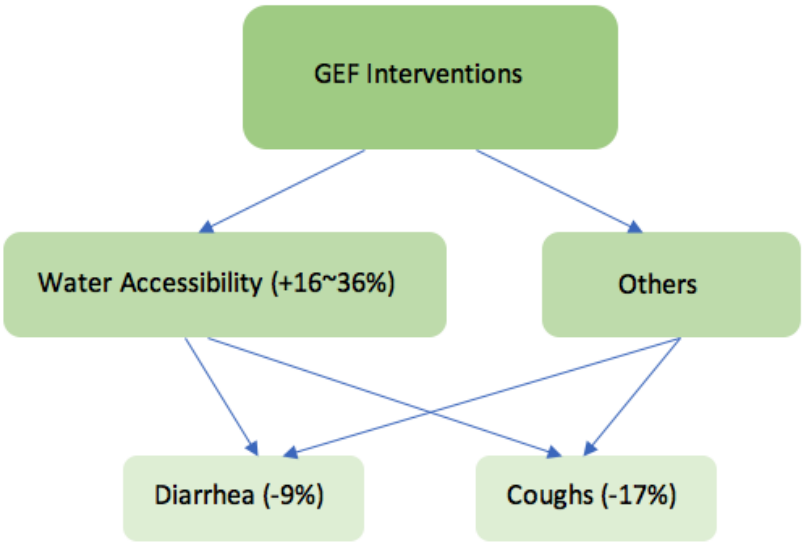
Quantifying the Association between GEF Interventions and Child Health in Kenya

Summary

The study presented here aims to quantify the association between GEF interventions and local health conditions of children under five years in Kenya, focusing on health measures including the prevalence of diarrhea and coughs. We test the hypothesis that improving environmental and socio-economic cobenefits of GEF project implementations may result in improved health outcomes. Our study found localized associations in both variables tested, with a 17% reduction in the prevalence of coughs within 10 km from the intervention areas and a 9% reduction in the prevalence of diarrhea was found within a distance smaller than 3 km. Besides the direct measure of health outcomes, GEF interventions also demonstrated positive impacts on water accessibility, including the access to source water in dwelling and the presence of water at hand-washing facilities. Past literature has shown these variables to be risk factors for diarrhea and/or coughs [1,2,3,4,5,6]. All the impacts above are stronger for clusters closer to GEF interventions. However, the estimated impacts on the health metrics were observed when the intermediate outcomes were controlled, meaning that GEF projects may also have influenced the metrics tested through other, still untested causal pathways.



Based on our study, we recommend the following steps to further understand the relationships between GEF interventions and the prevalence of diarrhea and coughing among children:

- Investigate GEF project components and identify other pathways through which GEF might impact the studied health outcomes
- Consider the health metrics that the GEF can impact - i.e., access to clean water - when choosing intervention sites. If two sites are equal in their potential environmental benefits, selecting sites with more vulnerable populations (i.e., those with poor access to water) may be appropriate.
- Perform the analysis with more precise distance measures (i.e., based on implementation GPS coordinates)
- Identify additional socioeconomic and health outcome data to enable a more detailed analysis of the distance decay of GEF impacts.
- Explore possible seasonal variances of GEF's impacts

Data Description and Methods

This analysis uses the health survey dataset from Kenya DHS 2014, which contains 1594 survey clusters - each cluster representing 19-25 households. The focal areas of

the GEF projects analyzed include biodiversity, land degradation, climate change, and sustainable forest management. Only projects started to be implemented before 2014 are considered for this analysis. The data is mapped in Figure 1(a) and Figure 1(b) with the prevalence of diarrhea and the prevalence of coughs respectively.

