of approximately 0.27% less deforestation each year, on average, than similar areas with no GEF SFM projects. This is equivalent to approximately 0.21 square kilometers of deforestation avoided each year for each GEF project implementation location, or 2.5 square kilometers over the average implementation lifespan attributable to this cohort – equivalent to approximately 4,875 square kilometers of avoided deforestation across all locations. This finding suggests that GEF project implementations are – on average – preventing all deforestation relative to the baseline, as well as providing some restoration (contrasted to the baseline rate of 0.2% deforestation across all GEF projects in table 1).

⁶ In cases where a randomized control trial is ethically or technically not possible, propensity score matching uses statistical characteristics (before the intervention starts) that influence the intervention and that are correlated to the outcome of the intervention. It creates “statistical twins” that allows for identification and statistical attribution of the intervention effects.

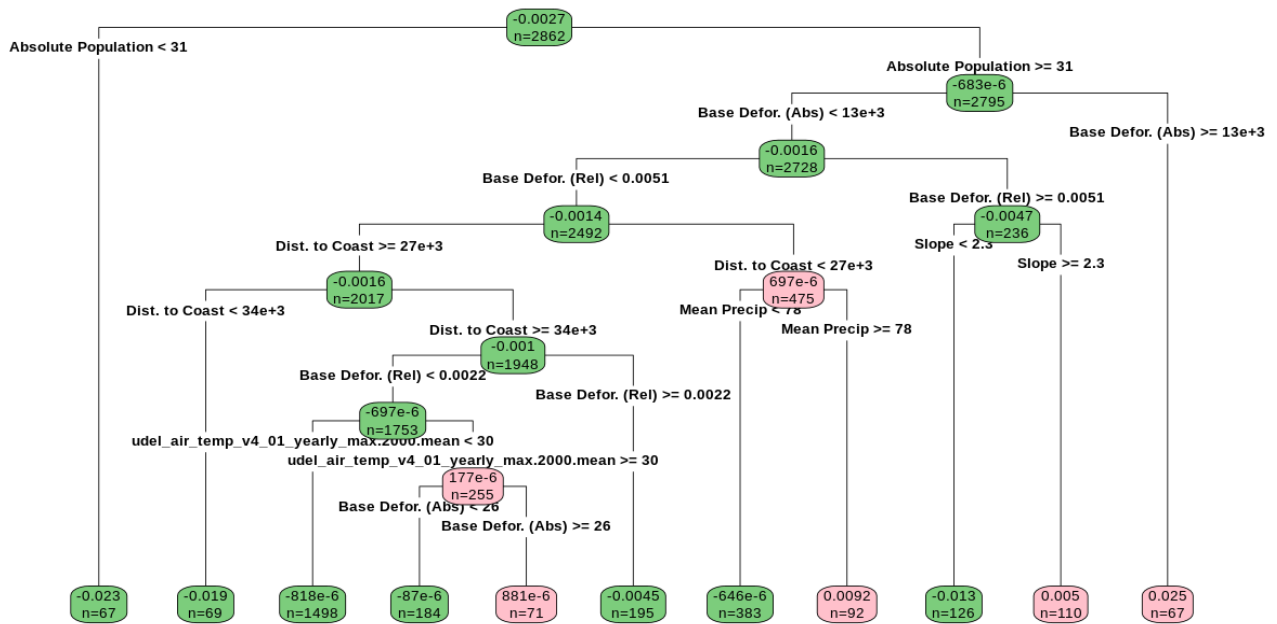


Figure 8: Causal Tree result examining the impact of GEF SFM projects on deforestation. Values indicate the percentage of avoided deforestation (negative values) attributable to GEF projects, as contrasted to similar areas with no GEF intervention. Green boxes.

34. The Causal Tree analysis is used for the estimation of treatment effects (Figure 8). This allows for the examination of the contextual factors that result in different impacts of GEF SFM projects. For example, Figure 8 indicates that GEF SFM projects implemented in locations with a population density less than 31 people per square kilometer will have an estimated effect of 2.3% less deforestation annually than similar projects with no GEF SFM projects. Contrasting to this positive outcome are areas that may be urban fringes (higher absolute populations greater than 31), coupled with poor initial states; these areas tend to be associated with poor outcomes, which may be indicative of urban encroachment into GEF project locations.

