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LINKING IRRIGATED LAND AND WATER SCARCITY: A GLOBAL VIEW

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Abstract

Based on an innovative analysis of country-level data reported from the United Nations Food and Agriculture Organization—in particular on area equipped for irrigation (a proxy for irrigated land), agricultural water withdrawals, and total renewable water resources—, the paper explores the link between irrigated land and water scarcity at the global level. Trends in agricultural water withdrawals show large increases, though with declining rates of growth since about 1980. Countries' agricultural withdrawals are closely linked to total water withdrawals, and also to the area equipped for irrigation. At the global level, agricultural water withdrawals are closely linked to water scarcity levels. With increasing scarcity, interventions related to irrigated land should therefore be moving to the center of water management concerns. In many countries, however, even high levels of water scarcity seem to have had little effect so far on trends in agricultural withdrawals and area equipped for irrigation.

Key Words:

Irrigated agriculture; water scarcity; agricultural water management

1. Introduction

Water scarcity is increasingly seen as a major risk in many parts of the world, and water crises consistently feature among the top-ranked global risks (World Economic Forum 2017). Projections indicate that without better resource management and more integrated policy making in both developed and developing countries, water scarcity and related water problems will significantly worsen over the next several decades (World Water Assessment Program 2012; Jiménez Cisneros et al. 2014).

Water use in irrigated agriculture is among the main factors that contribute to this situation. Irrigated agriculture is by far the largest user of water worldwide, estimated to account for about 70 percent of total freshwater withdrawals (Molden 2007). In many drier countries, it is not unusual for agricultural water use to account for more than 90 percent of total withdrawals (FAO 2016a). With increasing water scarcity, agricultural water management is therefore moving to the center of water management concerns.

This paper explores the link between irrigated agriculture, and the related water use, and global water scarcity. The data on area equipped for irrigation (a proxy for irrigated land) and the water use in irrigated agriculture indicate a close link between irrigated land and water scarcity. With increasing water scarcity, interventions related to irrigated land and agricultural water use should therefore be moving to the center of water management concerns. However, there still seems to be insufficient awareness of the link between irrigated land and water scarcity in many countries' policy debates, plans, and investments.

Our analysis is mainly based on an innovative use of data reported from the United Nations Food and Agriculture Organization (FAO), in particular, FAOSTAT and AQUASTAT (Scheierling and Tréguer 2018). These databases report estimates of the area equipped for irrigation, agricultural water withdrawals, total water withdrawals, and total renewable water resources, respectively—by country and for specific years, as reported by the respective country.

To examine the link between irrigated land and water scarcity, the paper proceeds in three steps. First, trends in agricultural water use and total water use at the global level are assessed. Second, the links between agricultural water withdrawals, total water withdrawals, and the area equipped for irrigation are analyzed. In a third step, we explore the relationship between irrigated agriculture and water scarcity. This is done at the global level, applying a widely used indicator for water scarcity. For a few countries, the data allows us to show trends in agricultural water withdrawals and area equipped for irrigation in connection with the respective levels of water scarcity. Overall, our analysis suggests a close link between agricultural water use and water scarcity. In many countries, however, even high levels of water scarcity seem to have had little effect so far on trends in agricultural withdrawals and area equipped for irrigation.

2. Trends in Agricultural and Total Water Use at the Global Level

Any discussion of water use needs to keep in mind the special characteristics of water that distinguish it from most other resources and commodities, and that pose significant challenges for defining and applying measures related to its use (Young 1986, 2005).

Special Water Characteristics. Among the characteristics of water on the supply side is its mobility. Typically found in liquid form, water tends to flow, evaporate, and seep as it moves through the hydrologic cycle. Although generally renewable, raw water supplies tend to be variable and unpredictable with regard to time, space, and quality. Local water availability usually changes systematically throughout the seasons of the year and over longer cyclical swings. Climate change now affects both short- and longer-term supply trends as well as the extremes of the probability distributions, such as floods and droughts. Variability also affects water demand. For example, the needs of irrigated agriculture change in response to rainfall and temperature patterns over the seasons of a year and over longer cycles. Another demand characteristic is the diversity of uses. Most water use—including in irrigated agriculture—is by producers who use it as an intermediate good; for other users, water is a final consumption good. Each use may change the place, form, time dimension, and quantity of water. Because of variations in water supply and local demand, water-related problems are typically site-specific.

Water also causes unique interdependencies among water users that become more pervasive and complex as water scarcity intensifies. This is because water is rarely completely “consumed” in the course of human production and consumption activities. In the case of irrigated agriculture, for example, it is not unusual for half of the water withdrawn to be returned to the hydrologic system in the form of surface runoff or subsurface drainage. An even larger proportion is typically returned from municipal and industrial withdrawals. Other users, particularly downstream users, are thus greatly affected by the quantity, quality, and timing of releases or return flows of upstream irrigators. The presence of these externalities implies that the full costs of an economic activity are not recognized in individual decisions. As a result, decisions that are rational from the individual perspective result in outcomes that are not optimal from the perspective of water users as a group, or of society. Public policy and interventions become necessary to align private and social objectives.

Key Water Measures. The special characteristics of water require different measures of water use. In particular, to take into account that water is rarely fully consumed in any of its uses, it is useful to distinguish here between two key measures of water use: water withdrawals, i.e. the amount of water removed from surface and groundwater sources; and water consumption (or consumptive use or evapotranspiration), i.e. the amount of water that is actually consumed by the use (Scheierling et al. 2004). The difference between the two measures are return flows. In many river basins they constitute an important part of the downstream water supply and have thus significant economic (and environmental) implications.[1] In discussing water use in agriculture, it is therefore essential to consider the water quantity being measured and to interpret the findings accordingly.

Trends in Global Agricultural Water Use. Figure 1 displays trends in agricultural water use and total water use at the global level since 1900. Data for both measures, water withdrawals and water consumption, are shown.

Figure 1. Global Trends in Agricultural and Total Water Withdrawals and Consumption

The data illustrate the central role of water use in irrigated agriculture. Historically, agricultural water withdrawals have accounted for, by far, the largest share of total water withdrawals.[2] In 1900 the agricultural share of total withdrawals was 89 percent, by 1995 it decreased to 66 percent, and more recently it increased again to 70 percent (FAO 2016a). Since the beginning of the 20th century, both agricultural withdrawals and total withdrawals have increased dramatically, but their rates of growth have declined since about 1980. One factor contributing to this outcome has been that in most OECD countries, total and agricultural water withdrawals have tended to remain stable or decrease (OECD 2015).

In terms of water consumption, irrigated agriculture has also accounted for much of total water consumption—with an even higher share than for water withdrawals. In 1900 its share was 92 percent, and it decreased to 93 percent in 1995. However, over the same period, agricultural consumption as a share of agricultural water withdrawals increased from 63 percent to 70 percent.

[1] The importance of distinguishing among these measures of water and the magnitude of return flows can be illustrated with data on the irrigation sector in the United States where it was shown that the amount of water consumed was less than half the amount of water originally withdrawn (Solley et al. 1998).

[2] Agricultural water withdrawals include the annual quantities of water withdrawn for irrigation, livestock, and aquaculture purposes. Total water withdrawals include the annual quantities of water withdrawn for agricultural, industrial, and municipal purposes. In-stream uses, such as recreation, navigation, and hydropower are not considered (FAO 2016a).

3. Country-Level Agricultural Water Use

In a second step, the links between agricultural withdrawals, total withdrawals, and the area equipped for irrigation are examined across countries. The analysis starts with a discussion of the countries with the largest agricultural withdrawals.