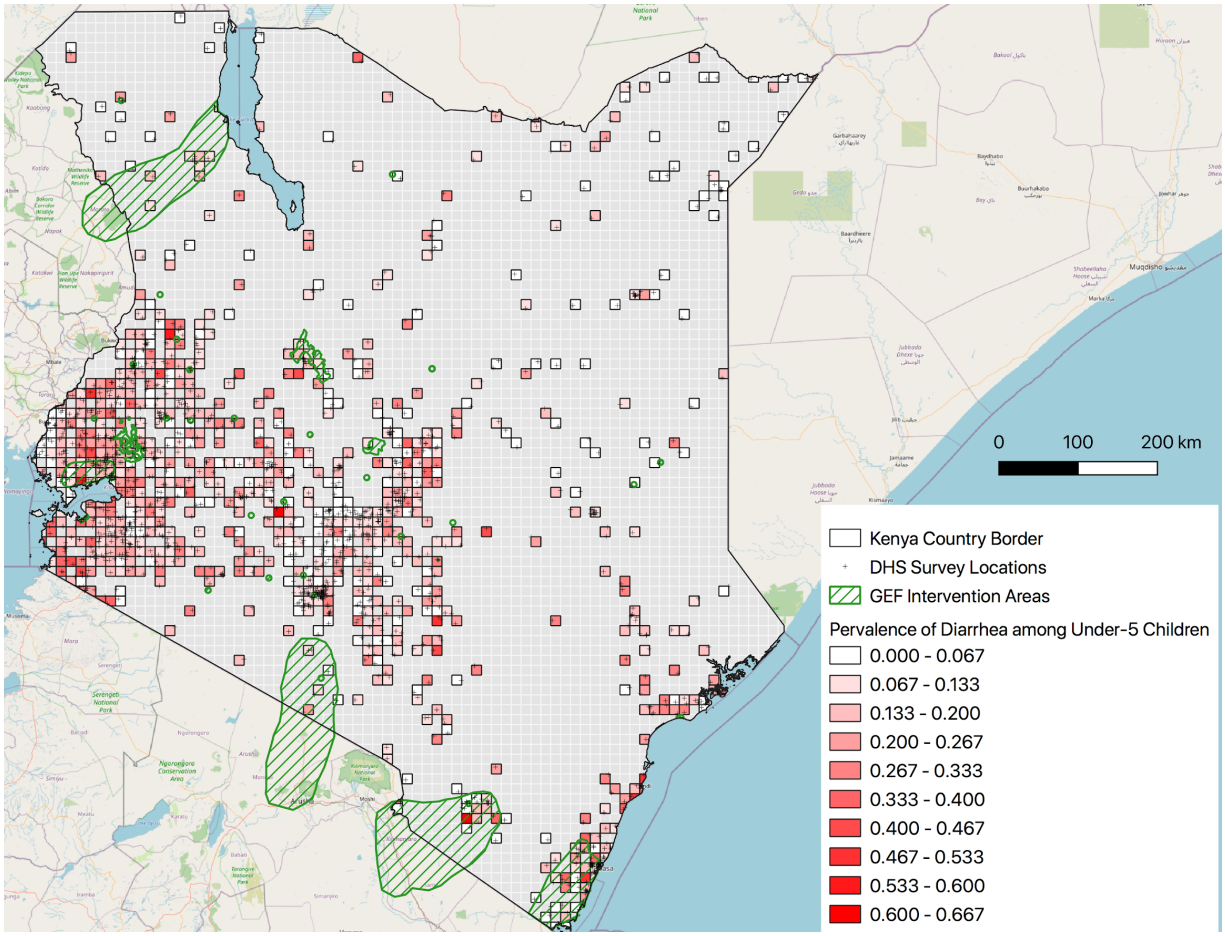


Figure 1 (a)