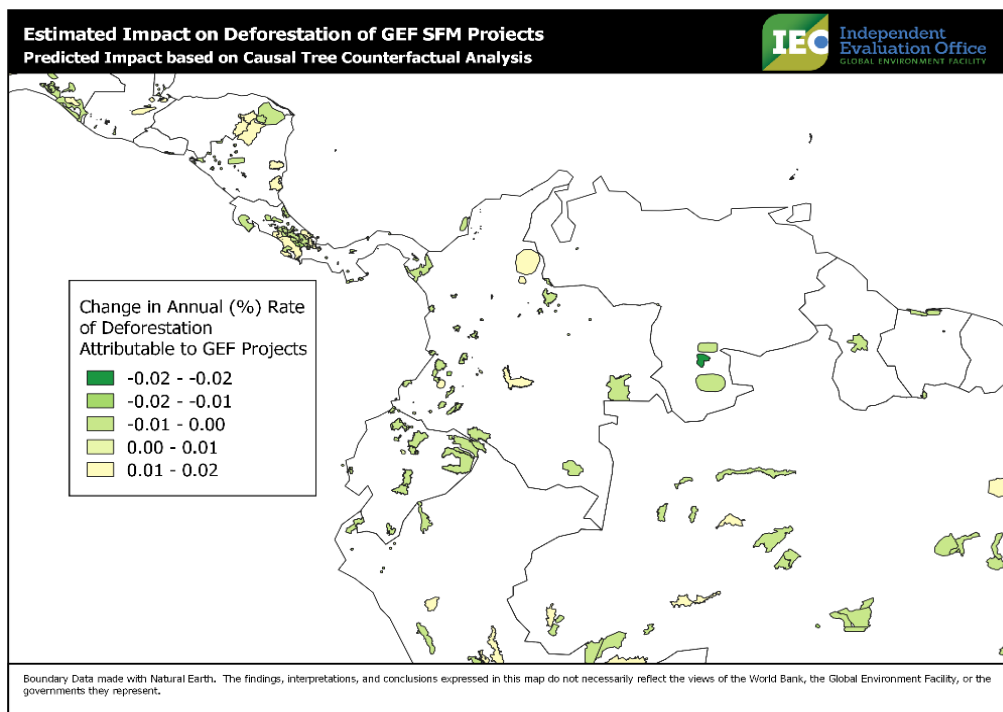


Figure 9: Estimated Impact (%) of GEF SFM Projects on Deforestation. Larger negative values indicate increased avoided deforestation.

35. The results from this analysis are mapped for every project location, as illustrated by the representative map in Figure 9. Both Figure 9 and the distribution of impacts seen in Table 1 illustrate that – in the case of deforestation – GEF SFM project locations were nearly universally associated with positive outcomes – i.e., rather than a small number of successful projects resulting in a large positive outcome, nearly every project tends to contribute in a modest, positive way. Across all estimations, only 169 of the 1,924 project locations assessed here did not provide evidence of a positive outcome (8.7%); and only 33 (1.7%) – all of which were apparently in areas likely susceptible to urban encroachment – illustrated strong evidence of negative outcomes. The remaining 91.3% of project implementation locations had evidence of net positive contributions (in terms of avoided deforestation) to forest cover.

6.4 Vegetation Density (NDVI)

36. Similarly, the Causal Tree analysis was run for the Normalized Difference Vegetation Index (NDVI) (Annex Figure A1). At a global scope GEF SFM projects have been successful in promoting vegetation densification (Table 1). Areas with GEF SFM interventions have NDVI values approximately 0.016 higher⁷ than areas that have similar biological regimes, but do not have a GEF project implementation. This is equivalent to approximately 3% more vegetation density relative to

⁷ NDVI ranges from -1 to 1, with larger values above 0 generally indicating more vegetation.

the global average when areas with GEF projects are compared to those without GEF projects. While this is overall a small net increase, it is meaningful in two key ways. First, because locations are compared to other, proximate locations without GEF projects, it is unlikely that the global difference found here is attributable to sources of error in measurement (as it is likely that any satellite errors would have equally impacted areas with GEF projects and without). Second, a 3% change in vegetation density has a large implication for carbon sequestration, as detailed later in this report.

37. The causal tree estimating impacts in terms of NDVI – provides an opportunity to examine the contextual factors that influence the success of GEF SFM projects. We specifically note a clear distinction in effectiveness - areas with relatively high average land surface temperatures (LST) (>30.4 degrees Celsius) tend to have less impact (and potentially even negative impacts) when contrasted to other GEF projects (Figure A1). Conversely, projects which do not meet these criteria have nearly universally positive outcomes. While this distinction is clear in the data, the exact reasons for this are not apparent, as two distinct drivers could be at play. First, areas with high LST tend to be located in biological regimes with less dense vegetation (i.e., savannah environments); thus, the ability to improve is lower than otherwise might be the case. Second, it is possible that the geographic areas with high LST – predominantly in African countries – could pose more challenging implementation environments. Further research focusing on these cases would be required to understand the processes which result in these distinctions; this represents a limitation of the Causal Tree approach in which only one variable (the presence of a GEF project) can be examined for causality within a single model.

38. An illustrative map of these outcomes can be seen in Figure 10, highlighting Southeast Asia. Similar to the case of deforestation, GEF SFM projects tended to have positive outcomes; 1,673 of the assessed cases (87%) illustrated clear evidence of a positive increase in vegetation density which is attributable to GEF projects. While a slightly higher percentage - ~13% - did not have clear evidence of positive effects, as noted above, these locations tended to be in areas with high land surface temperatures, which would be expected to have lower levels of vegetation density (and, thus, may be an outcome metric of less relevance in those cases).