Countries with the Largest Agricultural Withdrawals**.** Table 1 lists the ten countries with the largest annual agricultural water withdrawals, based on the latest available data from FAO (2016a). India is by far the leading country, followed by China, the United States, and Pakistan.

Table 1. Countries with the Largest Agricultural Water Withdrawals

The ten countries with the largest agricultural withdrawals are also responsible for the largest total withdrawals. Not surprisingly, they are also among the countries with the largest areas equipped for irrigation (FAO 2016b)[3] The ten countries are also among the 17 most populous in the world (World Bank 2016).

Except for the United States and China, the ten countries' percentage of total water withdrawals allocated for agriculture is larger than the worldwide average of about 70 percent that is usually cited in the literature (Molden 2007). A record 95 percent of total withdrawals in Vietnam are for agriculture, followed by 94 percent in Pakistan and 92 percent in Iran.

When dividing the amount of agricultural water withdrawals by the area equipped for irrigation, half of the 10 countries are shown to withdraw an irrigation depth of 1 meter or more for their respective areas equipped for irrigation. The lowest value of 0.5 meter is shown for China. Even though China has a larger area equipped for irrigation than India (69 million hectares compared with 67 million), it withdraws only 52 percent of the water India withdraws for agricultural purposes.

Linking Agricultural Withdrawals and Total Withdrawals**.** Accounting for all countries, we illustrate the close relationship between agricultural withdrawals and total withdrawals. Figure 2 shows agricultural and total water withdrawals based on the latest country-level data available from FAO (2016a). For example, the point in the upper right corner of the first graph represents India, the country with the largest agricultural and total withdrawals.

Figure 2. Agricultural Water Withdrawals and Total Water Withdrawals, by Country

[3] Data on the area equipped for irrigation includes areas equipped for full and partial control irrigation, equipped lowland areas, pastures, and areas equipped for spate irrigation (FAO, 2016b). The area equipped does not necessarily represent the area that is actually irrigated. However, the available data on the area actually irrigated are too limited to be included here.

Our estimates indicate that agricultural withdrawals are highly correlated with total withdrawals.[4] According to the first graph in figure 2, on average, one cubic meter of total withdrawals is associated with about 0.74 cubic meters of agricultural withdrawals. In other words, about 74 percent of the water withdrawals worldwide are for agricultural purposes. This reconfirms earlier estimates cited above. Alternatively, the second graph in figure 2 shows that a 1 percent increase in total water withdrawals leads to a similar increase, amounting to 1.08 percent, in agricultural water withdrawals.

Linking Agricultural Withdrawals and Area Equipped for Irrigation. Similarly, we show the close relationship between agricultural withdrawals and the area equipped for irrigation. Figure 3 displays the data for all countries.

Figure 3. Agricultural Water Withdrawals and Area Equipped for Irrigation, by Country

Our estimates indicate that agricultural water withdrawals are also highly correlated with the area equipped for irrigation. According to the first graph of figure 3, one square meter of area equipped for irrigation is, on average, associated with an agricultural water withdrawal amounting to 0.77 cubic meters. This implies an average irrigation depth worldwide of 0.77 meters. This is about the irrigation depth found for the United States (table 1). Alternatively, the second graph in figure 3 shows that a 1 percent increase in the area equipped for irrigation leads to a similar increase, amounting to 1.01 percent, in agricultural water withdrawals.

3. Irrigated Agriculture and Water Scarcity

In a third step, we explore the relationship between irrigated agriculture and water scarcity. A number of issues make this difficult. Among them are some of the special characteristics of water discussed in section 2, such as variability of water supply and demand over time and space; the problem of properly defining water scarcity; and the availability of historical data on agricultural water use water use (Scheierling and Tréguer 2016b).[5]

Linking Agricultural Withdrawals and Water Scarcity. Various definitions of water scarcity have been proposed in the literature and different indicators applied (UNEP 2012). One widely used

[4] Using a similar approach, a study by the International Monetary Fund found that population, GDP in purchasing power parity, and agricultural GDP are also highly correlated with total withdrawals (Kochhar et al. 2015).
[5] FAO (2016a) provides only withdrawal data at the country level—reported once, if at all, for a five-year interval. No data on water consumption are provided.

indicator is based on a comparison of annual data of total water withdrawals and total renewable water resources at the national level.[6] A country is considered to experience "scarcity" in a particular year if the total water withdrawals are from 20 to 40 percent of the total renewable water resources, and "severe scarcity" if this value exceeds 40 percent. Map 1 displays this indicator based on data for 2013, or the latest year available, from FAO (2016a).

Map 1. Total Water Withdrawals as a Percent of Total Renewable Water Resources

Countries in the Middle East and North Africa are all shown to experience severe water scarcity. In other parts of the world, including most countries in South Asia and Central Asia, water is also considered scarce or severely scarce. Some countries' water withdrawals are even higher than their total renewable water resources. Saudi Arabia is the most extreme case, withdrawing almost 10 times the amount of renewable resources available, and thus relying mostly on non-renewable groundwater.

To illustrate the link between water scarcity and irrigated agriculture, we modify the indicator and, instead of total water withdrawals, compare agricultural water withdrawals to total renewable water resources. Map 2 shows the data for the modified indicator, again for 2013 or the latest year available.

Map 2. Agricultural Water Withdrawals as a Percent of Total Renewable Water Resources

The classification of countries with "scarcity" and "severe scarcity" is almost the same as in map 1, even though only agricultural withdrawals are considered. The maps illustrate the central role of irrigated agriculture in assessments of water scarcity at the national level. The most extreme cases are in the Middle East and North Africa: in Saudi Arabia, water withdrawn for irrigated agriculture alone is more than eight times the amount of total renewable water resources; in Libya, it is about five times; in Yemen one and a half times; and in Egypt slightly more than the amount of total renewable water resources.

Some caveats need to be kept in mind with regard to both indicators. On the one hand, they may underestimate water scarcity. Since they refer to the national level and apply annual data, they do not indicate water scarcity situations that may occur at the regional or local levels—especially in large

[6] Total renewable water resources comprise internal renewable water resources (specifically, the long-term average annual flow of rivers and recharge of aquifers generated from endogenous precipitation) and external renewable water resources (such as surface water and groundwater inflows from upstream countries).

countries, such as the United States or China; they also do not reflect the large intra-annual variations in water supply and demand (referred to in section 2) that may lead to large variations in water scarcity within a year. They also do not consider water quality issues or water requirements for the environment, such as minimum flows in rivers. On the other hand, they may overestimate water scarcity, since withdrawal data include the reuse of return flows that can be substantial in many cases—such as along the Nile in Egypt, where return flows may be reused several times.

***Trends in the Area Equipped for Irrigation at the Regional Level*.** The available data on agricultural withdrawals do not allow for an analysis of how trends in agricultural water withdrawals have affected water scarcity over time at the global level. However, a look at historical data on area equipped for irrigation can provide some insights (FAO 2016b). Worldwide, the area equipped for irrigation almost doubled over the 50-year period, from 164 to 324 million hectares (ha). This represents an increase from 12 percent of the cultivated area in 1962 to 21 percent in 2012. Figure 4 shows the trends by geographical region (excluding high-income countries) from 1962 to 2012.

Figure 4. Trend in Area Equipped for Irrigation, by Region

Figure 5 presents trends over the same period by geographical region and globally, including cultivated area, area equipped for irrigation, and the percentage of the cultivated area that is equipped for irrigation.

