Global land and water grabbing

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Edited by B. L. Turner, Arizona State University, Tempe, AZ, and approved November 27, 2012 (received for review July 30, 2012)

Societal pressure on the global land and freshwater resources is increasing as a result of the rising food demand by the growing human population, dietary changes, and the enhancement of biofuel production induced by the rising oil prices and recent changes in United States and European Union bioethanol policies. Many countries and corporations have started to acquire relatively inexpensive and productive agricultural land located in foreign countries, as evidenced by the dramatic increase in the number of transnational land deals between 2005 and 2009. Often known as "land grabbing," this phenomenon is associated with an appropriation of freshwater resources that has never been assessed before. Here we gather land-grabbing data from multiple sources and use a hydrological model to determine the associated rates of freshwater grabbing. We find that land and water grabbing are occurring at alarming rates in all continents except Antarctica. The per capita volume of grabbed water often exceeds the water requirements for a balanced diet and would be sufficient to improve food security and abate malnourishment in the grabbed countries. It is found that about 0.31×10^{12} $m^3 \cdot y^{-1}$ of green water (i.e., rainwater) and up to 0.14×10^{12} $m^3 \cdot y^{-1}$ of blue water (i.e., irrigation water) are appropriated globally for crop and livestock production in 47×10^6 ha of grabbed land worldwide (i.e., in 90% of the reported global grabbed land).

virtual water | water security | land tenure | foreign direct investment

The increase in global food demand as a result of population growth (1) and changes in diet (2) is enhancing the human pressure on the global land and freshwater resources. The increase in oil prices (3), the 2007 changes in the United States policy on bioethanol use (4), and the 2009 Renewable Energy Directive adopted by European Union (5) have increased the global demand for biofuel production, thereby further enhancing the need for land and water. As a result, some corporations and governments are investing in agricultural land as part of a long-term strategy for food and energy security (6, 7). The number of land-related deals has dramatically increased since 2005, reaching a peak in 2009 (8). In 2010 the World Bank estimated that about 45 million ha had been acquired since 2008; most of these land deals were for areas ranging between 10,000 and 200,000 ha (9). Moreover, several institutions [e.g., the World Bank (WB), the Food and Agriculture Organization (FAO), and the International Fund for Agricultural Development (IFAD)] have reported that many deals were closed with limited consultation of the local population, without adequate compensation of the previous land users, and without seeking opportunities to create new jobs or enhance environment sustainability (9, 10).

This unprecedented increase in transnational land acquisitions has often been named by the critical press as "land grabbing" (11). Land grabbing is a measure used by some governments (and corporations) to meet their food and energy requirements by acquiring land in a foreign country. The 2011 Tirana conference of the International Land Coalition defined land grabbing as land acquisitions that are in violation of human rights, without prior consent of the preexisting land users, and with no consideration of the social and environmental impacts. In many cases, land grabbing is not the result of a transparent and democratic decision process (12). Lack of consultation with local land users, violation of human rights, and social or environmental impacts are, however, difficult to verify. Therefore, here we use a broader definition of land grabbing as the transfer of the right to own or use the land from local communities to foreign investors through large-scale land acquisitions (more than 200 ha per deal). Based on these definitions, land grabbing is a new form of colonialism that has intensified in the last 4 y, initially in response to the 2007–2008 increase in food prices (13, 14). At that time, the peaking in the price of wheat, rice, maize, and soy beans was induced by the growing food demand (especially in China and India), the increase in biofuel production, financial speculations, and the occurrence of adverse climate conditions in some of the breadbaskets of the world (United States, Ukraine, and Russia) (3). This situation placed the food security of some countries at risk, thereby drawing the World's attention toward agricultural land. Many corporations and governments quietly started to secure property rights on foreign farmlands (10, 15). This phenomenon was further enhanced by the rising demand for biofuels, timber, raw materials and carbon sequestration services.

The land grabbed for agriculture is constantly increasing and is currently reported (May 2012) to range between 32.7 and 82.2 million ha, depending on whether only completed or also ongoing property-right transactions are accounted for. Overall, these values correspond to 0.7–1.75% of the world's agricultural land (8).

What are the implications of land grabbing on the global redistribution of water resources?