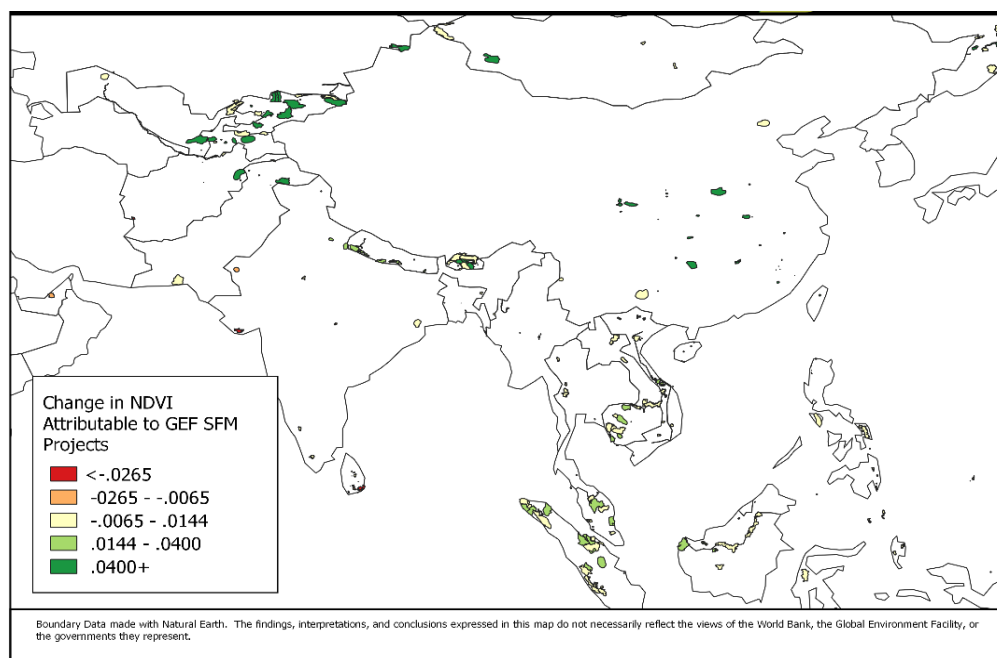


Figure 10: Estimated Impact of GEF SFM projects on Vegetation Density (NDVI) (see Table A1 for a detailed definition of values)

6.5 Estimating Carbon Sequestration & Valuation

39. After estimating the impact of GEF projects on both vegetation density and deforestation, an additional modeling step is employed to estimate how these impacts will modify carbon stocks at each GEF project location. Here, we adopt the empirical approach followed in the Value for Money Analysis for Land Degradation Projects of GEF (IEO, 2016), in which a linear model is used to approximate carbon sequestration. The linear model shows that slope, NDVI, air temperature, and tree cover are all significantly related with the amount of carbon sequestered (Table 2).

Table 2: Linear model for the estimation of carbon sequestered.

	<i>Dependent variable:</i>
	carbon_exfield_sum
Slope	508.95*** (50.90)
NDVI	0.42** (0.21)
Air temperature	-351.69*** (21.72)
Tree cover	642.65*** (6.57)
Constant	7,156.31*** (566.61)
Observations	2,594
R ²	0.84
Adjusted R ²	0.84
Residual Std. Error	9,215.66 (df = 2589)
F Statistic	3,470.59*** (df = 4; 2589)
Note:	*p<0.1; **p<0.05; ***p<0.01

40. We find that on average each project intervention site is sequestering approximately 1.33 tons of carbon / hectare / year *more* than if a GEF project was not present (an average of 10,178 tons / year per project location). Following the value transfer approach and findings from the Value for Money Analysis for Land Degradation Projects of GEF (IEO, 2016) which identified \$12.90/ton as a mean estimate of the value of a ton of carbon, we find that on average each GEF SFM project location sequestered approximately \$131,295 worth of carbon. This results in a total estimate of \$252,612,000 across all GEF SFM projects, or an average total value of \$728,000 for each of the 347 projects with geocoded information examined in this study. Of note, this estimate may be conservative due to lack of information on all intervention locations (i.e., if an area is not geocoded, we do not include it in this estimate). Estimation of carbon sequestration and its valuation could be further improved with the availability of precise geographic location of project sites. We contrast the valuation of GEF SFM projects to other sequestration interventions in the discussion section of this report.

6.6 Portfolio-scale Impacts of GEF SFM Projects on Socioeconomic Outcomes

41. We examined the impact of GEF SFM projects on the annual rate of change of nighttime lights using the causal Tree analysis (Figure A2 and Table 1) by contrasting the annual change in nighttime lights – as detected by satellites – at locations with GEF projects to the same annual change at locations without such projects. In both the Causal Tree (Figure A2) and Table 1, a positive value indicates that a GEF SFM project improved the trend in nighttime lights; larger values indicate a larger estimated magnitude of effect on a scale from 0 (no light) to 63 (brightest light detectable).

42. The results from the nighttime lights at the portfolio level are not clear, suggesting the need for local level data and analysis. Nighttime lights limit measurement accuracy at areas with very low light intensity (such as forest environments common in the GEF SFM portfolio), we therefore (a) conduct a local-scale analysis with an alternative, in-country survey-based data in Uganda to further explore the impact of GEF SFM projects on socioeconomic outcomes and (b) limit our interpretation to areas with large degrees of change that are unlikely to be attributable to error. So, while the global-scope average in Table 1 indicates an average positive effect (+0.91, or 24% relative to baseline) on nighttime light intensity, we focus on the most prominent outcome in the causal tree which is the travel time to an urban area. (Figure A2). Specifically, we note that a relatively large number of GEF projects within a 23 minutes drive of an urban area had a relatively large positive change in nighttime light intensity when contrasted to similar areas without GEF projects (10 on a scale from 0-63, in which most values at GEF implementation sites are skewed towards smaller values (see Table 1). Further, preliminary analysis suggests that the GEF intervention locations which were estimated to have the largest positive increase in nighttime light intensity also tended to have below-average results for both land cover and vegetation outcomes. This is in-line with the results found in this report on the impacts of GEF SFM projects on areas that may be proximate to urban fringes – such projects may have better outcomes on socioeconomic status, but worse outcomes in terms of deforestation (as indicated by the prominence of the population density variable in the case of deforestation).