Figure 5. Area Cultivated and Area Equipped for Irrigation, by Region

Among the regions, the largest expansion in the area equipped for irrigation during the period from 1962 to 2012 occurred in South Asia, followed by East Asia and the Pacific—the two regions that already had the largest irrigated areas in 1962. The only decline in the area equipped for irrigation occurred in the Europe and Central Asia region since around the mid–1990s, mainly due to reductions in the countries of the former Soviet Union. As of 2012, South Asia was the region with the largest area equipped for irrigation (about 97 million hectares), and with the highest share of its cultivated area equipped for irrigation (46 percent). Sub-Saharan Africa has the lowest share with 4 percent, but it experienced the largest relative increase (by more than 400 percent) in area equipped for irrigation between 1962 and 2012.

At the country level, some of the largest expansions in percentage terms occurred in countries of the Middle East and North Africa. The highest percentage increase occurred in Saudi Arabia, with more than 430 percent (from 0.3 to 1.6 million ha), followed by Libya with 300 percent (from 0.1 to 0.5 million ha) and Yemen with 150 percent (from 0.2 to 0.7 million ha). As mentioned in connection with map 2, the same three countries are now also experiencing the most severe levels of water scarcity. Large area increases, in both percentage and absolute terms, also occurred in India (from 26 to 67 million ha), a country now considered water scarce, and in China (from 45 to 68 million ha).

Trends in Agricultural Withdrawals, Area Equipped for Irrigation and Scarcity Levels for Selected Countries. Data from FAO (2016a, 2016b) do not allow for an analysis of how trends in the area equipped for irrigation and agricultural withdrawals have affected scarcity levels over time at the global level. However, it is possible to do a partial analysis of the trends for a few countries. Figure 6 exhibits the trends for some of the countries with the largest agricultural withdrawals.[7] Changes over time for a number of other countries are in figure 7.

Figure 6. Trends in Agricultural Withdrawals and Area Equipped for Irrigation for Countries with the Largest Agricultural Withdrawals

Figure 7. Trends in Agricultural Withdrawals and Area Equipped for Irrigation for Other Countries

Each point represents a year for which data are available, with the color indicating the country's scarcity level. (The water scarcity level is in terms of agricultural withdrawals as a percent of total renewable water resources, as in map 2.) The slope of a ray from the origin through a point represents the irrigation depth for that observation. The dotted lines in figures 6 and 7 indicate the average irrigation depth of 0.77 meters worldwide (as in figure 3).

Figures 6 and 7 suggest that countries are on diverging, and in some instances counterintuitive, paths. India and China are striking examples: the two countries with the largest agricultural withdrawals and area equipped for irrigation. While both countries substantially expanded the area equipped for irrigation over the past three or four decades, agricultural withdrawals increased concomitantly in India, but remained the same in China (and were slightly lower in 2017 than in 1982). The average irrigation depth in India was higher in 2012 than it was in 1977, while in China it significantly decreased.

[7] The countries are the same as in table 1, except Indonesia and the Philippines.

Table 2 groups the countries according to the direction of their respective developments in agricultural withdrawals and area equipped for irrigation.

Table 2. Trend in Agricultural Withdrawals and Area Equipped for Irrigation for Selected Countries

Most countries have continued to increase agricultural withdrawals and the area equipped for irrigation—including countries that already suffer from severe water scarcity, such as Egypt, Turkmenistan, and Saudi Arabia. Based on the latest available data, they now all withdraw more water for agriculture than their available renewable water resources. The most extreme trends are found in Saudi Arabia, where the area equipped for irrigation expanded only slightly between 1992 and 2007, but agricultural withdrawals grew by about 40 percent. These examples suggest that even severe water scarcity does not necessarily lead countries to limit agricultural water withdrawals.

A few countries show a decrease in both agricultural withdrawals and the area equipped for irrigation. Among the countries with the largest agricultural withdrawals, the United States is the only one with relatively small decreases. Among the other countries, Kazakhstan and the Kyrgyz Republic show larger reductions in these variables; both countries experienced significant declines in the irrigation sector in the years following the breakup of the Soviet Union.

A number of countries show decreasing trends in water withdrawals while the area equipped for irrigation continued to increase. Besides China, these include Australia, Morocco, South Africa, and Jordan. One factor that may have contributed to this development was the transition to more capital-intensive irrigation technologies. Some data on trends in the use of on-farm irrigation systems are available from FAO (2016a). Figures 8 and 9 show trends in the area equipped for irrigation and irrigation systems for countries with the largest agricultural withdrawals and for other countries, respectively.

Figure 8. Trends in Area Equipped for Irrigation and Irrigation Systems for Countries with the Largest Withdrawals

Figure 9. Trends in Area Equipped for Irrigation and Irrigation Systems for Other Countries

All of the five countries show a move away from gravity irrigation toward more capital-intensive irrigation technologies, such as sprinklers and drip irrigation. As shown in figure 9, Jordan and South

Africa are furthest along in this conversion—with only about 18 percent of the area equipped for irrigation remaining under gravity irrigation in Jordan by 2007, and 23 percent in South Africa by 2012. However, no data are available on the effect of this switch of irrigation technologies on water consumption and return flows.

Some caution needs to be applied when interpreting the trend analyses above, in particular with regard to water use. Because the underlying data refer to annual amounts and are aggregated at the country level and, they may hide potentially significant temporal and spatial and variations. Also, even if a country shows a reduction in agricultural withdrawals as a result of a switch to more capital-intensive irrigation technologies and possibly other interventions, this does not necessarily imply that the amount of water actually consumed by the crops is also reduced (Scheierling and Tréguer 2016b). It may be the case that just the withdrawals and the resulting return flows are reduced, with no real effect on reducing water scarcity. Especially if the irrigated area continues to increase, it is likely that water consumption increases concomitantly—and the effect on water scarcity would be negative, even if agricultural withdrawals decline.

4. Conclusions

Keeping these caveats in mind, our analysis of the link between irrigated land and water scarcity provides some interesting insights. Trends in global water withdrawals and water consumption show large increases, though with declining growth rated during the last four decades, with water use in agriculture playing a major role. Worldwide, based on the latest available data, the share of agricultural consumption in total consumption amounts to more than 90 percent, and the share of agricultural withdrawals in total withdrawals to about 70 percent. However, this share may vary largely between countries, even among the countries with the largest agricultural withdrawals; for example, while 40 percent of total withdrawals are used for irrigated agriculture in the United States, the share may be as high as 94 percent for Pakistan and 95 percent for Vietnam.

Our estimates based on the latest data for all countries indicate that agricultural withdrawals are highly correlated with total water withdrawals: on average, one cubic meter of total withdrawals is associated with about 0.74 cubic meters of agricultural withdrawals. Agricultural withdrawals are also highly correlated with the area equipped for irrigation: on average, one square meter of area equipped for irrigation is associated with an agricultural withdrawal of 0.77 cubic meter.

When modifying a widely used indicator for water scarcity that compares country-level total water withdrawals and total renewable water resources, and comparing just country-level agricultural withdrawals and total renewable water resources, we show that the classification of countries with "scarcity" and "severe scarcity" remains almost the same. (Among the few exceptions of countries that are considered water scarce under the commonly used indicator and not water scarce when only agricultural withdrawals are included, are Germany, Italy, and Japan.) This illustrates the central role of irrigated agriculture in such assessments of water scarcity at the national level. It also suggests that agricultural water use is a key contributor to water scarcity in an increasing number of countries, especially in drier areas.