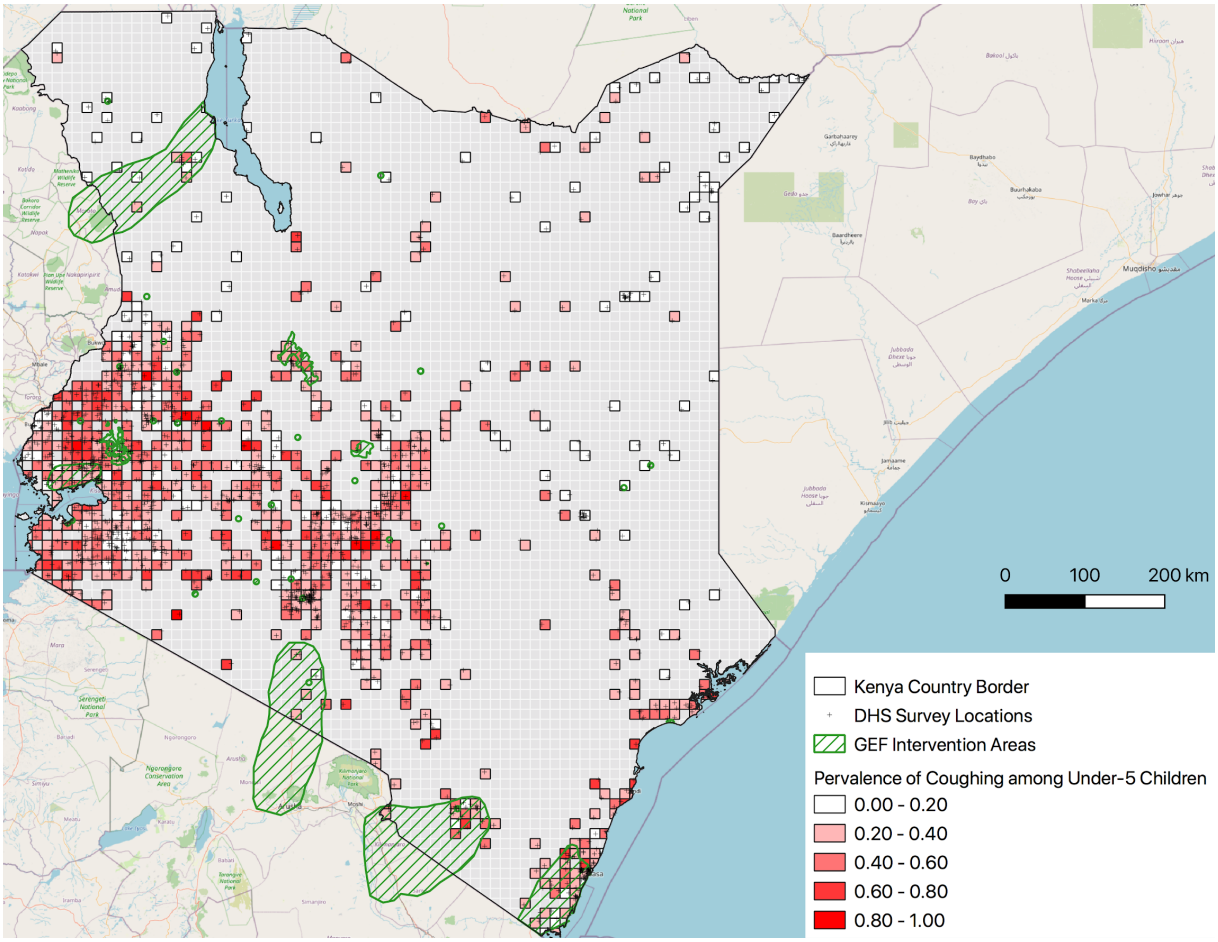


Figure 1 (b)

To quantify the association between GEF interventions and children's health conditions, a quasi-experimental geospatial interpolation (QGI) method is used on Kenya's DHS data. The QGI method needs three parameters: the sample density, the upper distance bound and the maximum matching difference. The QGI method uses a propensity-matching approach to pair treated and controlled survey clusters based on covariates. A treated cluster (i.e., a cluster close to a GEF project) and a controlled cluster (i.e., a cluster far from any GEF project) were paired if the difference in their propensity scores was smaller than the maximum matching difference. Then the outcome measures were contrasted within each pair to get an estimated impact, across all observations. This process was performed iteratively by increasing the radius of treated areas until it reaches the upper distance bound. The increase of radius in each

iteration is determined by the sample density. When the estimation was obtained for each iteration, the relationship between distance and the estimated association is modeled through a third-degree polynomial. More details on the QGI approach can be found in (Runfola et al. 2019).

