The decline of global per capita renewable internal freshwater resources

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Abstract

Supplies of per capita renewable internal freshwater resources are declining at alarming rates around the globe, necessitating efforts to better manage population growth and the use and distribution of freshwater. All major geographic regions saw substantial reductions in per capita renewable internal freshwater supplies between 1962 and 2011. Over this period, the global per capita freshwater stock declined by 54%, with decreases of 75% in Sub-Saharan Africa, 71% in the Middle East and North Africa, 64% in South Asia, 61% in Latin America and the Caribbean, 52% in East Asia and the Pacific, and 41% in North America. At current rates of depletion, global per capita renewable internal freshwater resources are projected to decline by 65% compared to 1962 values before stabilizing, having regional variation ranging from 60% in East Asia and the Pacific to 86% of the Middle East and North Africa. Sub-Saharan Africa is predicted to reach a negative per capita renewable internal freshwater balance by the year 2120. Per capita renewable internal freshwater resources are declining more rapidly in low income countries than their middle and high income counterparts. All countries except Hungary and Bulgaria experienced declines in their per capita renewable internal freshwater supply between 1962 and 2011. Most countries (55%) experienced a decline of between 60% to 80% in per capita renewable internal freshwater resources over this period. The majority of nations are projected to maintain positive per capita renewable internal freshwater balances under steady-state conditions, although overall declines of between 80% to almost 100% from 1962 levels are dominant (∼52% of all countries). A group of 28 nations is projected to reach zero per capita internal freshwater resources within the near future. African countries dominate the list of nations projected to reach zero per capita internal freshwater resources, comprising 16 of the 28 countries - of which six are landlocked. A further group of 25 nations have data records that are too short, and recent population dynamics that are generally too complex, for reliable trend extrapolation. Close attention will need to be paid to the per capita renewable internal freshwater resource trends for these countries over the coming decades in order to obtain a better understanding of their resource depletion rates.

Keywords:
Water resources, Freshwater, Environmental policy, Environmental degradation

Introduction

Increasing strain is being placed on worldwide water resources, leading to concerns over progressively decreasing quantity and quality [1–3]. Here we show that supplies of per capita renewable internal freshwater resources [4] are declining at alarming rates around the globe, necessitating efforts to better manage population growth and the use and distribution of freshwater. All major geographic regions saw substantial reductions in per capita renewable internal freshwater supplies between 1962 and 2011 (Figure 1). Over this period, the global (WLD) per capita freshwater stock declined by 54% (Table 1), with declines of 75% in Sub-Saharan Africa (SSF), 71% in the Middle East and North Africa (MEA), 64% in South Asia (SAS), 61% in Latin America and the Caribbean (LCN), 52% in East Asia and the Pacific (EAS), and 41% in North America (NAC).

At current rates of depletion, exponential decay projections (of the form y=a×e$^{(bx)}$+c) yield the following steady-state per capita renewable internal freshwater supplies (values are in m^3; 1962, 2011, and 1962-steady-state percent reductions are given in brackets): WLD, 4,600 [13,200 / 6,100 / -65%]; EAS, 3,900 [9,600 / 4,600 / -60%]; LCN, 16,300 [58,000 / 22,600 / -72%]; MEA, 300 [2,100 / 600 / -86%]; NAC, 4,200 [27,600 / 16,400 / -85%]; SAS, 600 [3,300 / 1,200 / -82%]; and SSF, -200 [17,600 / 4,500 / n/a]. Sub-Saharan Africa is predicted to reach a negative per capita renewable internal freshwater balance by the year 2120.

The Europe and Central Asia region only has per capita renewable internal freshwater supply data available since 1992, yielding five datapoints (1992, 1997, 2002, 2007, and 2011) between 1992 and 2011 - which is insufficient for reli-

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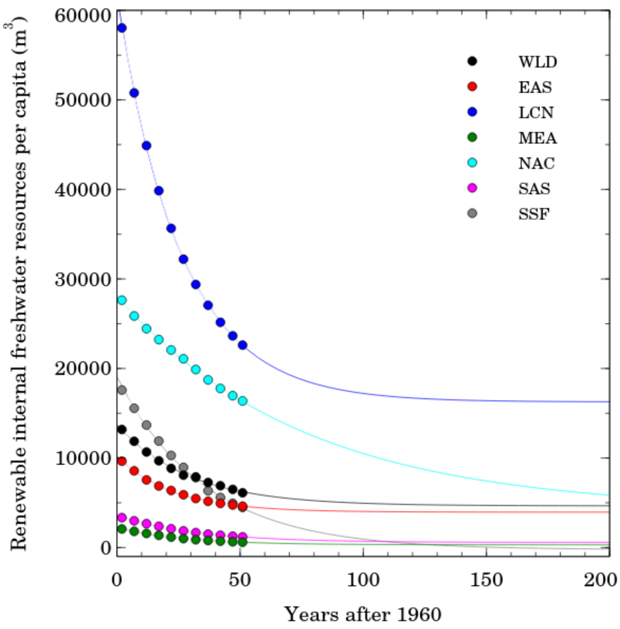

Figure 1: Trends in renewable internal freshwater resources per capita by geographic region between 1962 and 2011. WLD=World, EAS=East Asia and the Pacific, LCN=Latin America and the Caribbean, MEA=Middle East and North Africa, NAC=North America, SAS=South Asia, and SSF=Sub-Saharan Africa.