An analysis of trends in agricultural withdrawals, area equipped for irrigation and scarcity levels for selected countries shows that, during the last decades, most continued to increase agricultural withdrawals and expand the area equipped for irrigation. This was even the case for countries that already suffered from severe water scarcity, such as Egypt, Saudi Arabia and Turkmenistan; based on the latest available data, they now withdraw annually more water for irrigated agriculture than the total amount of renewable water resources available to them. A few countries show a reduction in both agricultural withdrawals and area equipped for irrigation, including the United States with relatively small decreases, and Kazakhstan and the Kyrgyz Republic with larger reductions following the breakup of the Soviet Union. A few countries, such as Australia, China, Morocco, South Africa and Jordan, reduced agricultural withdrawals but continued to expand the area equipped for irrigation; a contributing factor may have been these countries' increasing use of more capital-intensive irrigation technologies. Yet even if water withdrawn for irrigated agriculture was reduced, this does not necessarily imply that agricultural water consumption also decreased; it may have actually increased with the expansion of irrigated land—and the real effect on water scarcity could possibly have been negative. Further data collection efforts would be necessary to determine the overall outcome on the water situation.

Going forward, agricultural water use will continue to be a major factor shaping the water situation worldwide, particularly given the pressure to expand irrigated land as demand rises for agricultural products. Global projections vary depending on the models employed as well as the data, assumptions, and scenarios used. A review of recent projections on agricultural water use is in OECD (2014). Projections become even more dire, and uncertain, when the effects of climate change are taken into account. According to Elliott et al. (2014), by the end of this century total renewable water resources may still allow a net increase in irrigated agriculture in some areas, such as the northern and eastern United States, and in parts of South America and Southeast Asia. In other areas, such as the western United States, China, the Middle East and North Africa, and Central and South Asia, the previous expansion from rain-fed to irrigated agriculture would need to be reversed.

Our analysis of the historical data suggests that, so far, even severe water scarcity has had relatively little effect on the trends in agricultural withdrawals and area equipped for irrigation in many countries. Even in cases with dangerously worsening water scarcity levels, the area equipped for irrigation continued to grow. A few countries started to reduce agricultural withdrawals while continuing to expand the irrigated area. Yet it is likely that the effect on agricultural water consumption did not correspond to the trend in agricultural withdrawals—consumption tends to increase with an expansion of the irrigated land.

Overall, this suggests an insufficient awareness of the link between irrigated land and water scarcity in many countries' policy debates, plans, and investments. Much more effort will be necessary to adapt decisions on land use—and, implicitly, on water use—to situations of increasingly scarce water. Many adaptation options are currently not well explored, due in part to the lack of data on the key water measures and how they have changed, or may change, as a result of different interventions. Given the magnitude of the problem, this topic must attract increasing attention.

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Table 1. Countries with the Largest Agricultural Water Withdrawals

Country	Agricultural water withdrawals (billion cubic meters)	Total water withdrawals (billion cubic meters)	Agricultural water withdrawals as percent of total water withdrawals	Area equipped for irrigation (million hectares)	Area equipped for irrigation as percent of agricultural area	Agricultural water withdrawals per area equipped for irrigation (meters)
India	688	761	90%	67	37%	1.0
China	358	554	65%	69	13%	0.5
United States	175	486	40%	26	6%	0.7
Pakistan	172	184	94%	20	75%	0.9
Indonesia	93	113	82%	7	12%	1.3
Iran	86	93	92%	10	19%	0.9
Vietnam	78	82	95%	5	42%	1.6
Philippines	67	82	82%	2	13%	3.4
Egypt	67	78	86%	4	100%	1.5
Mexico	62	80	77%	7	6%	0.9

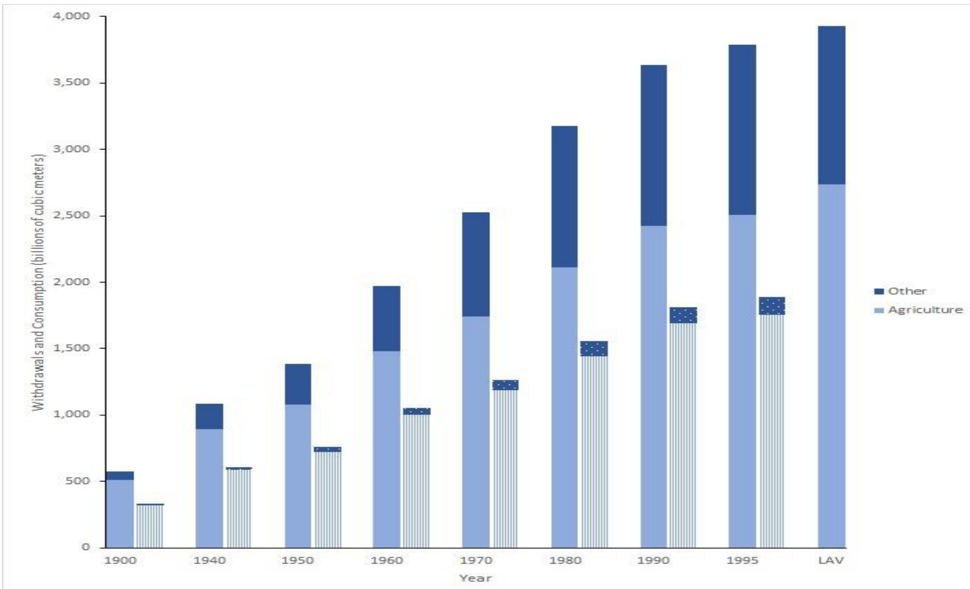
Source: Scheierling and Tréguer 2016b, based on FAO 2016a, 2016b.

Table 2. Trends in Agricultural Withdrawals and Area Equipped for Irrigation for Selected Countries

	Area Equipped for Irrigation	
Agricultural Withdrawals	**Increasing**	**Decreasing**
Increasing		
- Countries with Largest Withdrawals	India, Pakistan, Iran, Mexico, Vietnam, Egypt	
- Other Countries	Spain, Turkmenistan, Saudi Arabia, Algeria, Tunisia	Korea
Decreasing		
- Largest Withdrawal Countries	China	United States
- Other Countries	Australia, Morocco, South Africa, Jordan	Kazakhstan, Kyrgyzstan

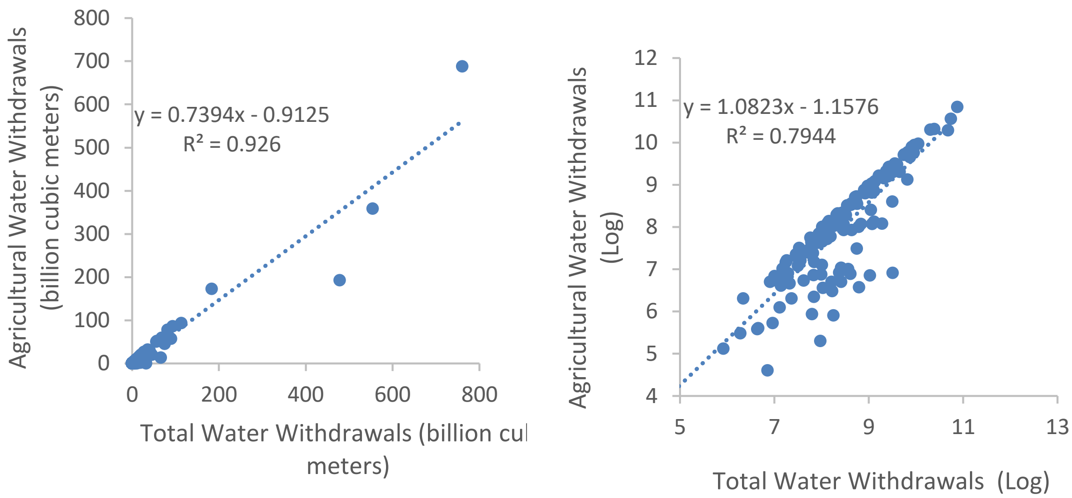
Source: Authors, based on FAO 2016a.