6.7 Local-scale Impacts of GEF SFM Projects on Socioeconomic Outcomes

43. To more precisely examine the relationship between GEF SFM projects and socioeconomic outcomes, a single case study in Uganda was examined. A survey-based approach was followed, in which surveyed households proximate to GEF SFM project sites were contrasted to surveyed households not proximate to GEF SFM project sites. After controlling for a number of other factors (see Table A1 in Annex), the difference between these matched “twin” cases was interpreted as the impact of GEF SFM projects on household assets.

44. The preliminary findings from this country case study analysis suggest that GEF SFM projects have had a significant, positive impact on household assets in Uganda, even after controlling for potential confounding contextual variables. Other significant variables included slope (higher slopes tended to be associated with negative impacts on households’ assets) and distance to coast (which may be serving as a proxy for other geographically-explicit effects).

45. In absolute terms, we find that the presence of a GEF project can result in – on average – approximately \$310 USD additional household assets compared to areas that do not have a GEF project. This finding is based on the initial assumption that households within 50 kilometers of a GEF SFM project may be impacted by the implementation location. To test the robustness of this finding, we varied this assumption downwards (to 40km), and upwards (to 60km). At both 40 and 60 kilometers, the presence of a nearby GEF project remained statistically significant (resulting in \$163.47 of additional household assets and \$353.37, respectively).

7 DISCUSSION AND CONCLUSION

46. This analysis examined the impacts of GEF SFM projects on four primary outcomes: vegetation density (NDVI), deforestation, carbon sequestration and socioeconomics. Global-scale findings suggested that the GEF has had largely positive impacts in terms of vegetation density and deforestation, and neutral to slightly positive benefits for socio-economics as proxied by nighttime lights. The local-scale country case study findings directly indicate that GEF interventions have contributed to improving local household assets, as measured by household surveys.

47. A majority of SFM project implementations are designed to address multiple focal area objectives, especially since GEF-5. This suggests that the impacts identified here – in particular, the valuations of carbon sequestered – are only representative of a subset of desired outcomes. Some evidence of the increasingly multi-focal approach to GEF SFM is observed in this analysis, as projects that were implemented in 2011 or later illustrated a positive effect on nighttime lights (+0.24), whereas those before showed no discernable impact. This may be representative of an increased focus on improving livelihoods specific to GEF-5 and GEF-6.

48. Co-benefits of GEF interventions are a rarely studied topic, and this analysis is one of the first attempts at both a global and local estimation of the contributions that GEF has made to local economies. The global scope study suggested a generally neutral impact, with some exceptions; however, the coarse nature of the nighttime lights data used to approximate economic productivity limits our conclusions to areas which experienced large degrees of change. Further, in the cases where exceptional increases in nighttime lights were observed, projects tended to underperform in terms of environmental metrics – representing a challenging tradeoff between co-benefits and primary benefits and how they are measured. Leveraging local survey data provided a more direct way to measure how the GEF may be impacting local socioeconomic conditions.

49. In the local study of Uganda, we found a robust, positive result suggesting that GEF projects may be contributing to increasing household assets. Specifically, we found that households proximate to a GEF implementation site tended to experience improvements in assets approximately \$310 (USD) higher than those not proximate to a GEF implementation site. Naidoo et al. 2019 used a similar “near vs. far” quasi-observational design with local survey data as leveraged in this study and found that protected areas have a positive impact of on human well-being.

50. Our findings for value for money in Uganda are in-line with a study by Jayachandran et al. 2017 that implemented a randomized control trial for a GEF payment for ecosystem services (PES) project. Households received payments to contribute to the protection of forests on their lands were paid based on success in avoiding deforestation and degradation as measured by satellite imagery. While Jayachandran et al. do not explicitly examine the impacts of this intervention on socioeconomic outcomes, they note that the benefits of averted CO₂ emissions over relatively small-time frames (i.e., a 2-year delay in deforestation) can result in a positive value for money even if deforestation occurs at a future date after project implementation.

51. Compared to the Jayachandran’s PES study, this study uses a more modest valuation for carbon sequestration (\$12.90 per MT, as contrasted to \$39 per MT in Jayachandran et al. [2017]) This

study also explicitly considers the benefits of permanently averting emissions (while Jayachandran et al. 2017 instead employ a baseline 4-year aversion valuation strategy).