Land grabbing is not only a rush for land but also for the freshwater resources available therein. The production of all food commodities (except fish) requires, directly or indirectly, both land and water. Because about 86% of the human appropriation of freshwater resources is used to sustain agricultural production (16), land grabbing is mainly a grabbing of freshwater resources, including both rainwater and irrigation water. About 19% of the agricultural area worldwide is irrigated and sustains 40% of the global food production (17). Agriculture accounts for major water withdrawals from streams, lakes, and the groundwater. Global freshwater withdrawals have increased nearly sevenfold in the past century (18), thereby contributing to an escalating competition for water resources.

When the grabbed land is irrigated, the associated appropriation of freshwater resources can reduce the availability of irrigation water in the surrounding and downstream farmland areas, with the potential effect of causing water stress, poor water quality, and social unrest (19, 20). For example, in the case of Sudan, the grabbed land is often located on the banks of the Blue Nile, a prime location in an otherwise arid region. Although large-scale commercial farmland is expanding, smallholder agriculture is losing access to land and water (20). The local population is becoming increasingly dependent on food aid and international food subsidies, despite Sudan being a major exporter of food commodities produced by large-scale farmers (21).

Even though the possible implications of land grabbing on the access to freshwater resources have started to be acknowledged (19, 22), a quantitative assessment of the associated water grabbing is still missing. The evaluation of the impact of land grabbing on the global use of water resources requires a comprehensive quantification of the amounts of water grabbed in each country by foreign corporations and governments. This study compiles data and information on land grabbing reported by multiple sources

Author contributions: M.C.R. and P.D. designed research; M.C.R., A.S., and P.D. performed research; A.S. analyzed data; and M.C.R. and P.D. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1213163110/-/DCSupplemental.

(Table S1) and provides a quantitative global assessment both of the total amount of water grabbed from each of the affected countries and of the total amount of water appropriated by each grabbing country.

Results

Based on this assessment, land grabbing is a global phenomenon, which involves at least 62 grabbed countries and 41 grabbers (Table S1) and affects all continents except Antarctica (Fig. 1). Africa and Asia account for 47% and 33% of the global grabbed area, respectively (Fig. 2*A*). About 90% of the grabbed area is located in the 24 countries listed in Table 1. The grabbed area is often a non-negligible fraction of the country area (up to 19.6% in Uruguay, 17.2% in the Philippines, or 6.9% in Sierra Leone). Some countries (e.g., Liberia, Gabon, Papua New Guinea, Sierra Leone, or Mozambique) (Table 1) exhibit relatively high grabbed-to-cultivated area ratios, which suggests that the grabbed land was not necessarily cultivated before the acquisition but was the result of intense deforestation and land-use change (23). The countries that are most active in land grabbing are located in the Middle East, Southeast East Asia, Europe, and North America. Through land grabbing these countries can virtually increase their agricultural land by up to several orders of magnitude (Table 2). Some of the grabbed countries are also grabbers (e.g., Argentina, Australia, the Philippines, and Sudan).

Our assessment of the water use for agricultural production in the top 24 grabbed countries (Table 3) shows that land grabbing is associated with a virtual grabbing of a substantial amount of freshwater resources, including both water supplied by rainfall and irrigation. In our study we have assumed that the grabbed water may range between a minimum value corresponding to crop water use in rain-fed agriculture (or "green water"), and a maximum value corresponding to the case of irrigated agriculture in conditions that optimize crop yield by preventing the emergence of crop water stress (i.e., green + $blue_{max}$ water) (Table 3). We also considered an average "blue water" consumption ($blue_{avg}$) (Table 3) based on the assumption that the fraction of grabbed land that is irrigated is the same as the country-specific fraction of agricultural land that is equipped for irrigation (*Methods*). No irrigation was assumed for pastureland.

The green and blue water consumption of agricultural production varies considerably across geographic areas and among crops, thereby explaining the substantially different amount of water grabbed in each country and continent (Fig. 2*B*). Fig. 3 shows the green and blue water grabbed in each country. The countries that are affected by the highest rates of total and green water grabbing are Indonesia, the Philippines, and the Democratic Republic of Congo; the highest rates of blue water grabbing would occur in Tanzania and Sudan (Table 3). Under the irrigation scenario of maximum productivity, the total grabbed water per unit area is highest in Cameroon and Tanzania (2.68×10^4 m^3/ha and 2.03×10^4 m^3/ha, respectively). These countries also exhibit the highest rates of blue water grabbing per unit area. The green water grabbing per unit area is highest in Papua New Guinea and Liberia (Table 3).