Figure 1. Global Trends in Agricultural and Total Water Withdrawals and Consumption



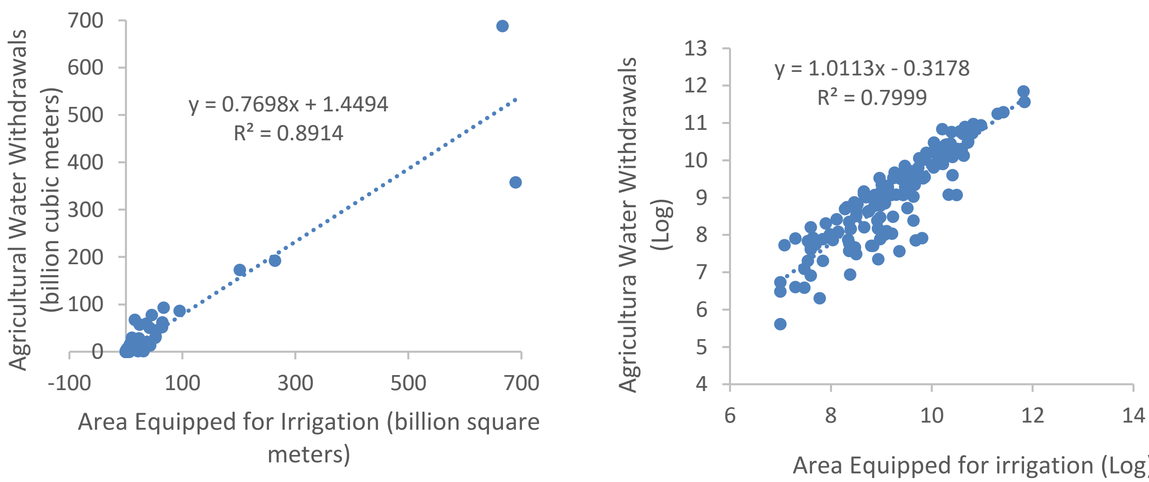
Source: Scheierling and Tréguer 2016a, based on Shiklomanov and Rodda 2003, and FAO 2016a.
Note: Solid colors show withdrawals, and patterned colors consumption. LAV=latest available value.

Figure 2. Agricultural Water Withdrawals and Total Water Withdrawals, by Country



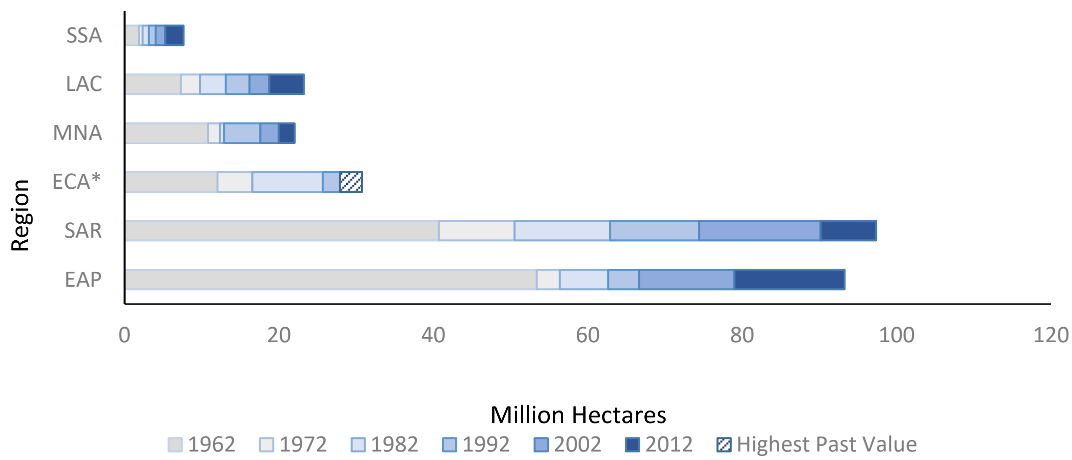
Source: Scheierling and Tréguer 2016b, based on FAO 2016a.
Note: First graph with standard error of 0.0174, and t stat of 42.46; second graph with standard error of 0.0457, and t stat of 23.67.

Figure 3. Agricultural Water Withdrawals and Area Equipped for Irrigation, by Country



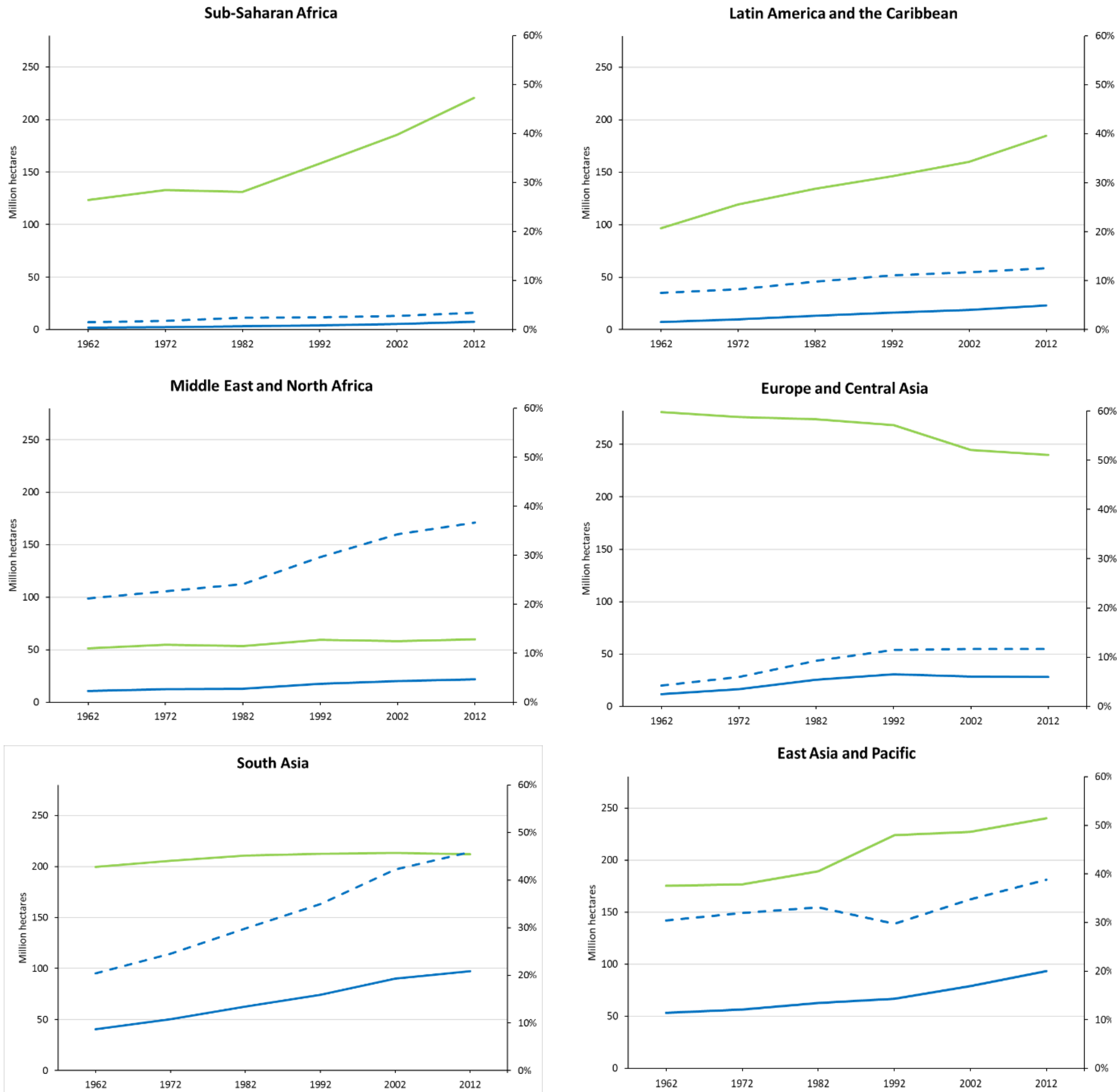
Source: Scheierling and Tréguer 2016b, based on FAO 2016a, 2016b.
Note: First graph with standard error of 0.0224, and t Stat of 34.37; second graph with standard error of 0.0423, and t stat of 23.91.