52. While many differences in study and program design inhibit direct contrasting of values found in these two studies (i.e., a lack of information on the dollar allocations sent to regional project implementation sites specifically located in Uganda, which make up the majority of observations presented here), under similar assumptions we are able to contrast our global-scope valuation cost-benefit to the Uganda findings in Jayachandran et al. 2017. Following the same 4-year aversion valuation strategy as presented in Jayachandran et al.⁸ we find that the average estimated value in USD for GEF SFM projects was approximately \$4.08 million. This contrasts to an average cost of implementation of \$5.88 million, resulting in an overall cost-benefit ratio of 0.69 across the full GEF SFM portfolio; this contrasts to the cost-benefit ratio of 2.4 for the PES case study. While the cost-benefit ratio identified in the analyses presented here is notably lower than in the PES case presented by Jayachandran et al. 2017, this finding is contextualized by both (a) the broad range of objectives of the SFM portfolio, as contrasted to the targeted PES objectives, and (b) broader literature suggesting that other targeted sequestration policies can have cost-benefit ratios ranging from 4 to 24 (Knittel, 2012, Gayer and Parker 2013, c.f. Jayachandran et al. 2017), and even from 130 to 460 in extreme cases (Greenstone 2019). This study is also limited by the availability of precise geographic information, likely leading to an under-estimate of the true total impacts across the GEF SFM portfolio as locations without any recorded high precision geographic data in project descriptions are not included in this total.

8 RECOMMENDATIONS

- (1) **Improve geographic precision in recording and reporting project locations.** This will allow for robust monitoring and evaluation of progress and results which are directly attributable to the GEF intervention. It will help gather additional information on ecological and socioeconomic changes within the aerial coverage of the GEF intervention. The requirement to collect geolocation in the GEF-7 results architecture is a step in the right direction. However, the geolocation data being collected is not precise. The GEF and partner agencies should ensure that location information is accurately captured for the site of the intervention. Collection of precise intervention boundaries is optional in the GEF-7 results architecture, but it should be highly encouraged.
- (2) **Capture socioeconomic co-benefits of interventions using a spatial approach.** GEF projects generate global environmental benefits (GEBs) as well as have the ability to produce socioeconomic co-benefits. Since GEF is capturing this co-benefit through the key indicator – the number of beneficiaries - using socioeconomic indicators which are available will shed more light than focusing on the number of beneficiaries. Project specific

⁸ In which treatment effects over the 1st and 2nd year are as estimated, and during the 3rd and 4th year are reduced by half each year, for a treatment effect of 0 in the final year.

indicators that capture the socioeconomic conditions at the baseline and project end should be encouraged to assess both direct and induced co-benefits over time, as well as possible trade-offs. This is specifically relevant for SFM interventions that are now targeted in unique geographies such as the Amazon, the Congo Basin and drylands areas with valuable forests in poor socioeconomic situations.

- (3) **Select projects or programs to improve the evidence base for GEF interventions.** In general, there is limited evidence on the effectiveness, efficiency, and impact of various approaches and instruments such as the landscape approaches, certification schemes, and PES including in SFM interventions. Therefore, it is important to gather empirical evidence. The GEF partnership should continue to encourage the adoption of innovative experimental or quasi-experimental design elements in SFM interventions to generate data and improve the evidence base using quasi-experimental designs or randomized control designs, such as that applied in Uganda, so that impacts can be more conclusively linked to GEF SFM interventions.

9 ANNEXES

9.1 SECTION A: Technical Approach & Findings – Portfolio Analysis

At the portfolio scale, this analysis uses a Causal Tree based approach to impact evaluation. Causal Trees are novel machine-learning models which are implemented in a multiple step process, summarized as (a) deriving a metric (propensity score) which indicates similarity between treatment and control groups; (b) using this metric to match pairs of treatment and control units via a tree; (c) contrasting the outcome of treated units to control units within every terminal node of the tree. By matching units that are similar along measurable dimensions, this approach seeks to replicate conditions similar to a clinical trial in which treatments are assigned randomly to different patients.

The Causal Tree approach has the further benefit of being able to identify the key dimensions along which differential intervention effects can be identified, a feature that is of interest for a portfolio-scale analysis. For example, if GEF interventions are generally more successful in regions proximate to urban areas in some countries, but most effective in regions proximate to roadways in other countries, the causal tree approach enables the automated identification of such differences. This contrasts to more traditional econometric approaches in which such interaction effects must be pre-specified for the modeling approach. Once the Causal Tree model is applied to estimate the impact of GEF SFM projects on both (a) vegetation density, and (b) forest land cover, a secondary model is leveraged to estimate the impact of GEF SFM projects on above-ground carbon sequestration and concomitant valuation. This process is described in more detail in Value for Money Analysis for Land Degradation Projects of GEF (IEO, 2016).

In the portfolio analysis, of the 1,924 project locations that had high resolution coding available, 1,908 also had satellite information on both pre- and post-trends. This reduction in total available observations was largely due to projects which had recent implementation dates, precluding analysis (specifically, 14 project locations had been implemented post-2015, resulting in a short data record by which to judge impact; these 14 cases were excluded).

To implement the causal tree at the portfolio scale, first a set of synthetic control locations – i.e., locations at which no known GEF implementation exists – are created. As illustrated in figure 3, the generation of synthetic controls follows a four-step process. First, the geographic locations of GEF SFM projects are digitized following the procedure outlined above. Second, these locations are buffered by a 25 kilometer exclusionary zone, in which no synthetic controls can be created. Third, these exclusionary zones are buffered by 25 kilometers to create a sampling zone in which synthetic controls will be derived. Finally, control locations are created at random latitude and longitude locations within the sampling zone, and buffered randomly between 1 and 10 square kilometers. Locations not on land (i.e., in lakes or other water bodies) are deemed ineligible.