Our results show that, presently, global land grabbing (469.4×10^5 ha) is associated with a maximum rate of water grabbing for agriculture of about 454×10^9 $m^3 \cdot yr^{-1}$, including 308×10^9 $m^3 \cdot yr^{-1}$ as green water, and an amount of blue water estimated in the range 11×10^9–146×10^9 $m^3 \cdot yr^{-1}$. The estimated maximum rate of actual water withdrawal for irrigation, or "gross irrigation" (i.e., irrigation water consumed by plants + unavoidable irrigation losses), is 280×10^9 $m^3 \cdot yr^{-1}$ (Table 3). Overall, about 60% of the total grabbed water is appropriated, through land grabbing, by the United States, United Arab Emirates, India, United Kingdom, Egypt, China, and Israel (Table 2).

Discussion and Conclusions

The analyses presented in this article are affected by some uncertainties associated with a few major factors, namely: (*i*) the imprecision and incompleteness of the land-grabbing data; (*ii*) the sparseness of meteorological stations in many of the grabbed countries; and (*iii*) the lack of adequate information on water used for irrigation in the grabbed land.

Land gabbing data are inherently inaccurate and incomplete because of the rapid pace of the phenomenon, its lack of transparency, and the absence of a standard criterion to classify and report these acquisitions. However, most of the contracts underlying the land acquisitions listed in Table S1 have been verified, and, whenever possible, data from multiple sources were cross-checked.

Moreover, data from as many meteorological stations as possible (in total 185 meteorological stations) were considered to calculate the spatially weighted averages used in each grabbed region.

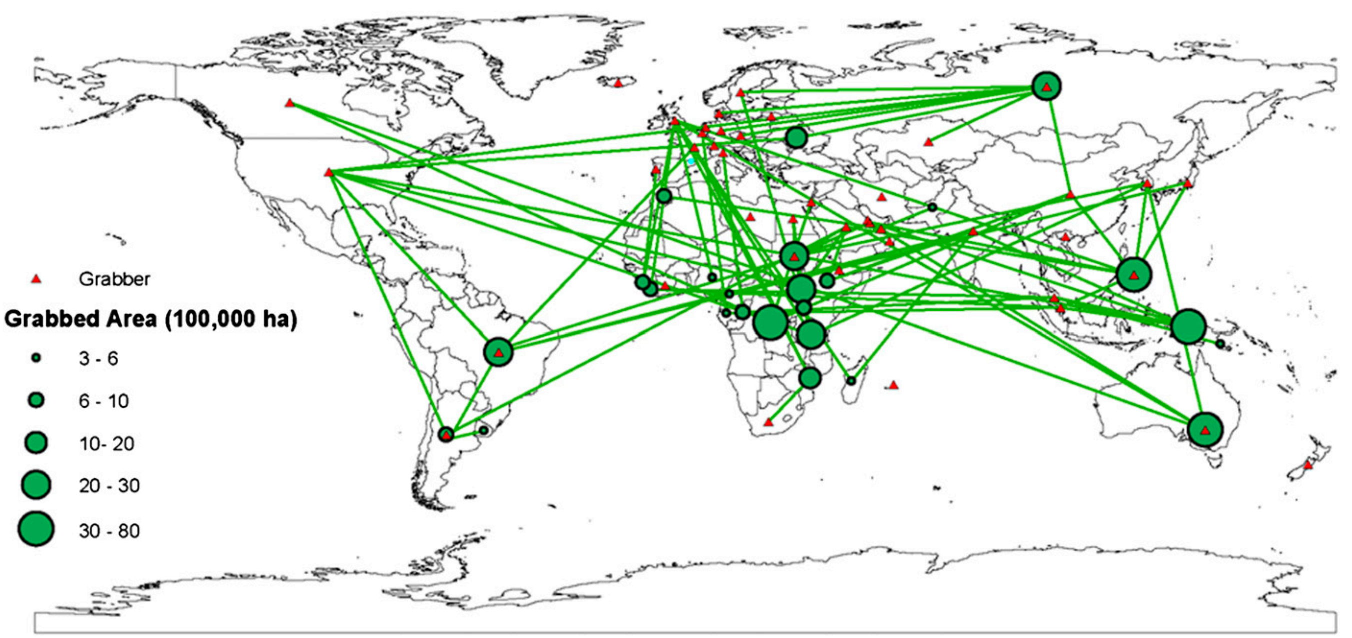

Fig. 1. A global map of the land-grabbing network: land-grabbed countries (green disks) are connected to their grabbers (red triangles) by a network link. Based on data in Table S1 but considering only 24 major grabbed countries (as in Table 1). Relations between grabbing (red triangles) and grabbed (green circles) countries are shown (green lines) only when they are associated with a land grabbing exceeding 100,000 ha.