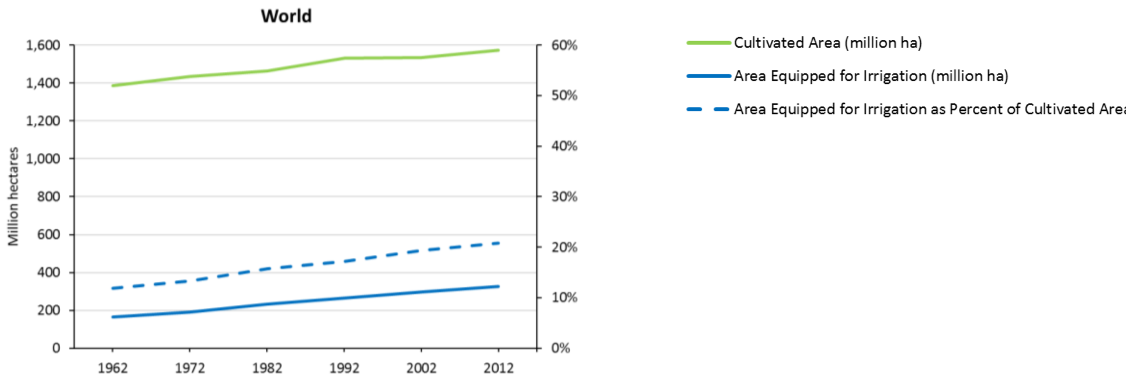
Figure 4. Trends in Area Equipped for Irrigation, 1962–2012, by Region



Source: Scheierling and Tréguer 2016a, based on FAO 2016b.
Note: SSA=Sub-Saharan Africa, LAC=Latin America and the Caribbean Region, MNA=Middle East and North Africa, ECA=Europe and Central Asia, SAR=South Asia Region, EAP=East Asia and Pacific. ECA* includes data for USSR/Russian Federation.

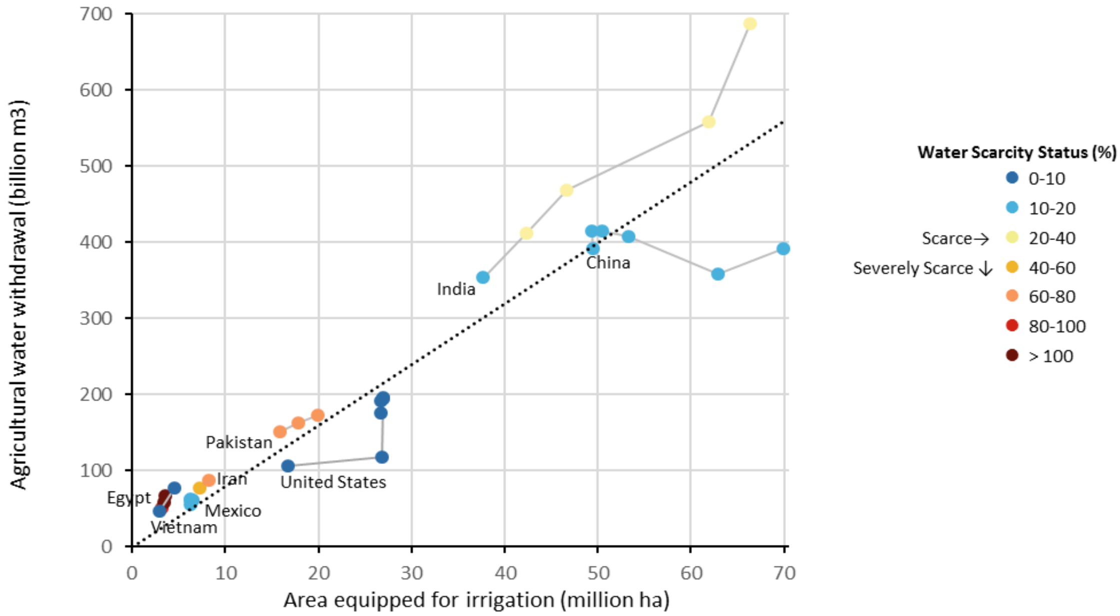
Figure 5. Area Cultivated and Area Equipped for Irrigation, by Region





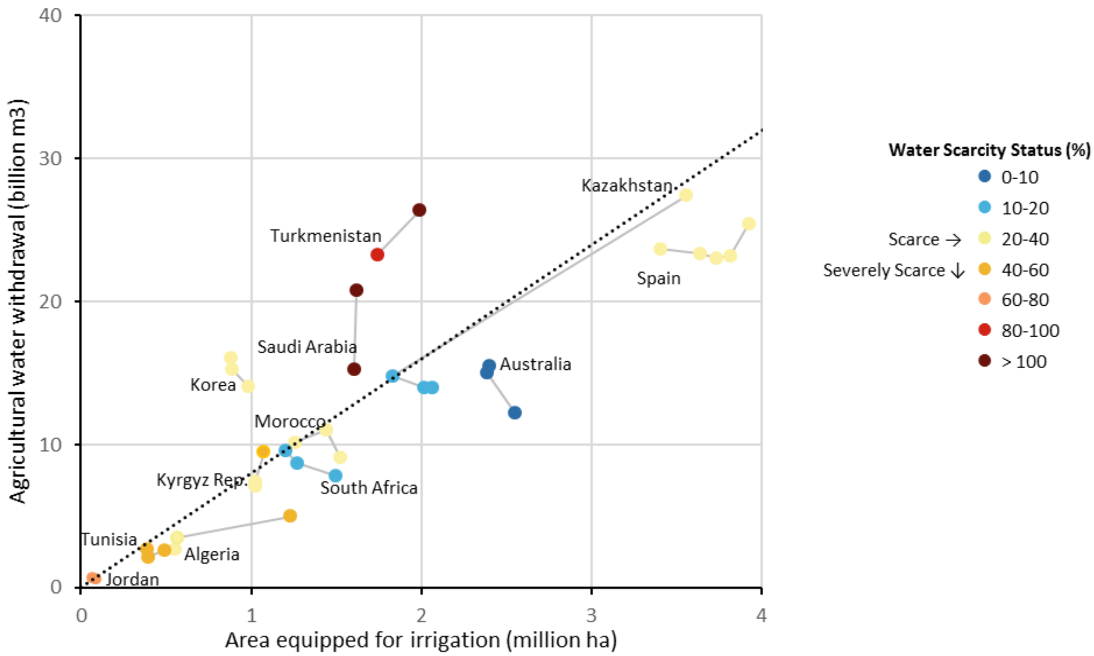
Source: Authors, based on FAO 2016a.