Case Study 1: Diarrhea

Previous research[1] conducted by WHO has found that diarrhoeal diseases could be attributable to risk factors such as drinking water (34%), sanitation (19%), and hygiene(20%). Since there were GEF projects that directly sought to influence water access and quality, we were interested in studying the impact of GEF projects on improving the sources of drinking water and the accessibility of water for sanitation and hygiene. We also investigated potential impacts from GEF on the diarrhea prevalence among children under five years.

Relevant to drinking water, sanitation, and hygiene, three outcome variables are identified: the average quality of source water for drinking, the presence of water at handwashing facilities, and the accessibility to source water in dwelling. Through the QGI method, GEF interventions demonstrated significant impacts on the percentage of households with the accessibility to source water in dwelling and the presence of water at handwashing facilities. The results showed consistency across robustness tests (see Appendix II (c), (d)). Note that measures on children's counts on these two variables indicated a positive insignificant trend.

In addition to the impacts on selected risk factors, we estimated GEF's impacts on diarrhea prevalence. The prevalence was defined as the percentage of children having diarrhea within the past two weeks of their interviews. The QGI method measured the pure impact of GEF interventions on diarrhea prevalence by controlling variables in Table 1 (with a maximum matching difference of 0.3) . The results are illustrated in

Figure 2, where the x-axis is the distance between a survey location and its nearest project location and the y-axis is the estimated impact of GEF interventions on the percentage of children having diarrhea. We found that the prevalence of diarrhea was around 9% lower on average for survey locations closer than 3 km from GEF intervention areas, compared with the prevalence at survey locations 33 km away[1]. The impacts were significant at distances smaller than 3 km. Since GEF interventions also demonstrated impacts on a few control variables, the impacts on diarrhea prevalence might be underestimated and there were other causal pathways not yet been tested.

Because of the uncertainties regarding the sample density and the maximum matching difference, robustness tests were performed for sample densities ranging from 30*2 to 30*16 and maximum matching differences ranging from 0.1 to 0.75. Across these tests, the directionality of relationships observed remained consistent for all of the analysis mentioned above, though the magnitude of these relationships and the statistically significant distance intervals varied. Detailed test results can be seen in Appendix II (a), (b), and (d).

Outcome Variable	**Min**	**Median**	**Max**	**Resolution**	**Source**
Percentage of children having diarrhea in the past two weeks	0.00	0.13	1.00	Household	Demographic and Health Surveys (DHS)
Control Variable	**Min**	**Median**	**Max**	**Resolution**	**Source**
Percentage of children having water source at home	0.00	0.18	1.00	Household	Demographic and Health Surveys (DHS)
Percentage of children having electricity at home	0.00	0.06	1.00	Household	Demographic and Health Surveys (DHS)
Percentage of children having water at hand-washing facility	0.00	1.00	1.00	Household	Demographic and Health Surveys (DHS)
Average quality of source water for drinking	0.00	1.25	2.00	Household	Demographic and Health Surveys (DHS)
Average quality of toilet facility	0.00	1.00	2.00	Household	Demographic and Health Surveys (DHS)

[1] This upper-distance threshold is arbitrary; as such, robustness tests are conducted and included in the appendix.