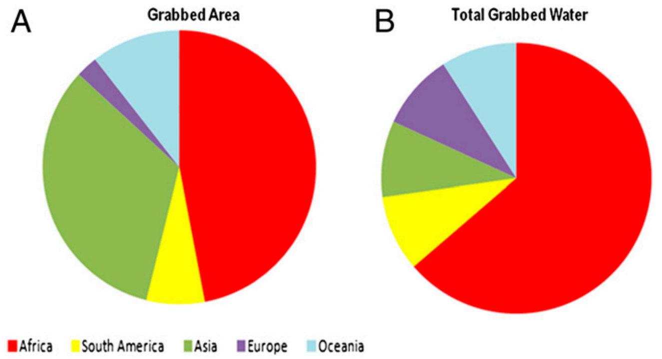

Fig. 2. Distribution of grabbed land (*A*) and water (*B*) across continents.

Finally, because of the lack of precise data on irrigation practices in the grabbed land, we have considered three possible irrigation scenarios: no irrigation, irrigation at the same average rate as the rest of the country, and irrigation rates that maximize crop production. By considering these scenarios we have estimated the lower and upper limits of the rates of blue water grabbing.

Despite these unavoidable uncertainties, the results presented in this study allow us to analyze some general aspects of land grabbing by looking at the hydrologic and geographic conditions of the countries it affects, and by analyzing the environmental and societal implications of this phenomenon.

The estimated values of water grabbed in each country (Table 3) can be explained by the extent of the grabbed land, type of crops, and climate. The levels of total water grabbing in Indonesia, the Philippines, and the Democratic Republic of Congo are relatively high because these countries have the largest total grabbed land (i.e., 71.4×10^5, 51.7×10^5, and 80.5×10^5 ha, respectively) (Table 1). The Philippines and Indonesia exhibit a wet climate, which explains their high values of grabbed green water per unit area; conversely, the relatively dry climates of Tanzania and Sudan and the cultivation of water demanding crops explain why these countries require the highest values of grabbed blue water per unit area. In Tanzania and Cameroon the grabbed lands are mainly cultivated with water-demanding crops, including sugar cane and oil palm, the water requirements of which per cultivation period are estimated (*Methods*) around 2,000–2,500 mm per cultivation period. These high values of crop water requirement explain why the highest rates of water grabbing per unit area are found in these countries (Table 3). In the case of Australia, only a relatively small amount of blue water is grabbed because in this country most of the grabbed land is used for livestock production (Table S1).

A few major environmental and societal issues are emerging as a result of land and water grabbing. Some of the countries affected by land grabbing exhibit relatively high levels of malnourishment (Table S2). In these countries, the impact of land and water grabbing on food security can be evaluated by looking at the per capita grabbed water (Table S2), which is found to be a substantial fraction (and sometimes even a multiple) of the per capita water requirements for a balanced diet (about 1,300 $m^3 \cdot yr^{-1}$) (16). On the other hand, land and water grabbing enhance food and energy availability in the grabbing country. The cultivation of crops suitable both for food and biofuel (Table S1) suggests that, although land grabbing is mainly because of food demand, other drivers, such as biofuel demand and financial speculations, also play a role.

The grabbed green water is relatively large compared with the green water used (until recently) for food (and energy) production in the grabbed countries (Table 3). This fact suggests that part of the grabbed land was not necessarily used for agriculture before the acquisition. Some of this land was claimed from forest and savanna ecosystems. By increasing the demand for agricultural areas, land grabbing may directly or indirectly contribute to the deforestation and associated land degradation that is occurring at alarming rates in most of the grabbed countries (24).