This multi-step process is repeated 10,000 times, with the goal of creating as many synthetic controls as possible that are very similar to locations at which GEF projects are located. By only placing controls a minimum of 25 kilometers away from GEF interventions, the risk of contamination across units is mediated; by ensuring that controls are no more than 50 kilometers away, we seek to ensure that locations contrasted to one another are in similar socioeconomic environments.

Table A1. Data sources used as control variables in this analysis.

Domain	Source	Attribute	Temporal	Spatial
Human Development	Defense Meteorological Satellite Program – Operational Linescan System (DMSP-OLS)	Nighttime lights	1992–2016	1km
	Visible Infrared Imaging Radiometer Suite (VIIRS)			250m
	Global Roads Open Access Data Set (gROADS)	Road networks	1980–2010	1km
	geoBounadaries Global Administrative Zones (Seitz et al. 2018)	Administrative Zones	Circa 2019	Variable
	Nelson, A. (2008)	Travel Time	~2000	1km
Conservation	World Database on Protected Areas (WDPA)	WDPA Environmental protection areas	2015	Variable
Demography	Gridded Population of the World (GPW)	Population	1990–2020 every five years	1km
Environment and Natural Resources	Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales (HydroSHEDS)	River Networks	1995–2005	~1km
	Shuttle Radar Topography Mission (SRTM)	Elevation / Slope	2000	500m
		Air temperature	1900–2014	50km

	University of Delaware	Precipitation	1900–2014	50km
	European Space Agency (ESA)	Land Cover	1992-2015	300m
	MODIS LST	Land Surface Temperature	2001-2017	1km
	NASA Long Term Data Record (LTDR)	Vegetation (NDVI)	1981-2016	~1km
	Hansen (2019)	Forest Cover	2000-2018	30m
	Balestri (2015)	Gold Deposits	2005	Variable
	Lujala (2009)	Gemstone Deposits, Drug Cultivation Locations	2009	Variable
	Brauer et al. 2015	PM 2.5 Ozone Concentration	1990-2013	~30m
	Peace Research Institute Oslo (PRIO; Lujala et al 2007)	On-shore Petroleum Deposits	2007	Variable

These synthetic control cases are used in the implementation of the Causal Tree for each of three cases – deforestation, NDVI and nighttime lights. These causal trees provides two types of information – estimates of the causally attributable impact of GEF projects (values in each box, or node, in Figure 8), and contextual factors associated with this effectiveness (the splits in the tree). The trees can thus be interpreted as providing information on the overall effectiveness of GEF SFM projects, as well as the geographic contexts in which they were most successful. Figure 8 shows these outcomes for Deforestation (in which negative values indicate a reduction in deforestation, and positive an increase). While this figure illustrates that, overall, GEF SFM projects had a positive impact, the differential estimates of impact across different subpopulations can be seen, with final estimates provided in each terminal “node” at the bottom of the tree. For example, GEF intervention

in areas with an absolute population less than 31/km sq would be estimated to experience approximately 2.3% less deforestation (avoided deforestation) annually than similar sites with no GEF intervention. Figures A1 and A2 illustrate the findings for NDVI and Nighttime Lights, respectively.

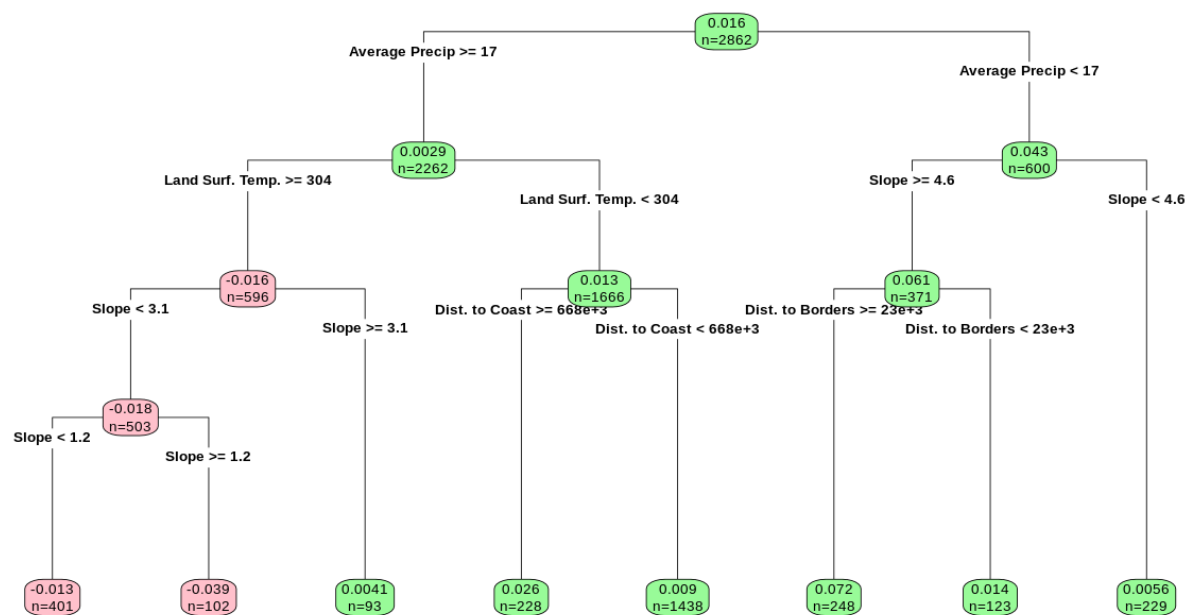


Figure A1. Estimated Impact on Vegetation Density, as proxied by NDVI (see table A1 for a