Figure 6. Trends in Agricultural Withdrawals and Area Equipped for Irrigation for Countries with the Largest Agricultural Withdrawals



Source: Authors, based on FAO 2016a, 2016b.
Note: India (1977, 1982, 1987, 2002, 2012); China (1982, 1987, 1992, 1997, 2007, 2017); United States (1977, 1982, 1992, 2002, 2007, 2012); Pakistan (1992, 2002, 2012); Iran (1997, 2007); Vietnam (1992, 2007); Egypt (1997, 2002, 2012); Mexico (1997, 2002, 2007, 2012).

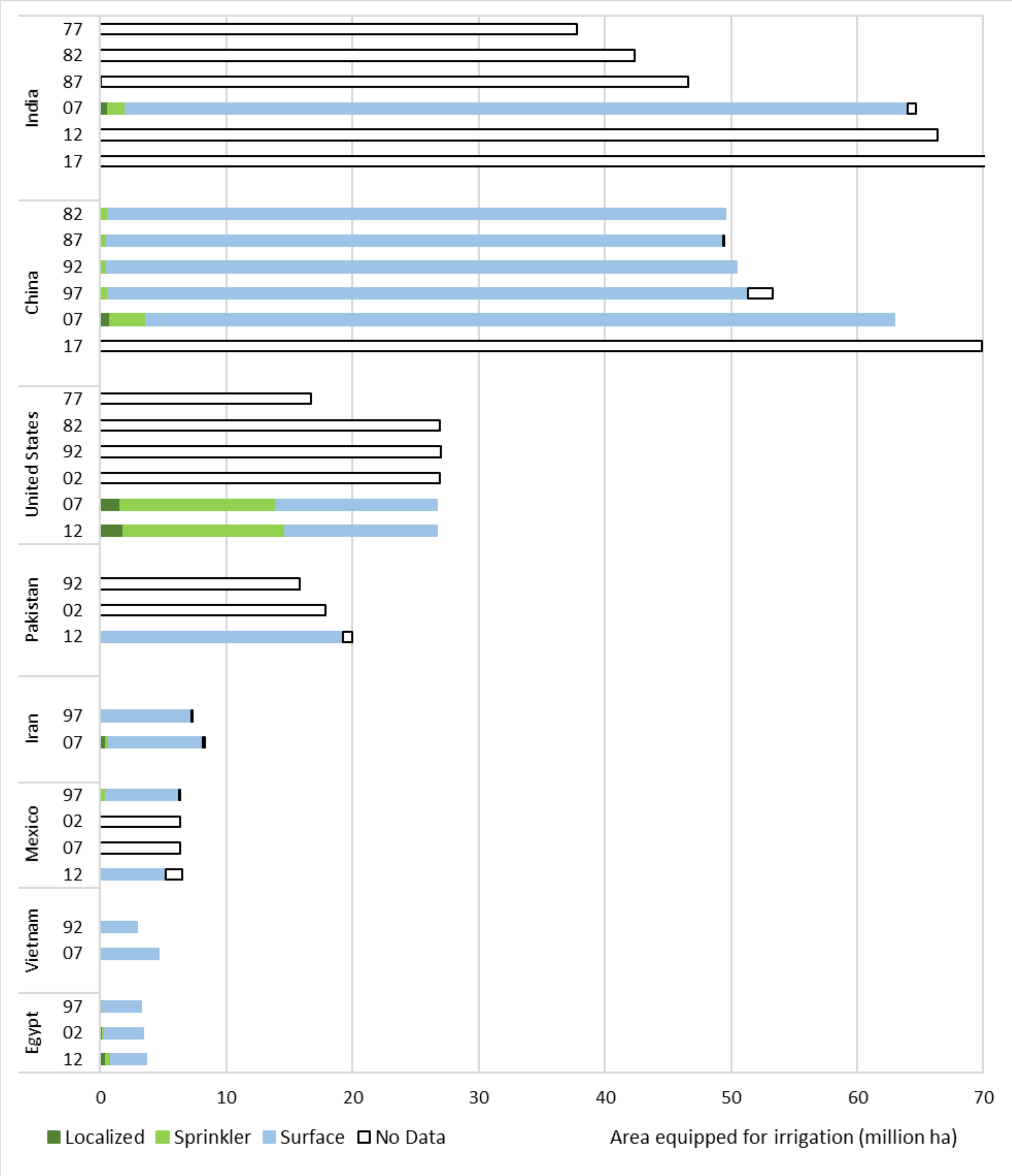
Figure 7. Trends in Agricultural Withdrawals and Area Equipped for Irrigation for Other Countries



Source: Authors, based on FAO 2016a, 2016b.

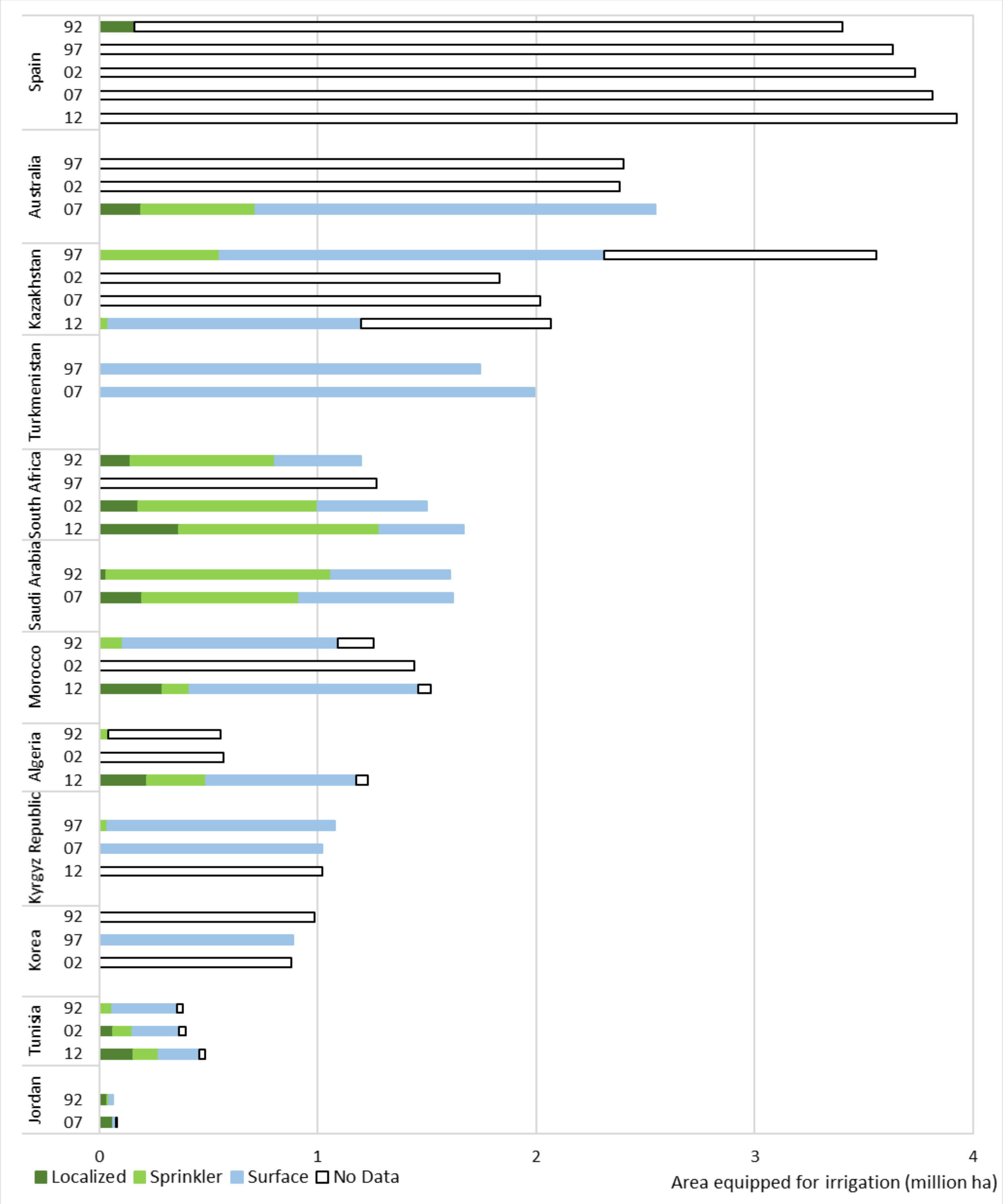
Note: Turkmenistan (1997, 2007); Spain (1992, 1997, 2002, 2007, 2012); Saudi Arabia (1992, 2007); Kazakhstan (1997, 2002, 2007, 2012); Korea, Republic of (1992, 1997, 2002); Australia (1997, 2002, 2007); Morocco (1992, 2002, 2012); South Africa (1992, 1997, 2002); Kyrgyz Republic (1997, 2007, 2012); Algeria (1992, 2002, 2012); Tunisia (1992, 2002, 2012); Jordan (1992, 2007).