Table 1. Land grabbed in the 24 most grabbed countries, which altogether account for about 90% of the global grabbed land (Table S1)

	Grabbed land			
Grabbed country	Grabbed area (A_g) (10^5 ha)	% of total global grabbed land	% of country's cultivated land	% of country area
Argentina	6.31	1.34	1.97	2.26
Australia	46.45	9.90	9.78	0.60
Brazil	22.55	4.80	3.29	0.26
Cameroon	2.95	0.63	4.01	0.62
Republic of Congo	6.64	1.41	8.91	0.28
Ethiopia	10.01	2.13	6.68	0.91
Gabon	4.07	0.87	85.75	1.52
Indonesia	71.39	15.21	16.76	3.75
Liberia	6.50	1.38	106.52	5.83
Madagascar	3.69	0.79	10.40	0.63
Morocco	7.00	1.49	7.73	1.57
Mozambique	14.97	3.19	28.24	1.87
Nigeria	3.62	0.77	0.98	0.39
Pakistan	3.34	0.71	1.57	0.42
Papua New Guinea	3.14	0.67	32.75	0.68
Philippines	51.71	11.02	49.48	17.24
Democratic Republic of Congo	80.50	17.15	1.08	3.43
Russia	28.31	6.03	2.29	0.17
Sierra Leone	4.94	1.05	40.62	6.88
Sudan	46.90	9.99	23.00	1.87
Tanzania	20.27	4.32	17.63	2.14
Uganda	8.59	1.83	9.70	3.56
Ukraine	12.08	2.57	35.53	2.00
Uruguay	3.46	0.74	18.08	19.61

In some countries the grabbed land is a substantial fraction of their cultivated land [reported by FAOSTAT (36), accessed in May, 2012)] (Table S2).

Table 2. Countries contributing the land grabbing reported in Table 1

Grabbing country	Grabbed land			Grabbed water (10^9 m^3)			
	Grabbed area (A_g) (10^5 ha)	% of total global grabbed land	% of "virtual" increase in cultivated land	Green	$Blue_{avg}$	$Blue_{max}$	Gross irrigation
Argentina	7.003	1.493	2.188	6.0020	0.0150	1.6035	3.1726
Australia	0.030	0.006	0.006	0.0287	0.0001	0.0054	0.0090
Bahrain	0.100	0.021	263.158	0.0870	0.0021	0.0250	0.0417
Belgium	1.116	0.238	12.942	0.8630	0.0020	0.3860	0.8099
Brazil	1.069	0.228	0.156	1.1580	0.0050	0.4233	0.8721
Canada	3.508	0.748	0.673	1.9960	0.0021	0.1583	0.2638
China	34.116	7.272	32.192	5.7900	0.0800	2.2505	5.4176
Côte d'Ivoire	0.088	0.019	0.124	0.0990	0.0010	0.0107	0.0178
Czech Republic	1.640	0.350	5.037	0.2870	0.0019	0.4790	1.4650
Denmark	2.249	0.479	9.230	1.0030	0.0011	0.1581	0.2634
Djibouti	0.092	0.020	460.000	0.0560	0.0007	0.0269	0.0449
Egypt	14.469	3.084	39.222	7.9000	0.9870	6.1007	13.5012
Franc	7.668	1.635	3.954	6.0450	0.0020	3.8864	8.9773
Germany	3.336	0.711	2.747	0.8030	0.0060	1.1096	1.8493
Iceland	0.003	0.001	3.857	0.0010	0.0002	0.0021	0.0035
India	12.117	2.583	0.714	8.6200	0.4257	10.3017	22.1695
Iran	0.100	0.021	0.053	0.0710	0.0010	0.0679	0.1131
Israel	20.000	4.263	10.531	20.0500	0.0060	3.7800	6.3000
Italy	1.619	0.345	1.707	0.9980	0.0090	1.6213	2.7021
Japan	1.110	0.237	2.408	1.0450	0.0070	0.3244	0.5406
Kazakhstan	6.569	1.400	2.797	0.8760	0.0040	2.1556	4.7594
Libya	0.350	0.075	1.707	0.2630	0.0008	0.1826	0.3044
Lithuania	0.400	0.085	1.921	0.3520	0.0006	0.2513	0.3855
Malaysia	9.739	2.076	12.840	7.4100	0.0050	3.0857	6.8095
Mauritius	0.860	0.183	94.505	1.0120	0.0070	0.3889	0.8148
New Zealand	0.009	0.002	0.157	0.0010	0.0003	0.0064	0.0107
Philippines	0.250	0.053	0.239	0.1080	0.0005	0.0786	0.1310
Portugal	2.088	0.445	10.970	0.3530	0.0010	1.3361	2.2269
Qatar	8.500	1.812	5666.660	2.8400	0.0070	2.0897	3.4828
Russia	2.500	0.533	0.202	1.0290	0.0050	0.6716	1.1193
Saudi Arabia	7.585	1.617	21.968	3.8960	0.0080	3.2316	5.3860
Singapore	9.262	1.974	132318.000	8.8720	0.0090	3.6806	6.1010
South Africa	11.142	2.375	7.282	7.2300	0.0200	5.2430	10.9050
S. Korea	12.639	2.694	70.373	8.4000	0.0800	3.2468	6.5780
Sudan	1.510	0.322	0.741	0.7540	0.0900	1.7685	2.9474
Sweden	8.344	1.779	31.570	3.0210	0.9000	3.2074	6.5124
Switzerland	0.155	0.033	3.601	0.1880	0.0070	0.2236	0.3727
United Arab Emirates	26.772	5.707	1014.090	16.8300	1.5000	11.9246	24.7077
United Kingdom	44.092	9.399	72.378	26.8700	0.3000	7.5489	12.5815
United States	37.002	7.887	2.236	28.2300	0.7000	15.2393	32.2322
Vietnam	0.140	0.030	0.145	0.2360	0.0050	0.1482	0.2470
Unknown	167.800	—	—	126.5560	6.2000	47.5340	81.8900
Total	469.139	—	—	308.2300	11.4050	145.9600	279.6800