Average quality of roof material	0.71	1.00	2.00	Household	Demographic and Health Surveys (DHS)
Wealth index	0.00	1.75	4.00	Household	Demographic and Health Surveys (DHS)
Percentage of children living with household members who wash their hands with soap	0.00	1.00	1.00	Household	Demographic and Health Surveys (DHS)
Average education level of mothers	0.00	1.28	3.00	Household	Demographic and Health Surveys (DHS)
Percentage of children living in households where water is purified before drinking	0.00	0.41	1.00	Household	Demographic and Health Surveys (DHS)
Aridity (2000)	3.30	27.92	72.70	55 km	Climate Research Unit
Mean temperature (2000)	14.18	21.35	30.10	55 km	Climate Research Unit
EVI (2000)	309.00	3388.70	5438.00	5 km	Climate Hazards Group
Annual precipitation (2000)	20.96	104.64	177.50	55 km	Climate Research Unit
Population (2015)	0.00	43206.14	645457.00	1 km	Global Human Settlement Layer (GHSL)
Nighttime luminosity (2015)	0.00	0.06	51.23	0.5 km	National Centers for Environmental Information
Travel time to population centers (2000)	0.00	31.04	652.82	1 km	Malaria Atlas Project
Proximity to water (2017)	0.00	52194.29	438089.30	1 m	Global Self-consistent, Hierarchical, High-resolution Geography Database(GSHHG)
Land surface temperature (2000)	12.60	23.36	38.41	6 km	MODIS

Table 1

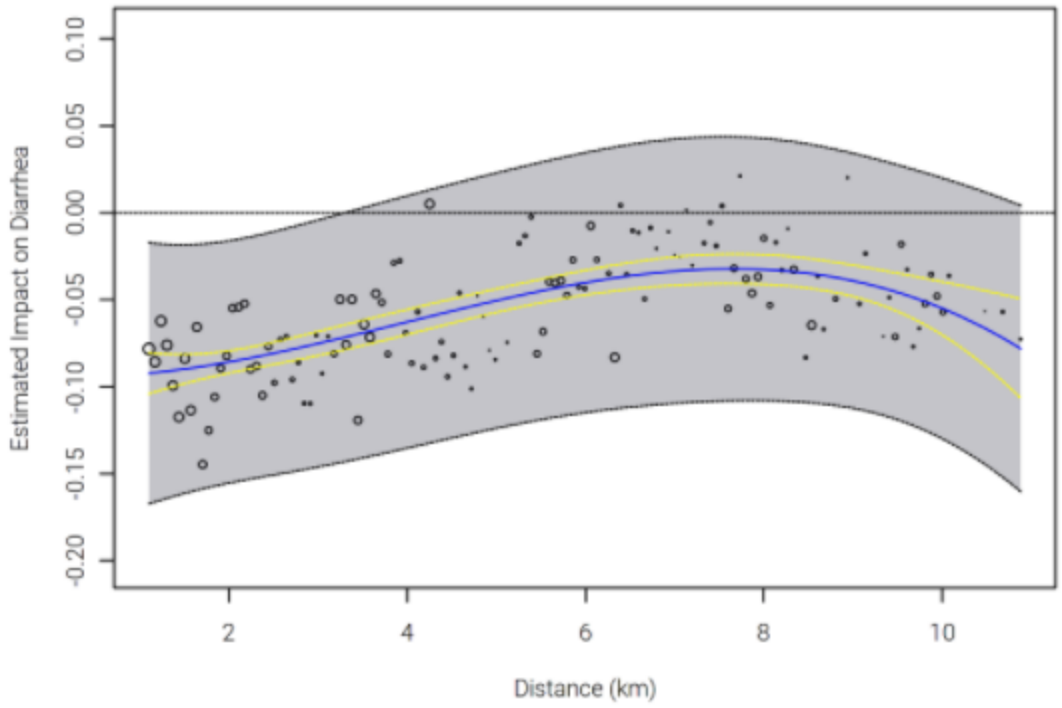


Figure 2

Case Study 2: Lower Respiratory Infections

Previous studies conducted by the World Health Organization (WHO)[1] have shown that environmental factors, including household air pollution from the use of solid fuels for cooking, can contribute to more than 50% of lower respiratory infections among children under five years in low- and middle-income countries. Inadequate hand hygiene and ambient air pollution are also considered risk factors of lower respiratory infections. As a primary or secondary outcome of many GEF projects is water quality and quantity as well as clean energy, we anticipate these projects might improve children's hand hygiene by improving their accessibility to water and reduce household air pollution by reducing the use of solid fuels like wood. Therefore, we are interested in how GEF projects could influence those risk factors and whether GEF ultimately had impacts on lower respiratory infections among under-5 children.