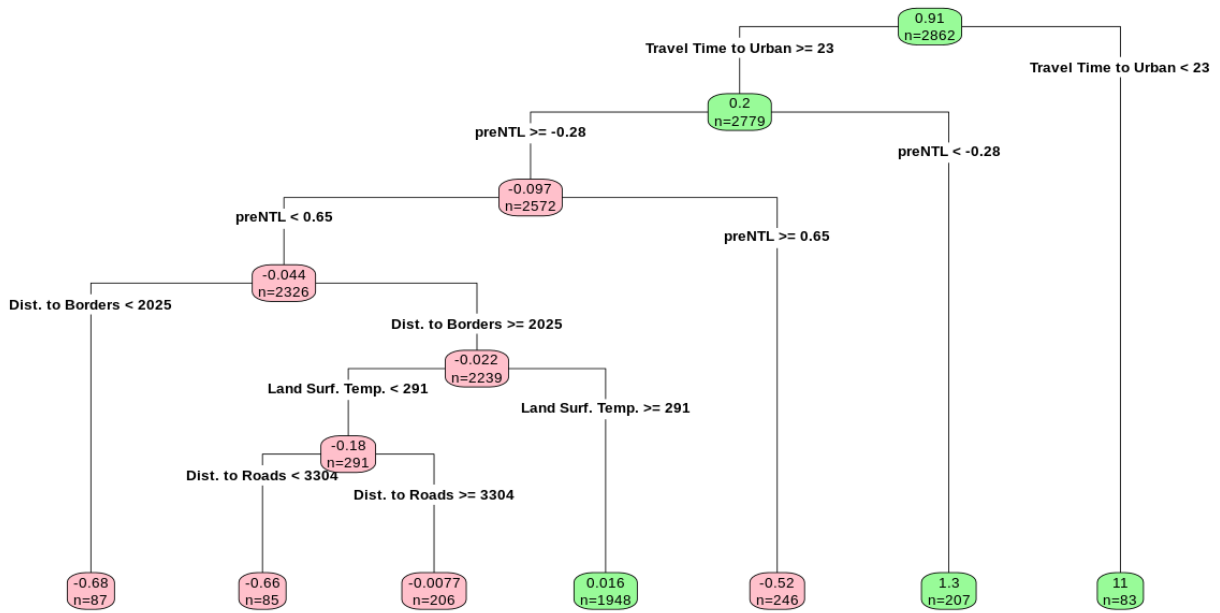


Figure A2. Estimated Impact on Nighttime Lights (see Table A1 for absolute values and definitions).

After the estimation of global-scope impacts, a linear model is estimated to calculate the anticipated impacts on carbon sequestration. Specifically, leveraging the National Carbon Storage dataset (NASA JPL; Xu et al. 2017) and the United Nation’s IPCC Tier-1 Global Biomass Carbon Zones (CDIAC; <http://goo.gl/bECFSx>), a linear model is fit to identify the estimated impact of a one-unit increase in both NDVI and tree cover for a GEF project location. This model takes the form of:

$$C_i = \beta_0 + \beta_1 * Slope + \beta_2 * NDVI + \beta_3 * Air\ Temperature + \beta_4 * Tree\ Cover + \varepsilon$$

where C_i represents the estimated total carbon sequestered at GEF project location i , β_0 a constant, ε an error term, and $\beta_{1..4}$ parameters estimating the impact of slope, NDVI, air temperature and tree cover on sequestered carbon. This equation, the results of which can be seen in Table 2 (main text), is used to estimate the total estimated carbon sequestered that is directly attributable to each GEF project. Of note, both slope and air temperature were found to be statistically significant; their inclusion in the model is to control for different phenological regimes that have different implications for carbon storage potential.

9.2 SECTION B: Technical Approach & Findings – Local Analysis

In this report, a local case study is applied to examine the impact of GEF SFM projects on socioeconomic outcomes, and these findings are contrasted to the findings identified in the portfolio-scale analysis. This local-scale model leverages a propensity-score matching approach to geospatial impact evaluation, a modeling approach which seeks to estimate the effect of a spatial intervention based on pairs of similar areas at which interventions did and did not occur. Unlike the Causal Tree approach, the regression-based approach applied to the local study is not able to autonomously identify the dimensions along which impact effects are larger or smaller; however, regression-based approaches are better suited to datasets with a smaller total number of observations.

A threshold of 50km was used to estimate the zone of influence of each GEF project – i.e., it was assumed that a GEF project would have an influence up to 50km away from its boundary. This threshold results in a total of 1,222 of the 1,896 grid cells being considered treated. Each of these treated cells are matched to an untreated cell according to a propensity matching approach; after matching, a total of 160 observations (80 treated and 80 controls) remain after excluding units for which similar matched units were not available. This is a larger concern within the local analysis, as the total number of grid cells that could be examined for matches was limited (i.e., only 1,896 10km grid cells can be overlaid across Uganda, and a large fraction of these will be considered treated); this is contrasted to the global case in which an arbitrary number of controls could be searched across. The propensity score model can be seen in Annex Table A2. This model can be interpreted as explaining the dimensions along which GEF projects were allocated within Uganda. Results for the propensity model itself are similar to the global-scope propensity mode; within Uganda, projects tended to be located far from the coast in areas with steeper slopes.