For each country the values of grabbed area, percentage of the total global grabbed land, and the "virtual" increase in cultivated land afforded by land grabbing (i.e., grabbed area/grabber's cultivated area) are reported along with the associated values of grabbed green and blue water.

In some countries the grabbed blue water is also relatively large with respect to the blue water currently used for agricultural production (Table 3). This finding is because of the fact that no detailed information on grabbed-land irrigation is available. Here we have assumed that rangelands are not irrigated but, in the case of croplands, we have calculated the volumes of irrigation water that would be required either to maximize crop yield or to sustain rates of irrigation consistent with those currently existing in the grabbed country (in terms of the average irrigated fraction of agricultural land). Therefore, the actual blue water withdrawals in grabbed areas can range between zero and the maximum values ($Blue_{max}$) reported in Table 3. The estimated high values of blue water grabbing are of particular concern because their effects can be felt both locally and downstream, thereby contributing to the possible emergence of water stress, poor water quality, and social conflicts (25).

Land grabbers concentrate on countries where agricultural productivity can be strongly enhanced by technological investments (Table S2). In fact, grabbed countries have a relatively high potential for the enhancement of agricultural production. The current total water withdrawals of grabbed countries are only a small fraction of the renewable freshwater resources (Table S2), which suggests that there is a good potential to enhance irrigation. Moreover, in these countries cropland productivity can be improved by adopting methods able to reduce the gap existing between potential and actual yields (Table S2). Finally, with the exception of Morocco, Pakistan, and the Philippines, in all of the other grabbed countries the land suitable for agriculture exceeds the actual agricultural land (Table S2); therefore suitable land can be still converted into crop and range land.

These conditions are completely reversed in the grabbers. In fact, three main factors appear to be driving the tendency of some countries to become land and water grabbers: (*i*) some grabbers (e.g., United Arab Emirates, Israel, Egypt, Saudi Arabia, Libya) are affected by chronic and severe water scarcity, as reflected by the fact that their withdrawals may exceed the rate at which their renewable freshwater resources become available (Table S3); (*ii*)

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Table 3. Assessment of the grabbed water in the top 24 grabbed countries, accounting of about 90% of the global grabbed land