We used the QGI model to estimate GEF's impact on the use of solid fuels for cooking. Here, solid fuels include straw, grass, wood, agricultural crops, coal, etc. The model controlled a list of variables (see Table 2), but the impact was not statistically significant.

Outcome Variable	**Min**	**Median**	**Max**	**Resolution**	**Source**
Percentage of children living in households where solid fuel is used for cooking	0.00	1.00	1.00	Household	Demographic and Health Surveys (DHS)
Control Variable	**Min**	**Median**	**Max**	**Resolution**	**Source**
Percentage of children having water source at home	0.00	0.18	1.00	Household	Demographic and Health Surveys (DHS)
Percentage of children having electricity at home	0.00	0.06	1.00	Household	Demographic and Health Surveys (DHS)
Average quality of roof material	0.71	1.00	2.00	Household	Demographic and Health Surveys (DHS)
Wealth index	0.00	1.75	4.00	Household	Demographic and Health Surveys (DHS)
Average education level of mothers	0.00	1.28	3.00	Household	Demographic and Health Surveys (DHS)
Aridity (2015)	3.30	27.92	72.70	55 km	Climate Research Unit
Mean temperature (2015)	14.18	21.35	30.10	55 km	Climate Research Unit
EVI (2015)	309.00	3388.70	5438.00	5 km	Climate Hazards Group
Annual precipitation (2015)	20.96	104.64	177.50	55 km	Climate Research Unit
Population (2015)	0.00	43206.14	645457.00	1 km	Global Human Settlement Layer (GHSL)
Nighttime luminosity (2015)	0.00	0.06	51.23	0.5 km	National Centers for Environmental Information
Travel time to population centers (2015)	0.00	31.04	652.82	1 km	Malaria Atlas Project
Proximity to water (2017)	0.00	52194.29	438089.30	1 m	Global Self-consistent, Hierarchical, High-resolution Geography Database(GSHHG)
Land surface temperature (2015)	12.60	23.36	38.41	6 km	MODIS

Table 2

To estimate potential impacts on lower respiratory infections, we chose the prevalence of coughing among children under five years as an outcome measure. The pure impacts of GEF projects were estimated through the QGI model with the control variables listed in Table 3. The maximum matching difference was set to 0.2. Figure 3 illustrates the fitted regression line for the estimated impact of GEF projects on the prevalence of coughing. The impacts were significant for distances smaller than 10 km. Compared with clusters not proximate to GEF projects, communities within 10km of GEF interventions have estimated prevalence of coughing 17% less, on average. As shown in the appendix, we also find that the GEF has influence on two control variables potentially associated with coughing - accessibility to water and handwashing facilities.

The result was robust in terms of the dictionary in the relationship, despite the small variations in magnitude (see Appendix II (e)). Similar to the study of diarrhea prevalence, the impacts on the prevalence of coughing might be underrated as GEF projects also influenced some control variables (e.g. the accessibility to water), and GEF projects impacted the prevalence of coughing in other ways that we could not capture.