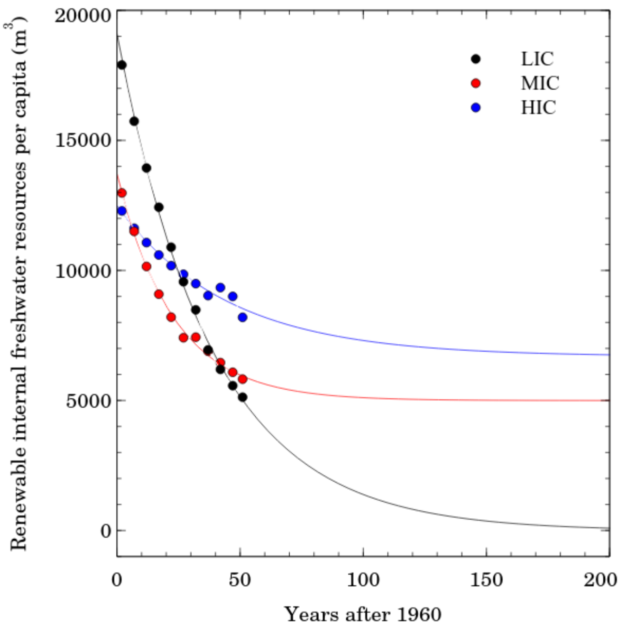

Figure 2: Trends in renewable internal freshwater resources per capita by income class between 1962 and 2011. LIC=Low Income Countries, MIC=Middle Income Countries, and HIC=High Income Countries

able trend extrapolations. A higher resolution record over this period can be obtained by utilizing total renewable internal freshwater resources for this region [5], provided on a five-year interval between 1992 and 2007 and a four-year interval between 2007 and 2011, coupled with annual total population data [6]. Via this approach, an annual per capita renewable internal freshwater supply record can be constructed. In general, the World Bank's records for total renewable internal freshwater resources by various divisions (e.g., region, income class, country, etc.) are invariant with time. This represents a physically unrealistic situation, since total renewable internal freshwater resources within all geographic subdivisions must vary over time due to net depletions/additions from anthropogenic activities coupled with changing annual water balances driven by climatic variability. Consequently, trends in renewable internal freshwater resources per capita considered herein are being driven effectively entirely by population changes, and do not incorporate changes in the resource base itself. As such, for many regions, supplies of per capita renewable internal freshwater resources reported in ref. [4] may be significantly under- or over-estimated.

Europe and Central Asia is one of the few regions reporting any change in total renewable internal freshwater resources between 1992 and 2011. The resource quantity in each reporting year is as follows (values in billions of m^3): 1992, 7,038; 1997, 7,064; 2002, 7,667; 2007, 7,675; and 2011, 7,072. The reasons for the substantial increase between 1997 and 2002, and corresponding decline of approximately equal magnitude between 2007 and 2011, are unknown. Since no individual nations exhibited changes in their total renewable internal freshwater resources over these time periods, we must assume the changes reported for the Europe and Central Asia region as a whole during the 1997-2002 and 2007-2011 intervals are incorrect. Thus, we employ a value of 7,058 billion m^3 for our analyses between 1992-2011, equal to average of the 1992, 1997, and 2011 data. The resulting annual per capita renewable internal freshwater supply data for this region between 1992 and 2011 is best fit via linear regression, giving an approximate x-intercept for resource depletion in the year 2390.

Per capita renewable internal freshwater resources are declining more rapidly in low income countries (LIC; 2011 gross national income [GNI] of $1,025 or less) than their middle income (MIC; 2011 GNI $1,026-$12,475) and high income (HIC; 2011 GNI of $12,476 or more) counterparts (Figure 2). In 1962, the order of per capita renewable internal freshwater supplies was LIC>MIC>HIC. By 2002, this order had been reversed to LIC<MIC<HIC. Exponential decay projections yield the following steady-state per capita renewable internal freshwater supplies (values are in m^3; 1962, 2011, and 1962-steady-state percent reductions are given in brackets): LIC, -13 [17,900 / 5,100 / n/a]; MIC, 5,000 [13,000 / 5,800 / -61%]; and HIC, 6,700 [12,300 / 8,200 / -45%]. Low income countries are predicted to reach a negative per capita renewable internal freshwater balance by the early 23rd century.