	Grabbed water (10^9 m^3)				Grabbed water per unit area (10^4 m^3/ha)		Water for food production (10^9 m^3)	
Grabbed country	Green	$Blue_{avg}$	$Blue_{max}$	Gross irrigation	Green	$Blue_{max}$	Green	Blue
Argentina	0.49	0.01	0.26	0.52	0.08	0.04	176.19	5.08
Australia	1.00	0.21	3.64	5.21	0.02	0.08	113.49	14.39
Brazil	20.23	0.36	8.43	16.86	0.90	0.37	435.97	12.09
Cameroon	2.62	0.02	6.75	13.50	0.89	1.79	24.62	0.21
Republic of Congo	5.54	0.02	4.48	8.95	0.83	0.67	1.20	0.02
Ethiopia	5.54	0.21	7.87	15.74	0.55	0.79	75.34	1.81
Gabon	3.26	0.04	3.32	6.65	0.80	0.82	1.26	0.01
Indonesia	117.40	1.19	7.01	14.01	1.64	0.10	292.35	11.94
Liberia	10.85	0.02	0.79	1.58	1.67	0.12	3.97	0.01
Madagascar	1.66	0.23	0.74	1.48	0.45	0.20	21.98	2.53
Morocco	3.70	0.46	2.79	5.59	0.53	0.40	29.99	5.25
Mozambique	7.97	0.31	12.18	24.37	0.53	0.81	23.21	0.20
Nigeria	1.42	0.02	2.76	5.52	0.39	0.76	195.87	1.54
Pakistan	0.95	3.52	3.75	7.50	0.29	1.12	74.67	75.18
Papua New Guinea	5.43	0.00	1.36	2.71	1.73	0.43	7.94	0.04
Philippines	36.67	0.26	1.39	2.78	0.71	0.03	108.75	3.43
Democratic Republic of Congo	24.88	0.05	10.42	20.85	0.31	0.13	26.57	0.08
Russia	3.42	0.49	13.70	19.57	0.12	0.48	320.29	11.27
Sierra Leone	4.85	0.13	2.49	4.98	0.98	0.50	5.53	0.06
Sudan	24.51	2.44	19.84	39.67	0.52	0.42	48.37	9.10
Tanzania	15.55	0.48	25.47	50.94	0.77	1.26	37.69	1.04
Uganda	3.14	0.01	2.35	4.70	0.37	0.27	35.32	0.14
Ukraine	5.62	0.90	4.08	5.83	0.47	0.34	103.18	2.95
Uruguay	1.52	0.01	0.09	0.17	0.44	0.03	11.50	0.88
Total	308.23	11.41	145.96	279.68	—	—	—	—

Green water refers to rainwater used for agricultural production. Average blue water ($blue_{avg}$) assumes that the fraction the grabbed lands that is irrigated is the same as the country-specific percentage of cultivated area equipped with irrigation [data available from the AQUASTAT (37) (database, accessed May, 2012)]. The maximum blue water consumption ($blue_{max}$) is calculated assuming optimal levels of irrigation that maximize production. Blue water is the water actually used by the crops and gross irrigation accounts for water losses (evaporation and drainage) and is the ratio between blue water and irrigation efficiency. Values per unit area refer to green and max blue water per unit of cultivated land area (Table 2). Country-specific values of water use for food production are taken from Mekonnen and Hoekstra (38).

in some of these countries (e.g., Israel and United Arab Emirates) there is also a high degree of utilization of the land suitable for agriculture (Table S3), which explains the need to expand agricultural production by looking for opportunities in foreign land; (*iii*) other countries (e.g., United Kingdom, China, Australia, and Argentina) might have high levels both of renewable freshwater resources and of land potentially suitable for agriculture (Table S3). However, if the suitable agricultural soils and the availability of adequate water resources do not occur in the same areas, the in-country transfer of water between regions may be more expensive than the investments required by land grabbing (25). Similarly, the cost of land grabbing may be lower than acquiring land in the home country (10). All of these factors, combined with carbon trade opportunities (26) and water savings associated with the lower water cost of crop production in the foreign country (26), explain why land grabbing is not exclusively driven by the limited availability of agricultural land or water resources. Moreover, land grabbing can enhance the resilience of a country's food production by diversifying the regions of the world it relies on, thereby making it less vulnerable to disturbance from droughts, pests, and climate change (27, 28).

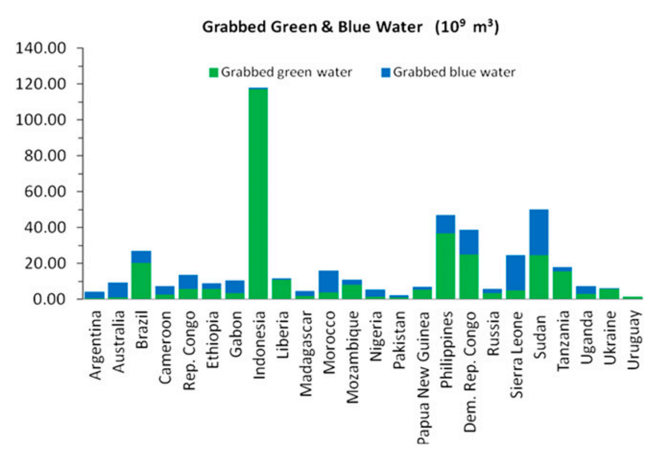

Fig. 3. Water grabbing in the 24 most land-grabbed countries (Table 1). Green and maximum blue water grabbing (Table 3).