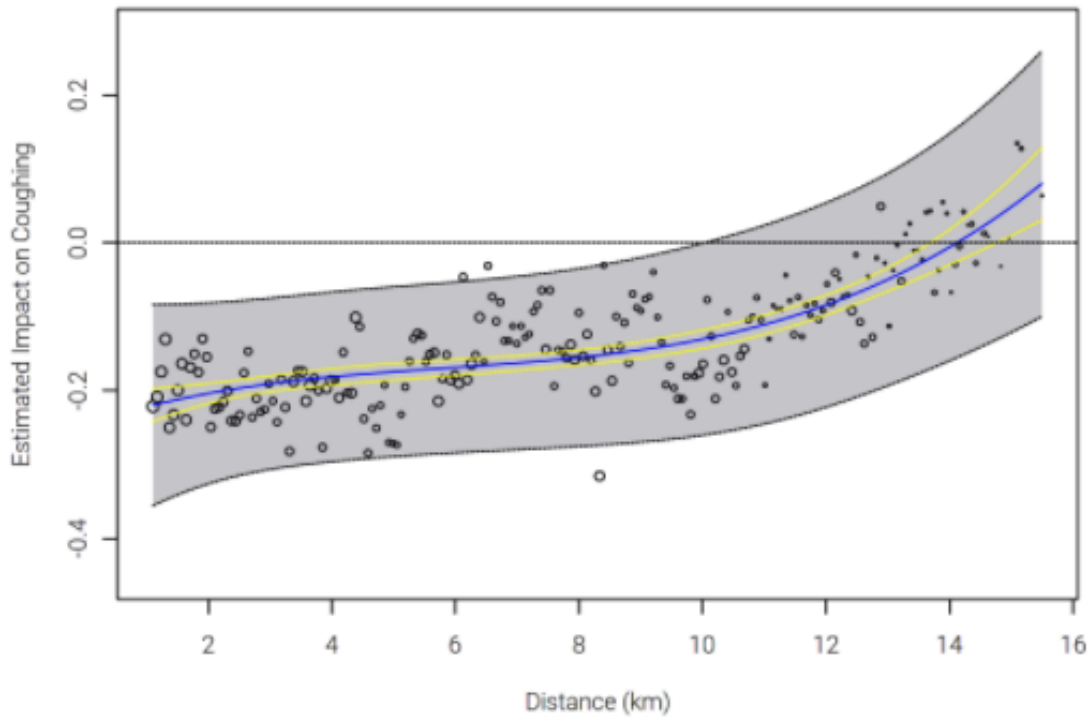


Figure 3

Outcome Variable	Min	Median	Max	Resolution	Source
Percentage of children having coughs in the past two weeks	0.00	0.35	1.00	Household	Demographic and Health Surveys (DHS)
Control Variable	**Min**	**Median**	**Max**	**Resolution**	**Source**
Percentage of children having water source at home	0.00	0.18	1.00	Household	Demographic and Health Surveys (DHS)
Percentage of children having electricity at home	0.00	0.06	1.00	Household	Demographic and Health Surveys (DHS)
Percentage of children having water at hand-washing facility	0.00	1.00	1.00	Household	Demographic and Health Surveys (DHS)
Average quality of roof material	0.71	1.00	2.00	Household	Demographic and Health Surveys (DHS)
Wealth index	0.00	1.75	4.00	Household	Demographic and Health Surveys (DHS)
Percentage of children living in a household where a separated room is used as kitchen	0.00	0.25	1.00	Household	Demographic and Health Surveys (DHS)
Average number of household members sharing one sleeping room	1.00	3.55	10.00	Household	Demographic and Health Surveys (DHS)

Average frequency of household members smoking at home	0.00	0.00	4.00	Household	Demographic and Health Surveys (DHS)
Percentage of children living in households where solid fuel is used for cooking	0.00	1.00	1.00	Household	Demographic and Health Surveys (DHS)
Average education level of mothers	0.00	1.28	3.00	Household	Demographic and Health Surveys (DHS)
Percentage of children living in households where water is purified before drinking	0.00	0.41	1.00	Household	Demographic and Health Surveys (DHS)
Aridity (2000)	3.30	27.92	72.70	55 km	Climate Research Unit
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Table 2

Limitations

Possible errors include inaccurate distance measures, seasonal biases and the mismatch in time of some covariates. In this study, distances were calculated as the

distances between survey clusters and the boundaries of GEF interventions. Since our dataset only contained polygons for SFM project boundaries, we created 3 km buffers to represent intervention areas for those projects with point locations only. This representation may not precisely reflect the intervention areas. Moreover, for privacy concerns, the locations of survey clusters are randomly displaced up to 2 km for urban areas and up to 5 km for rural areas, which also introduces inaccuracies in the distance measure. Besides the distance and outcome measures, the data for some of the geographical characteristics (see Table 1) of the survey locations was from 2015, which was one year after our year of study.