Renewable internal freshwater resources per capita by country in 1962, 2011, and the percent change over this

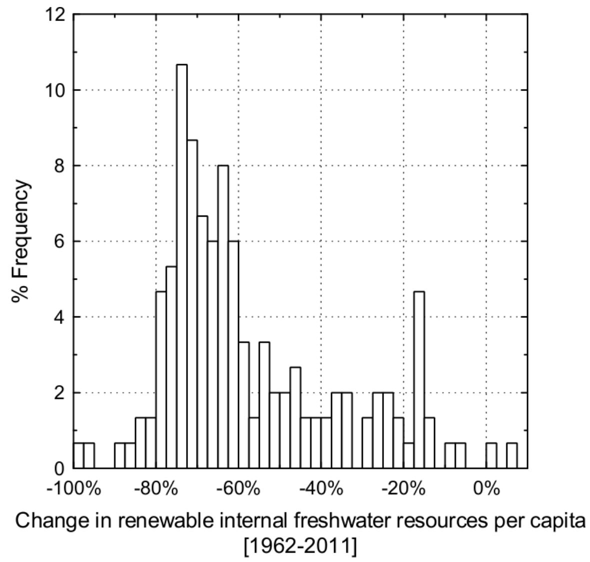

Figure 3: Histogram of the change in renewable internal freshwater resources per capita over all nations between 1962 and 2011.

timeframe are provided in Table 1. All countries except Hungary (+0.9%) and Bulgaria (+7.2%) experienced declines in their per capita renewable internal freshwater supply between 1962 and 2011. Kuwait is not included in this list as it has always been ranked as having no renewable internal freshwater resources. The following nations have incomplete data records over this period and are also not included in Table 1: Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Croatia, Czech Republic, Eritrea, Estonia, Ethiopia, Georgia, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Macedonia, Moldova, Russian Federation, Serbia, Slovak Republic, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, and the West Bank and Gaza. Remarkably high rates of depletion have taken place in the United Arab Emirates (-98.6%) and Qatar (-97.0%) over the past half-century, effectively depleting the resource. A histogram of the change in renewable internal freshwater resources per capita over all nations (Figure 3) shows that most countries (55%) experienced a decline of between 60% to 80% between 1962 and 2011.

A summary of the data for nations without complete records from 1962 to 2011 is given in Table 2. With four individual data points or less available for each country, detailed regression fitting models cannot be employed. However, it is clear that Azerbaijan, Eritrea, Ethiopia, the Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan, and the West Bank and Gaza are depleting their per capita renewable internal freshwater resources at a rapid rate. If these declines continue in a linear fashion, resource depletion will occur by the year 2094 for Azerbaijan, 2033 for Eritrea, 2045 for Ethiopia, 2096 for the Kyrgyz Republic, 2085 for Tajikistan, 2073 for Turkmenistan, 2066 for Uzbekistan, and 2031 for the West Bank and Gaza. The nations with apparent increases in per capita renewable

Table 2: Renewable internal freshwater resources per capita by country for nations lacking a complete 1962 to 2011 data record.

Country	Record length	2011[a]	Δ[b]
Armenia	1992-2011	2,200	11.3%
Azerbaijan	1992-2011	880	-19.5%
Belarus	1992-2011	3,900	7.8%
Bosnia and Herzegovina	1992-2011	9,500	4.8%
Croatia	1992-2011	8,600	1.4%
Czech Republic	1997-2011	1,200	-2.3%
Eritrea	1997-2011	520	-38.4%
Estonia	1992-2011	9,500	14.4%
Ethiopia	1997-2011	1,400	-28.6%
Georgia	1992-2011	13,000	8.6%
Kazakhstan	1992-2011	3,900	-0.7%
Kyrgyz Republic	1992-2011	8,900	-18.0%
Latvia	1992-2011	7,500	17.8%
Lithuania	1992-2011	4,900	15.5%
Macedonia, FYR	1992-2011	2,600	-6.3%
Moldova	1992-2011	280	4.2%
Russian Federation	1992-2011	30,400	4.8%
Serbia	2007-2011	1,200	1.7%
Slovak Republic	1997-2011	2,300	-1.0%
Slovenia	1992-2011	9,100	-2.7%
Tajikistan	1992-2011	9,100	-20.9%
Turkmenistan	1992-2011	270	-24.0%
Ukraine	1992-2011	1,200	14.1%
Uzbekistan	1992-2011	560	-26.9%
West Bank and Gaza	1992-2011	200	-46.2%

[a] Per capita renewable internal freshwater resources in 2011. Values are in m^3. [b] Change in per capita renewable internal freshwater resources over the available record length.

internal freshwater resources over their short-term records (Armenia, Belarus, Bosnia and Herzegovina, Croatia, Estonia, Georgia, Latvia, Lithuania, Moldova, the Russian Federation, Serbia, and the Ukraine) all achieved this goal via population reductions. However, Armenia and Georgia have recently achieved net population growth, whereas Belarus, Bosnia and Herzegovina, Croatia, Estonia, Latvia, Lithuania, Moldova, the Russian Federation, Serbia, and the Ukraine remain in net population decline. For the nations with continuing net population declines, per capita renewable internal freshwater resources are expected to remain stable or increase in the near future. Over the past decade, population growth has accelerated in the Czech Republic, Kazakhstan, the Slovak Republic, and Slovenia. If these trends continue, expected rates of per capita renewable internal freshwater resource depletion for these countries during the 21^{st} century will be much higher than expected from extrapolating the recent short-term declines provided in Table 2.

