Supplementary Information for
Recently constructed hydropower dams reduced economic production, population, and environment in nearby areas

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Other supplementary materials for this manuscript include the following:

Dataset S1. Selected hydro-power dams for this study (separate file)

Supplementary Text

Materials

Active dam builders in the Global South

Asia and South America have led in hydropower dam construction in recent decades. Asia accounts for 36% of the number and 76% of capacity of recently constructed hydropower dams (total=632). China and countries in the Mekong River Basin are the most active dam builders in Asia, with China and Vietnam leading in building large- and medium/small-sized dams, respectively. As the largest renewable energy source and the second largest energy source (after coal), hydroelectricity in China reached 356GW in 2019, generating ~18% of China's overall electricity. This represents about 27% of the world's installed capacity [1]. China hosts two of the world's largest hydropower dams -- Three Gorges Dam and Xiluodu Dam, both commissioned and constructed in the new millennium, with installed capacities of 22.5GW and 13.9GW, respectively. The recently constructed dams in Asia had an average hydropower capacity of 410MW, with the highest from Xiluodu (12.6GW) and the lowest from Gusar (1MW) in Azerbaijan and Houli (1MW) in Taiwan.

The Mekong River Basin experienced a booming construction over the past two decades. The Mekong, one of world's last large rivers, remained mostly undammed until the early 2000s [2], when it became a hotspot for dam construction. There were 102 commissioned dams, as well as 41 under construction, 78 planned, and 15 proposed along the river by 2017 [3]. The proliferation of hydropower dams may be due to the accelerated impacts of global climate change for the region, where dams can help to mitigate extreme climate events such as flooding and droughts that directly affect irrigation for agriculture. These dams are also expected to increase energy security for the region [4]. Of the 228 newly constructed dams in Asia, two-thirds are located in the Mekong River Basin region. Vietnam topped in the number of dams (58% of dams in Asia) after 2000, with most being small- and medium-sized. The country constructed 38 out 40 small-sized dams, 89 out of 136 medium-sized dams, and 7 out of 52 large-sized dams. In addition to Vietnam, Laos PDR, Myanmar, Cambodia are also avid dam builders. While they are latecomers in dam construction, they engaged in planned efforts to promote their hydropower sectors, with strong involvement of Chinese and Vietnam corporations. It is worth mentioning that India and Russia are also active dam builders in Asia; they are ranked fifth and seventh place in hydropower capacity in 2019, respectively [1].

Recent hydropower dam construction in South America has been dominated by Brazil, which has built 292 out 298 dams in the continent. With 75% of its electricity coming from hydropower, Brazil is the second largest producer of hydroelectricity in the world, next to China [1]. In 2019 Brazil led in the new installed capacity by 4919MW, more than China (4170MW) [1]. The most notable hydropower dams in Brazil are Itaipu Dam completed in 1984 at the border of Brazil and Paraguay, and Belo Monte Dam completed in 2019; they ranked as the world's third and fourth largest hydro dams after China's Three Gorges Dam and Xiluodu Dam. Located on the northern side of the Xingu River, Belo Monte Dam has an installed capacity of 11.2GW. Because they were completed in 1984 and 2019, these dams are not included in our study. The 298 dams in South America had a much smaller average installed capacity (74MW) when compared with the Asian dams, with the largest from Jirau (3568MW).

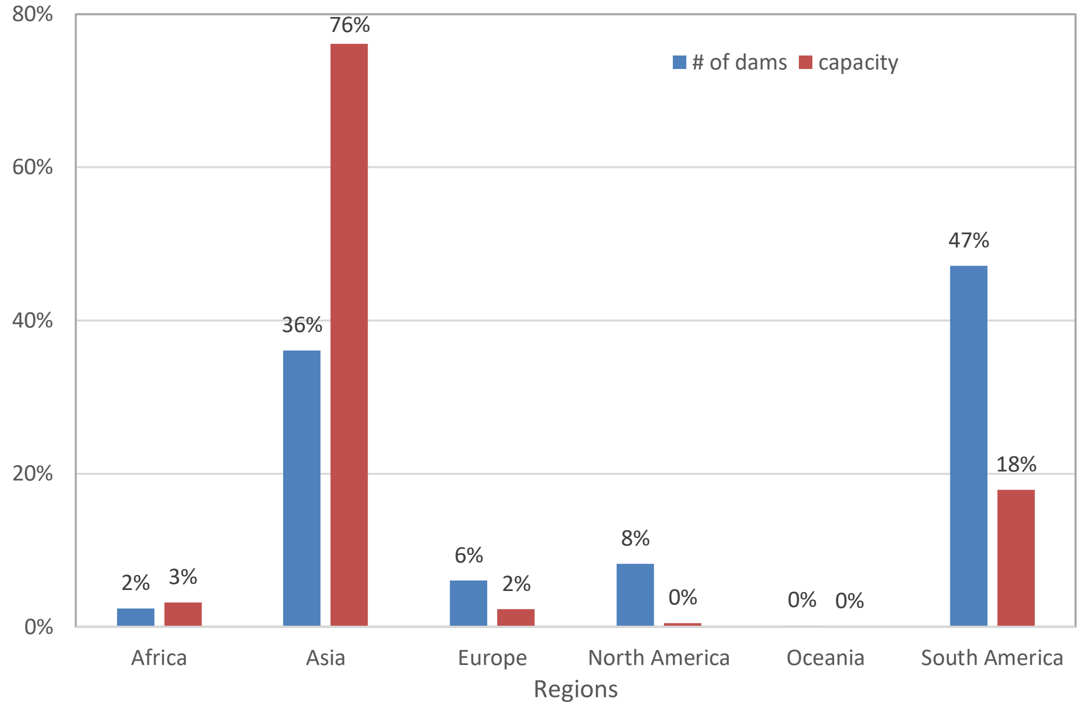

Figure. S1. Distribution of recently constructed hydropower dams by number hydropower capacity. These 632 dams are predominately medium- and small-sized (53% and 35%, respectively) and located mostly in South America (47%) and Asia (37%). Asia leads in total capacity, with hydropower dams contributing 76% of total newly added capacity.