Figure 8. Trends in Area Equipped for Irrigation and Irrigation Systems for Countries with the Largest Agricultural Withdrawals



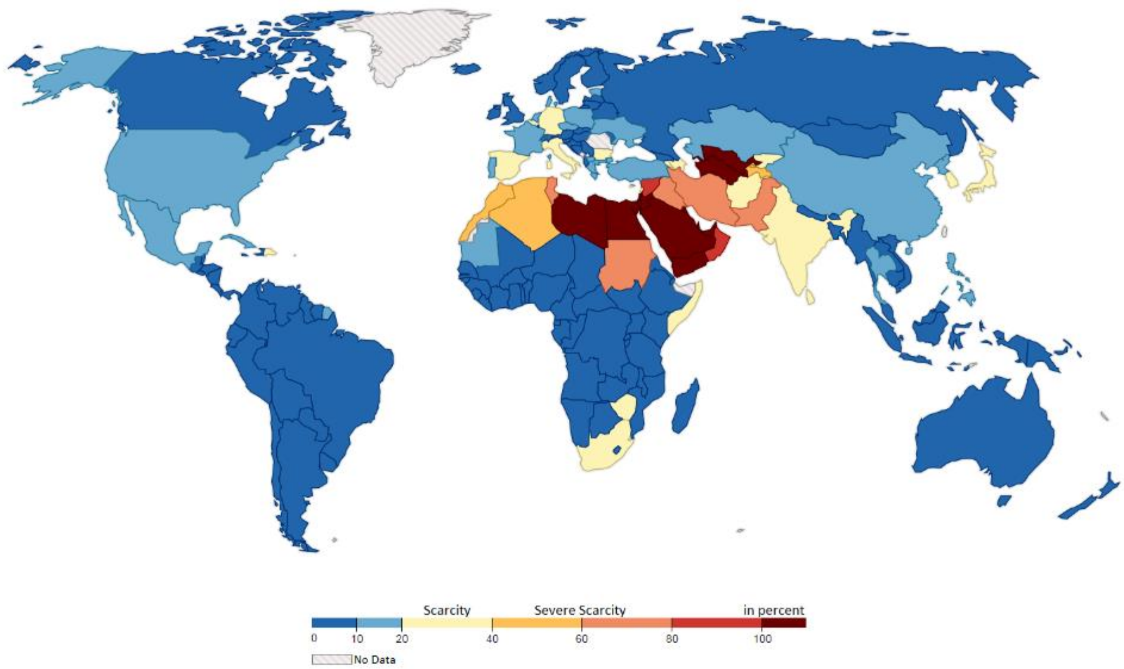
Source: Based on FAO 2016a.

Figure 9. Trends in Area Equipped for Irrigation and Irrigation Systems for Other Countries



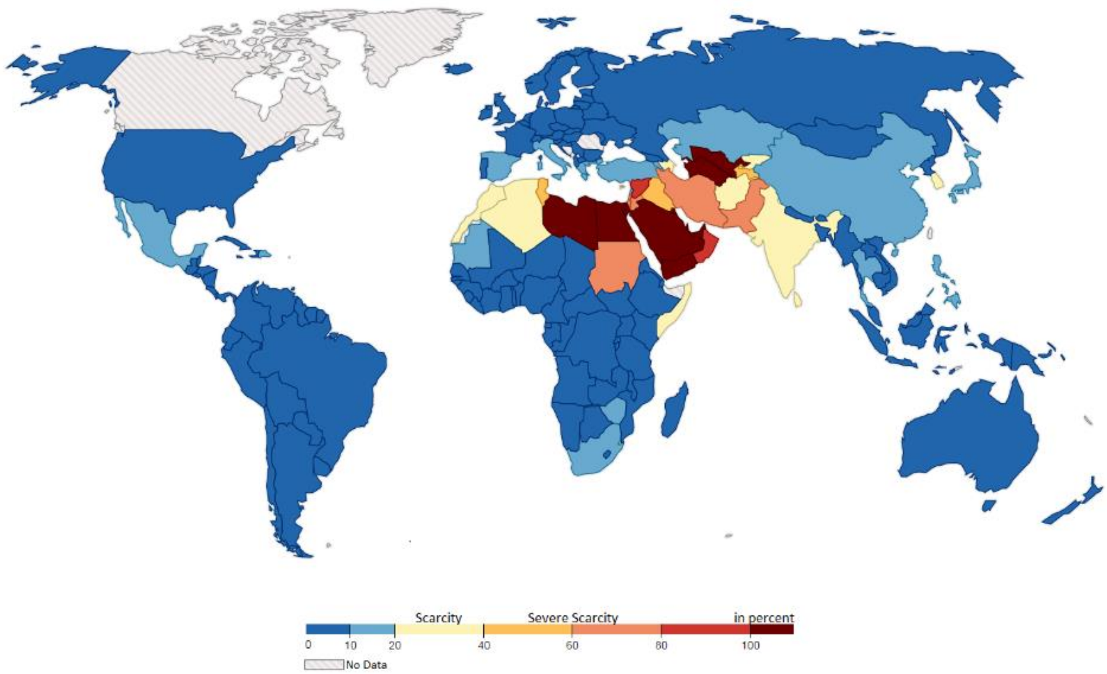
Source: Authors, based on FAO 2016a.

Map 2. Total Water Withdrawals as a Percent of Total Renewable Water Resources



Source: Scheierling and Tréguer 2016b, based on FAO 2016a.

Map 2. Agricultural Water Withdrawals as a Percent of Total Renewable Water Resources



Source: Scheierling and Tréguer 2016b, based on FAO 2016a.