Among countries with complete data records from 1962 to 2011, the majority are projected to maintain positive per capita renewable internal freshwater balances under steady-state conditions (Table 3). Projected changes in renewable internal freshwater resources per capita over all nations between 2011 and the anticipated steady-state conditions are distributed approximately evenly (Figure 4(a)), whereas the predicted changes between 1962 and steady-state conditions illustrate that the majority ($\sim$52%) of countries are expected to experience overall declines of between 80% to almost 100% (Figure 4(b)).

A group of 28 nations is projected to reach zero per

Table 1: Renewable internal freshwater resources per capita by country in 1962, 2011, and the percent change (Δ) over this timeframe.

Rank	Country	1962 [a]	2011	Δ	Rank	Country	1962	2011	Δ	Rank	Country	1962	2011	Δ
1	United Arab Emirates	1,377	19	-98.6%	51	Maldives	315	94	-70.3%	101	Chile	109,810	51,188	-53.4%
2	Qatar	1,002	30	-97.0%	52	Guatemala	24,867	7,400	-70.2%	102	Korea, Dem. Rep.	5,837	2,740	-53.1%
3	Djibouti	3,136	331	-89.4%	53	Malaysia	66,591	20,098	-69.8%	103	El Salvador	6,014	2,850	-52.6%
4	Bahrain	23	3	-87.0%	54	Costa Rica	78,553	23,780	-69.7%	104	Australia	45,802	21,750	-52.5%
5	Jordan	723	110	-84.7%	55	Paraguay	46,786	14,311	-69.4%	105	Lebanon	2,367	1,127	-52.4%
6	Saudi Arabia	557	85	-84.6%	56	Somalia	2,032	628	-69.1%	106	Fiji	67,724	32,876	-51.5%
7	Andorra	20,578	3,663	-82.2%	57	Iran, Islamic Rep.	5,547	1,718	-69.0%	107	China	4,225	2,093	-50.5%
8	Cote d'Ivoire	19,568	3,813	-80.5%	58	Algeria	1,004	313	-68.8%	108	Sri Lanka	5,056	2,530	-50.0%
9	Oman	2,396	492	-79.5%	59	Zimbabwe	3,060	961	-68.6%	109	Cyprus	1,350	699	-48.3%
10	Kenya	2,399	497	-79.3%	60	Gabon	333,751	106,892	-68.0%	110	Argentina	12,959	6,771	-47.8%
11	Uganda	5,386	1,130	-79.0%	61	Ecuador	91,787	29,456	-67.9%	111	Korea, Rep.	2,453	1,303	-46.9%
12	Niger	1,016	218	-78.6%	62	Nicaragua	100,632	32,318	-67.9%	112	Albania	15,707	8,364	-46.7%
13	Yemen, Rep.	395	85	-78.6%	63	Nepal	19,620	6,501	-66.9%	113	Canada	153,111	82,650	-46.0%
14	Brunei Darussalam	97,486	20,939	-78.5%	64	Mozambique	12,601	4,191	-66.7%	114	Mauritius	3,928	2,139	-45.5%
15	Gambia, The	7,697	1,689	-78.1%	65	Panama	123,242	41,275	-66.5%	115	New Zealand	131,749	74,230	-43.7%
16	Libya	482	109	-77.4%	66	Singapore	343	116	-66.2%	116	Iceland	932,130	532,915	-42.8%
17	Solomon Islands	356,824	80,939	-77.3%	67	Mali	11,149	3,788	-66.0%	117	Suriname	287,137	166,220	-42.1%
18	Tanzania	7,862	1,817	-76.9%	68	Swaziland	7,220	2,472	-65.8%	118	United States	15,107	9,044	-40.1%
19	Syrian Arab Republic	1,464	343	-76.6%	69	Central African Republic	90,578	31,425	-65.3%	119	Jamaica	5,603	3,471	-38.0%
20	Iraq	4,528	1,068	-76.4%	70	Bolivia	86,531	30,085	-65.2%	120	Luxembourg	3,118	1,934	-38.0%
21	Congo, Dem. Rep.	55,620	13,283	-76.1%	71	Bahamas, The	165	58	-65.1%	121	Antigua and Barbuda	923	580	-37.1%