Table S1. Indicators and spatial datasets used for this analysis

Indicator	Unit	Spatial Resolution	Availability	Source & processing
NDVI	-	250 m	2000 - current	MODIS
Urban land	km^2	500 m	2001 - current	MODIS
Population density	Population/km^2	1 km	2000 - current	LandScan
GDP	US$ *	5 arc min.	1990 - 2015	Kummu *et al*. (2018) [5]
Nighttime light	-	1km	1992 - 2018	DMSP-OLS & VIIRS-DNB

Note: Monetary values are in constant 2011 international US$.

Table S2. Profiles of hydropower dams (≥1MW) constructed after 2001 and commissioned no later than 2015 in the WRI database

Regions	Africa	Asia	Europe	N. Amer.	Oceania	S. Amer.	Total
Number							
Small	2	40	19	39	0	126	226
Medium	9	136	15	13	1	159	333
Large	4	52	4	0	0	13	73
Total	15	228	38	52	1	298	632
Capacity (MW)							
Small	10	218	65	164	0	460	916
Medium	728	12813	626	431	40	6121	20760
Large	3150	80547	2133	0	0	15364	101194
Total	3887	93578	2824	595	40	21945	122870
Average capacity (MW)							
Small	5	5	3	4	0	4	4
Medium	81	94	42	33	40	38	62
Large	788	1549	533	0	0	1182	1386
Total	259	410	74	11	40	74	194

Table S3. Correlation matrixes of impacts of 631 recently constructed dams

Zone 1 (<5km)	△GDP	△Urban	△NTL	△Pop	△NDVI	**Zone 2 (5-20km)**	△GDP	△Urban	△NTL	△ Pop	△NDVI
△GDP	1.000	**0.283**	**0.215**	**0.239**	-0.030	△GDP	1.000	**0.408**	**0.218**	**0.463**	0.010
△Urban		1.000	**0.250**	0.360	-0.014	△Urban		1.000	**0.338**	**0.452**	0.005
△NTL			1.000	**0.154**	-0.100	△NTL			1.000	**0.459**	0.012
△Pop				1.000	0.010	△Pop				1.000	0.068
△NDVI					1.000	△NDVI					1.000
Zone 3 (20-50km)	△GDP	△Urban	△NTL	△Pop	△NDVI	**Ref. Zone (50-60km)**	△GDP	△Urban	△NTL	△ Pop	△NDVI
△GDP	1.000	**0.436**	**0.249**	**0.453**	-0.002	△GDP	1.000	**0.562**	**0.243**	**0.417**	-0.076
△Urban		1.000	**0.365**	**0.524**	-0.043	△Urban		1.000	**0.327**	**0.442**	-0.099
△NTL			1.000	**0.535**	-0.022	△NTL			1.000	**0.454**	0.013
△Pop				1.000	0.000	△Pop				1.000	-0.056
△NDVI					1.000	△NDVI					1.000

Note: Correlations that are significant are bolded ($p<0.001$).

△GDP, △urban, △NTL, and △population are positively correlated with each other significantly for Zones 1, 2, and 3 and the reference zone, except for △urban and △population for Zone 1. However, △NDVI showed no significant correlation with △GDP, △urban, △NTL, and △ population. △NDVI is negatively correlated with △GDP, △urban, and △NTL, but positively correlated with △population for Zone 1 (<5km) and Zone 3 (20-50km), whereas △NDVI is positively correlated with △GDP, △urban, △NTL, and △population.

Table S4. Proportions of land cover types of nearby areas of 631 recently constructed dams

Continent	Cropland	Forest	Grass /Shrubland	Built-up area	Bare area	Water body
Africa	49.2%	14.6%	23.6%	0.2%	6.9%	5.0%
Asia	38.2%	33.0%	24.1%	0.4%	1.6%	2.6%
Europe	38.9%	34.0%	23.9%	1.1%	0.6%	1.3%
North America	14.1%	53.9%	23.8%	0.8%	0.7%	6.6%
South America	50.1%	36.6%	11.2%	0.1%	0.3%	1.2%
Global North	24.3%	45.7%	23.8%	0.9%	0.7%	4.4%
Global South	44.7%	33.9%	17.6%	0.2%	1.2%	2.0%
Global Total	39.9%	36.6%	19.1%	0.4%	1.1%	2.6%

Note: The Global South has more cropland (44.7%) than the Global North (24.3%) but less forest, grass/shrubland, and built-up areas (33.9%, 17.6%, and 0.2%) than the Global North (45.7%, 23.8%, 0.9%) in the NAHDs of the 631 dams.

SI References

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