Besides possible errors in the data, there were a few limitations in our findings. First, we were not sure if the impacts on the prevalence of diarrhea and coughing were localized, since the significant distance range varied for different sample densities. This is also influenced by the distribution of the distances, as there are fewer clusters farther away from GEF locations - i.e., it is harder to detect statistical significance due to a smaller N as distances increase. Second, the estimated impacts on the health metrics were observed when the intermediate outcomes (e.g. water accessibility) were controlled, meaning that GEF projects may influence the metrics through other factors that have not yet been recognized.

References

[1] World Health Organization. 2016. *Preventing Disease Through Healthy Environments: A Global Assessment Of The Burden Of Disease From Environmental Risks*. [online] Available at: <https://www.who.int/quantifying_ehimpacts/publications/preventing-disease/en/> [Accessed 25 August 2020].

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Appendix I: QGI Result for Intermediate Outcomes

outcome	mean	significant distance interval	Control Variables	sample density	maximum matching difference	upper distance bound
percentage of households accessible to water at hand-washing facilities	36%	1-4 km	1. Wealth index 2. Month of Interview 3. Aridity (2000) 4. Mean Temperature (2000) 5. EVI (2000) 6. Annual Precipitation (2000) 7. Nighttime luminosity (2015) 8. Travel time to population centers (2015) 9. Proximity to water (2017) 10.Land surface temperature (2015)	30*16	0.2	0.4
percentage of households having water source in dwelling	16%	1-3 km		30*16	0.2	0.3
average water quality	Not significant					
percentage of households using solid fuels for cooking	Not significant					

Appendix II: Robustness Test Results

Outcome	**Sample Density**	**Maximum Matching Difference**	**Mean**	**Significant Distance Interval**
percentage of children experienced coughing in the past two weeks	30*16	0.3	-17%	1-10 km
	30*8	0.3	-16%	1-9 km
	30*4	0.3	-17%	1-6 km
	30*2	0.3	-22%	2-4 km
	30*16	0.1	NaN	NaN
	30*16	0.2	-18%	1-10 km

	30*16	0.4	-17%	1-10 km
	30*16	0.5	-17%	1-9 km
	30*16	0.6	-21%	1-9 km
	30*16	0.75	NaN	NaN

(a)

Outcome	Sample Density	Maximum Matching Difference	Mean	Significant Distance Interval
percentage of children having water source in dwelling	30*16	0.2	16%	1-3 km
	30*8	0.2	14%	1-4 km
	30*4	0.2	15%	2-5 km
	30*2	0.2	16%	3-6 km
	30*16	0.1	16%	1-3 km
	30*16	0.3	16%	1-2 km
	30*16	0.4	16%	1-2 km
	30*16	0.5	15%	1-2 km
	30*16	0.6	16%	1-2 km
	30*16	0.75	16%	1-2 km

(b)

Outcome	Sample density	Maximum Matching Difference	Mean	Significant Distance Interval
children's accessibility to water at handwashing facilities	30*16	0.2	36%	1-4 km
	30*8	0.2	38%	1-3 km
	30*4	0.2	NaN	NaN
	30*2	0.2	NaN	NaN
	30*16	0.1	NaN	NaN
	30*16	0.3	36%	1-4 km
	30*16	0.4	38%	1-3 km
	30*16	0.5	38%	1-3 km
	30*16	0.6	39%	1-3 km
	30*16	0.75	40%	1-2 km

(c)

Outcome	Sample density	Maximum Matching Difference	Mean	Significant Distance Interval
	30*16	0.3	-9%	0-3 km
	30*8	0.3	-8%	0-3 km
	30*4	0.3	-9%	0-3 km
	30*2	0.3	NaN	NaN
	30*16	0.1	NaN	NaN
	30*16	0.2	-10%	1-2 km
	30*16	0.4	-9%	0-3 km
	30*16	0.5	-9%	0-3 km
	30*16	0.6	-8%	0-4 km
diarrhea	30*16	0.75	-9%	0-3 km

(d)