22	Zambia	24,835	5,952	-76.0%	72	Dominican Republic	5,938	2,088	-64.8%	122	Ireland	17,278	10,920	-36.8%
23	Malawi	4,369	1,049	-76.0%	73	Bangladesh	1,982	698	-64.8%	123	Trinidad and Tobago	4,429	2,852	-35.6%
24	Madagascar	62,937	15,810	-74.9%	74	Lao PDR	85,362	30,280	-64.5%	124	Puerto Rico	2,898	1,915	-33.9%
25	Senegal	8,020	2,021	-74.8%	75	Burundi	3,303	1,173	-64.5%	125	Cuba	5,122	3,387	-33.9%
26	Mauritania	443	113	-74.5%	76	Egypt, Arab Rep.	61	22	-64.4%	126	Spain	3,584	2,405	-32.9%
27	Congo, Rep.	207,944	53,626	-74.2%	77	Guinea	61,988	22,110	-64.3%	127	Switzerland	7,248	5,109	-29.5%
28	Togo	7,153	1,868	-73.9%	78	Mexico	9,984	3,563	-64.3%	128	Netherlands	932	659	-29.3%
29	Angola	28,754	7,544	-73.8%	79	Peru	153,675	54,966	-64.2%	129	France	4,174	3,056	-26.8%
30	Bhutan	398,823	105,653	-73.5%	80	Equatorial Guinea	100,798	36,100	-64.2%	130	Norway	104,976	77,141	-26.5%
31	Comoros	5,994	1,592	-73.4%	81	Mongolia	34,350	12,428	-63.8%	131	Greece	6,865	5,131	-25.3%
32	Chad	4,865	1,301	-73.3%	82	Colombia	124,348	45,006	-63.8%	132	Japan	4,487	3,364	-25.0%
33	Rwanda	3,228	868	-73.1%	83	South Africa	2,427	886	-63.5%	133	Uruguay	22,663	17,515	-22.7%
34	Botswana	4,364	1,182	-72.9%	84	India	3,101	1,165	-62.4%	134	Malta	156	121	-22.7%
35	Sudan	2,475	672	-72.8%	85	Sierra Leone	70,861	26,678	-62.4%	135	Guyana	407,402	318,766	-21.8%
36	Namibia	9,737	2,651	-72.8%	86	Morocco	2,363	899	-62.0%	136	Poland	1,768	1,403	-20.7%
37	Pakistan	1,141	311	-72.7%	87	Sao Tome and Principe	33,812	12,936	-61.7%	137	Sweden	22,614	18,089	-20.0%
38	Benin	4,144	1,132	-72.7%	88	Guinea-Bissau	26,785	10,342	-61.4%	138	Finland	23,823	19,863	-16.6%
39	Belize	163,816	44,868	-72.6%	89	Brazil	70,109	27,551	-60.7%	139	Denmark	1,291	1,076	-16.6%
40	Honduras	44,909	12,371	-72.5%	90	Haiti	3,233	1,285	-60.3%	140	Italy	3,587	3,003	-16.3%
41	Venezuela, RB	88,632	24,674	-72.2%	91	Cambodia	21,167	8,431	-60.2%	141	Belgium	1,301	1,090	-16.2%
42	Cameroon	48,338	13,629	-71.8%	92	Indonesia	20,904	8,332	-60.1%	142	Portugal	4,225	3,572	-15.4%
43	Liberia	170,837	48,443	-71.6%	93	Lesotho	5,929	2,384	-59.8%	143	Austria	7,714	6,533	-15.3%
44	Afghanistan	4,689	1,335	-71.5%	94	Turkey	7,660	3,083	-59.8%	144	Barbados	344	292	-15.1%
45	Ghana	4,220	1,214	-71.2%	95	Tunisia	964	393	-59.2%	145	United Kingdom	2,723	2,315	-15.0%
46	Papua New Guinea	393,194	114,203	-71.0%	96	Vietnam	9,949	4,092	-58.9%	146	Romania	2,265	1,978	-12.7%
47	Philippines	17,230	5,050	-70.7%	97	Thailand	7,737	3,229	-58.3%	147	Germany	1,445	1,309	-9.4%
48	Nigeria	4,610	1,360	-70.5%	98	Timor-Leste	15,868	6,986	-56.0%	148	St. Kitts and Nevis	479	452	-5.6%
49	Israel	327	97	-70.5%	99	Cape Verde	1,355	599	-55.8%	149	Hungary	596	602	0.9%
50	Burkina Faso	2,483	737	-70.3%	100	Myanmar	45,870	20,750	-54.8%	150	Bulgaria	2,621	2,809	7.2%

[a] Values are in m^3.

Table 3: Projected steady-state renewable internal freshwater resources per capita by country and the percent change between the steady-state condition and values reported in 1962 and 2011.