After matching, a linear model is estimated following:

$$y = \beta_0 + \theta * T + \sum \beta_n * X_n + \varepsilon$$

where y is the difference between reported assets in 2011 and 2009, β_0 is a constant term, θ is the estimated effect of the presence of a GEF project on outcome y , T is a binary value (1 or 0) indicating

Table A2 Propensity matching model used to pair Control and Treatment locations

	Treatment
2009 Household Assets (LSMS)	-0.00000004 (0.00000003)
2005 Population (Absolute)	0.00001 (0.00001)
2005 Population (Density)	-0.002 (0.003)
Elevation	-0.004* (0.002)
Slope	0.632** (0.262)
Urban Travel Time	-0.004 (0.004)
Land Surface Temperature	-0.013 (0.165)
NDVI	-0.0005 (0.0005)
Nighttime Lights	0.299 (0.377)
Mean Temperature	-3.656 (2.340)
Mean Precipitation	-0.082 (0.057)
Min Temperature	1.853 (1.376)
Min Precipitation	0.182*** (0.039)
Max Temperature	0.684 (1.053)
Max Precipitation	0.021 (0.022)
2009 Deforestation (Absolute)	-0.001* (0.0003)
Distance to Country Borders	-0.00001 (0.00001)
Distance to Water	-0.000001 (0.00001)
Distance to Roads	0.00005 (0.0001)
Conflict Deaths (UCDP)	18.623 (4,288.262)
Distance to Coast	0.00001*** (0.000004)
Constant	31.339 (54.303)
N	287
Log Likelihood	-111.320
Akaike Inf. Crit.	266.640

Notes: ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

if a cell is considered as being treated by a GEF project, β_n is a vector of coefficients for each covariate X_n , and ε is an error term. The goal of the propensity matching approach is to provide an accurate estimate of θ , which can be directly interpreted as the causally attributable effect of GEF SFM projects on household assets.

There are a number of technical limitations to the work presented here. Assessments could be only be made in a limited number of cases due to non-availability of precise geographic information. The use of survey data was also limited by the frequent lack of spatial data which is necessary to enable this style of analysis. Additionally, there was a lack of regular collection of data to provide both a baseline before projects were implemented (or began to be implemented), and a secondary measurement after the project implementation period had started (or, optimally, closed). This proved a large challenge for this analysis – even leveraging a source as rich as the World Bank’s LSMS, many surveys did not have the appropriate temporal or spatial resolution for use in this study. Because of this limitation, the choice of the Uganda case study was largely data-availability driven.

Table A3. Impact of the presence of a GEF project, as contrasted to areas at which no GEF project was located (after matching).

	outcome
Presence of GEF Project	309.663** (133.490)
2009 Household Assets (LSMS)	-0.00003 (0.00004)
2005 Population (Absolute)	0.002 (0.002)
2005 Population (Density)	-0.517 (0.425)
Elevation	0.532* (0.297)
Slope	-58.656** (24.828)
Urban Travel Time	-0.303 (0.649)
Land Surface Temperature	-10.757 (29.019)
NDVI	-0.090 (0.089)
Nighttime Lights	15.399 (33.156)
Mean Temperature	581.845 (364.554)
Mean Precipitation	5.694 (8.326)
Min Temperature	-254.333 (187.990)
Min Precipitation	-1.675 (4.794)
Max Temperature	-257.347 (172.256)
Max Precipitation	-1.109 (2.995)
2009 Deforestation (Absolute)	-0.021 (0.055)
Distance to Country Borders	0.001 (0.001)
Distance to Water	-0.00002 (0.001)
Distance to Roads	0.005 (0.022)
Conflict Deaths (UCDP)	-1,865.566 (2,152.474)
Distance to Coast	0.001** (0.0005)
Constant	440.843 (9,446.025)
N	160
R ²	0.218
Adjusted R ²	0.092
Residual Std. Error	358.612 (df = 137)
F Statistic	1.733** (df = 22; 137)

Notes:

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

A secondary concern with the use of survey data is in the approaches used for anonymization. Because survey providers do not want to reveal the exact latitude and longitude at which an individual lives, geospatial information on where surveys were collected is necessarily offset – in the case of the LSMS, by 5 kilometers. Because the analysis presented here used 10 kilometer cells for analysis, in the worst case scenario a LSMS survey may be offset by a single cell; this is a source of uncertainty that would require further modeling efforts to overcome, and a source that is present in the use of LSMS, DHS, or any other survey instrument.

Overcoming these challenges in data would improve the ability of such models to attribute findings directly to GEF project interventions. While the matching model followed here attempts to mitigate the challenges of missing information by matching on available metric, other confounds that are not present in the study – such as the presence of other interventions such as NGO projects that may not be tracked in public databases – could result in erroneous attribution (or lack of attribution). Leveraging the LSMS forestry module that links forest livelihood to income generation could assist in overcoming such a challenge.

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