Some institutions (e.g., WB, FAO, IFAD) are trying to turn land grabbing into an opportunity for both investors and targeted countries. FAO "win-win" strategies indicate that the interests of foreign land purchasers can be reconciled with those of developing countries (29) if land grabbing can be used as a means to create new jobs and bring in the grabbed country investments and technological advances from which the local economy could benefit either directly or indirectly. In May 2012 the FAO Committee on World Food Security officially endorsed the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries, and Forests in the Context of National Food Security (30). It is important to assess how the compliance to these guidelines could modify the way freshwater resources are used in small-holder agriculture versus large-scale commercial farming. Accounting for freshwater resource allocation is fundamental to the development of successful policies for responsible land tenure governance.

Methods

An inventory of grabbed and grabbing countries was developed through a survey of the peer-reviewed literature, reports developed by the United Nations, nongovernmental organizations, and other sources. For each grabbed country, the grabbing country, grabbed area, dominant cultivation, and the source of information were reported (Table S1). The primary data source used in this study (99% of the data) is Grain (31), consisting of 316 land deals covering a total area of 47×10^6 ha. More than 75% of land deals corresponding to more than 90% of the grabbed area were cross-checked by using other data sources (reported in Table S1). In particular, 55% of land deals (i.e., more than 75% of the grabbed area) coincide with those reported by the Land Matrix (32).

Unlike Grain (31), the Land Matrix (32) research group publishes only data that have been verified with a well-defined protocol. Therefore, if the same land-grabbing data were reported both by Grain and the Land Matrix, in Table S1 we listed as a source also the Land Matrix to stress the fact that those data entries have been verified. Similarly, in those cases in which verification by the Land Matrix was missing we listed also other sources used for crosschecking the Grain data.

The verification protocol used by the Land Matrix assigns a reliability score to each data entry, based on how the data have been verified; that is, through cross-checking with data reported in research articles based on empirical research or government records (low reliability), "on ground" verification by Land Matrix partners (intermediate reliability), or by obtaining copy of the contracts from public records (high reliability). Failed and unverified deals are not included in the Land Matrix database. We stress that even after these quality checks the dataset could remain affected by a few biases resulting from the lack of transparency inherent to the land-grabbing phenomenon.

The agricultural area existing in each country was identified using the agro-economical zoning (AEZ) system (33). AEZ is a geo-referenced land-resources database, which provides spatially explicit information on land use and land cover. Areas with high livestock density and cropland were classified as agricultural areas. The centroid of each agricultural area was then calculated.

Hourly data of precipitation, maximum and minimum temperature, relative humidity, solar radiation, and wind speed were taken from the archives of the National Climate Data Center National Oceanic and Atmospheric Administration, using climate stations within 300 km from the centroid of the agricultural area for the period of record 1992–2012. The values of each climate variable were referred to the centroid of the agricultural area and calculated as a weighted mean of the station records using the inverse distance method. The daily values were aggregated to the monthly scale. The average year was then calculated as an ensemble mean of the 20 y in the 1992–2012 period. Soil properties were obtained from the Harmonized World Soil Database (34). Effective precipitation was determined with the US Department of Agriculture Soil Conservation Service method (35). Green and blue water consumption by crops planted in the grabbed land were calculated with the CROPWAT 8.0 model (36) as explained in *SI Methods*.

ACKNOWLEDGMENTS. We thank B. L. Turner and anonymous reviewers for their contributions; GRAIN and the Land Matrix for making available their records of large-scale land acquisitions; Dr. Ward Anseeuw and Dr. Mathieu Boche (Centre de Coopération Internationale en Recherche Agronomique pour le Développement) for providing detailed information about the verification protocol developed and used by the Land Matrix; and Dr. Devlin Kuyek for providing information about the Grain dataset. This research was partly funded by a grant from The African Growth and Development Policy Modeling Consortium.

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