Country	$SS_{t\to\infty}$ [a]	2011→SS [b]	1962→SS [c]	Country	$SS_{t\to\infty}$	2011→SS	1962→SS	Country	$SS_{t\to\infty}$	2011→SS	1962→SS
Albania	8,100	-3%	-48%	Greece	3,900	-23%	-43%	Pakistan	140	-54%	-87%
Algeria	200	-32%	-79%	Guatemala	1,500	-79%	-94%	Panama	24,500	-41%	-80%
Andorra	3,100	-17%	-85%	Guinea-Bissau	40	-99.6%	-99.8%	Papua New Guinea	13,400	-88%	-97%
Argentina	4,400	-34%	-66%	Guyana	322,000	1%	-21%	Paraguay	6,000	-58%	-87%
Australia	12,600	-42%	-73%	Haiti	470	-64%	-86%	Peru	41,100	-25%	-73%
Austria	2,700	-58%	-65%	Honduras	6,000	-51%	-87%	Philippines	2,700	-46%	-84%
Bahamas, The	50	-15%	-70%	Hungary	INC			Poland	1,400	-3%	-23%
Bangladesh	340	-51%	-83%	Iceland	189,000	-65%	-80%	Portugal	2,900	-20%	-32%
Barbados	250	-14%	-27%	India	610	-47%	-80%	Puerto Rico	1,800	-8%	-39%
Belgium	390	-64%	-70%	Indonesia	6,400	-23%	-69%	Qatar	5	-83%	-99%
Bhutan	50,300	-52%	-87%	Iran, Islamic Rep.	1,200	-31%	-79%	Romania	1,900	-4%	-16%
Bolivia	10,900	-64%	-87%	Iraq	240	-78%	-95%	Rwanda	360	-58%	-89%
Botswana	800	-32%	-82%	Israel	39	-60%	-88%	Sao Tome and Principe	5,300	-59%	-84%
Brazil	21,000	-24%	-70%	Italy	3,000	-1%	-17%	Saudi Arabia	58	-32%	-90%
Brunei Darussalam	15,700	-25%	-84%	Jamaica	3,000	-13%	-46%	Senegal	380	-81%	-95%
Bulgaria	INC[d]			Japan	3,300	-3%	-27%	Solomon Islands	30,000	-63%	-92%
Cameroon	3,900	-71%	-92%	Jordan	66	-40%	-91%	Somalia	580	-7%	-71%
Canada	58,500	-29%	-62%	Kenya	220	-55%	-91%	South Africa	420	-53%	-83%
Cape Verde	150	-75%	-89%	Korea, Dem. Rep.	2,400	-13%	-59%	Spain	1,400	-43%	-62%
Central African Republic	8,300	-73%	-91%	Korea, Rep.	1,200	-8%	-51%	Sri Lanka	2,100	-17%	-59%
Chile	31,300	-39%	-72%	Lao PDR	9,000	-70%	-90%	St. Kitts and Nevis	NT[e]		
China	1,900	-10%	-56%	Lebanon	290	-74%	-88%	Sudan	210	-69%	-92%
Colombia	28,900	-36%	-77%	Lesotho	1,500	-35%	-74%	Swaziland	1,900	-22%	-73%
Comoros	300	-81%	-95%	Libya	89	-19%	-82%	Sweden	12,000	-33%	-47%
Congo, Dem. Rep.	290	-98%	-99%	Malawi	330	-69%	-93%	Switzerland	1,100	-78%	-85%
Congo, Rep.	13,200	-75%	-94%	Malaysia	6,400	-68%	-90%	Syrian Arab Republic	160	-53%	-89%
Costa Rica	11,200	-53%	-86%	Maldives	56	-40%	-82%	Tanzania	440	-76%	-94%
Cote d'Ivoire	2,700	-28%	-86%	Mauritania	15	-87%	-97%	Thailand	2,900	-10%	-63%
Cuba	3,300	-3%	-36%	Mauritius	1,800	-16%	-54%	Togo	560	-70%	-92%
Denmark	1,000	-10%	-25%	Mexico	2,800	-22%	-72%	Trinidad and Tobago	2,500	-11%	-43%
Djibouti	290	-14%	-91%	Mongolia	10,600	-15%	-69%	Tunisia	260	-33%	-73%
Dominican Republic	1,500	-29%	-75%	Morocco	700	-22%	-70%	Turkey	2,000	-36%	-74%
Ecuador	20,400	-31%	-78%	Myanmar	17,200	-17%	-62%	United Arab Emirates	17	-10%	-99%
Egypt, Arab Rep.	11	-50%	-82%	Namibia	700	-74%	-93%	United Kingdom	840	-64%	-69%
El Salvador	2,700	-7%	-56%	Nepal	510	-92%	-97%	United States	2,800	-69%	-82%
Fiji	30,600	-7%	-55%	Netherlands	590	-10%	-37%	Uruguay	14,700	-16%	-35%
Finland	12,500	-37%	-47%	New Zealand	6,600	-91%	-95%	Venezuela, RB	17,800	-28%	-80%
France	2,400	-22%	-43%	Nicaragua	23,400	-28%	-77%	Vietnam	2,700	-34%	-73%
Gambia, The	72	-96%	-99%	Nigeria	180	-87%	-96%	Zambia	2,500	-58%	-90%
Germany	1,300	-4%	-13%	Norway	15,300	-80%	-85%	Zimbabwe	790	-18%	-74%
Ghana	52	-96%	-99%	Oman	370	-26%	-85%				

[a] Projected steady-state per capita renewable internal freshwater supplies at $_{t\to\infty}$ using an exponential decay projection of the form $y = a\times e^{(bx)} + c$. Values are in m^3. [b] Predicted decline in per capita renewable internal freshwater supplies between 2011 and the steady-state projection. [c] Predicted decline in per capita renewable internal freshwater supplies between 1962 and the steady-state projection. [d] Trend is increasing. [e] No clear trend is evident.

Table 4: Projected steady-state renewable internal freshwater resources per capita by country and the estimated depletion year for nations expected to reach zero per capita renewable internal freshwater supplies in the future.

Country	$SS_{t\rightarrow\infty}$ [a]	Depletion year[b]
Afghanistan	-700	2063
Angola	-4,900	2055
Antigua and Barbuda	-800	2164
Bahrain	-3	2038
Belize	-47,500	2051
Benin	-1,100	2050
Burkina Faso	-700	2054
Burundi	-250	2103
Cambodia	-6,300	2072
Chad	-1,300	2049
Cyprus	-1,200	2082
Equatorial Guinea	-214,000	2039
Gabon	-20,000	2090
Guinea	-35,000	2051
Ireland	-2,800	2223
Liberia	-45,000	2059
Luxembourg	-3,000	2133
Madagascar	-5,000	2069
Mali	-8,600	2049
Malta	-140	2194
Mozambique	-1,500	2084
Niger	-90	2058
Sierra Leone	-15,400	2083
Singapore	-70	2071
Suriname	-134,000	2141
Timor-Leste	-19,900	2067
Uganda	-35	2123
Yemen, Rep.	-45	2049

[a] Projected steady-state per capita renewable internal freshwater supplies at $t\rightarrow\infty$ using an exponential decay projection of the form $y=a\times e^{(bx)}+c$. Values are in m^3. [b] Predicted year of zero per capita renewable internal freshwater supplies.

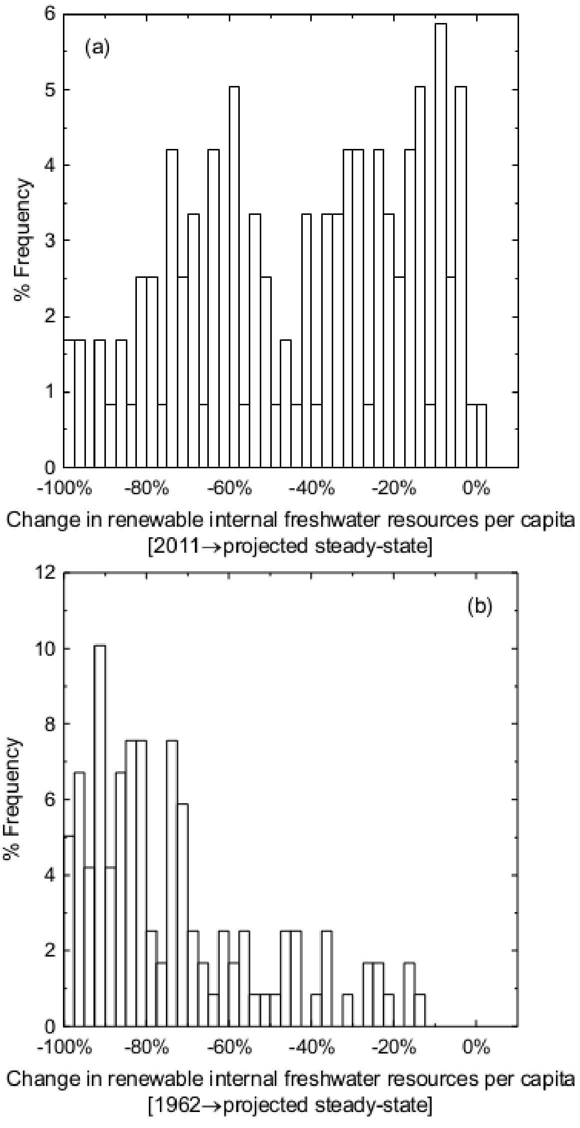

Figure 4: Histogram of the projected changes in renewable internal freshwater resources per capita over all nations between (a) 2011 and (b) 1962 and the respective anticipated steady-state conditions.

capita internal freshwater resources (Table 4) within the near future with depletion years ranging from 2038 (Bahrain) and 2039 (Equatorial Guinea) out to the early 23^{rd} century (Ireland). Example trends are given in Figure 5 for eight representative nations (Afghanistan, Angola, Burkina Faso, Chad, Madagascar, Mali, Niger, and Uganda). African countries dominate the list of nations projected to reach zero per capita internal freshwater resources, comprising 16 of the 28 countries - of which six are landlocked (Burkina Faso, Burundi, Chad, Mali, Niger, and Uganda), thereby restricting their access to domestic marine desalination options.

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[4] Renewable internal freshwater resources per capita (cubic meters), The World Bank Group: Washington, DC, USA, 2012.

[5] Renewable internal freshwater resources, total (billion cubic meters), The World Bank Group: Washington, DC, USA, 2012.

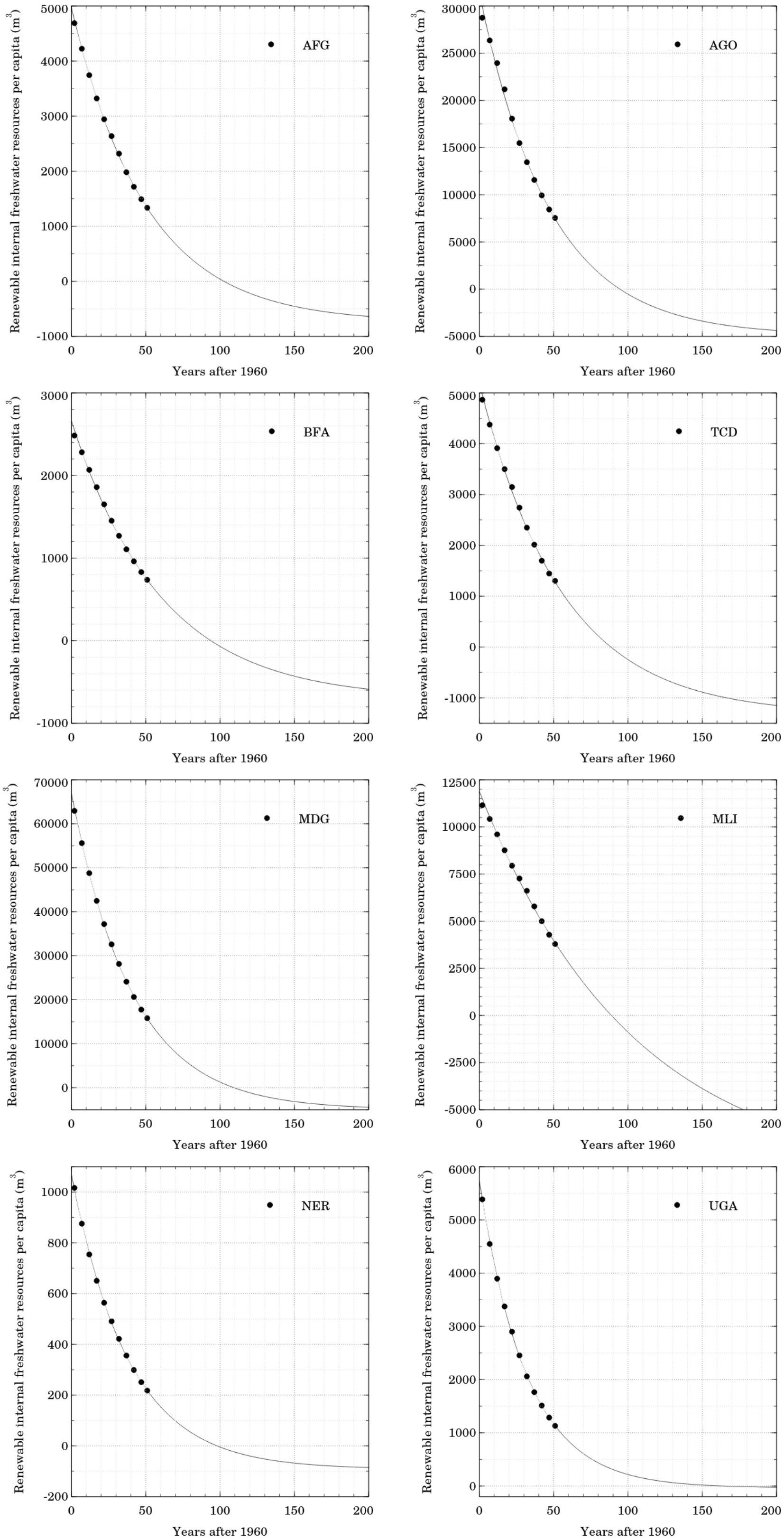

Figure 5: Trends in renewable internal freshwater resources per capita for Afghanistan (AFG), Angola (AGO), Burkina Faso (BFA), Chad (TCD), Madagascar (MDG), Mali (MLI), Niger (NER), and Uganda (UGA) between 1962 and 2011 along with exponential decay projections of the form $y=a\times e^{(bx)}+c$.

[6] Population, total, The World Bank Group: Washington, DC, USA, 2012.