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Research Report

World Water Demand and Supply, 1990 to 2025: Scenarios and Issues

David Seckler, Upali Amarasinghe
David Molden, Radhika de Silva
and
Randolph Barker

IWMI

International Water Management Institute

Research Reports

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David Seckler, Upali Amarasinghe,
David Molden, Radhika de Silva, and Randolph Barker

International Water Management Institute
P O Box 2075, Colombo, Sri Lanka

The authors: Radhika de Silva was a consultant at IWMI, the other authors are all on the staff of IWMI.

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The International Irrigation Management Institute, one of sixteen centers supported by the Consultative Group on International Agricultural Research (CGIAR), was incorporated by an Act of Parliament in Sri Lanka. The Act is currently under amendment to read as International Water Management Institute (IWMI).

Contents

Summary

It is widely recognized that many countries are entering an era of severe water shortage. The International Water Management Institute (IWMI) has a long-term research program to determine the extent and depth of this problem, its consequences to individual countries, and what can be done about it. This study is the first step in that program. We hope that water resource experts from around the world will help us by contributing their comments on this report and sharing their knowledge and data with the research program.

The study began as what we thought would be a rather straightforward exercise of projecting water demand and supply for the major countries in the world over the 1990 to 2025 period. But as the study progressed, we discovered increasingly severe data problems and conceptual and methodological issues in this field. We therefore created a simulation model that is based on a conceptual and methodological structure that we believe is valid and on various estimates and assumptions about key parameters when data are either missing or subject to a high degree of error and misinterpretation.

The model is in a spreadsheet format and is made as simple and transparent as possible so that others can use it to test their own ideas and data (and we would like to see the results). One of the strengths of this model is that it includes a submodel on the irrigation sector that is much more thorough than any used to date in this context. Since irrigation uses over 70 percent of the world's supplies of developed water, getting this component right is extremely important. The full model, with a guide, can be downloaded on IWMI's home page (http://www.cgiar.org/iimi).

Most of the discussion in this report is devoted to explaining why this simulation model is needed and how it works. Once this is done, two alternative scenarios of water supply and demand over the 1990 to 2025 period are produced, and indicators of water scarcity are developed for each country and for the world as whole.

Part I of the report describes the water balance approach which provides the conceptual framework for this study. The water balance framework is used to derive estimates of water supply and demand for countries. These estimates are adjusted to take explicit account of return flows and water recycling whose importance is often neglected in studies of water scarcity.

Part II presents the data for the spreadsheet model of water supply and demand for 118 countries that include 93 percent of the world's 1990 population. Following a discussion of the 1990 data, two scenarios of world water supply and demand are presented. Both make the same assumptions regarding the domestic and industrial sectors. And both scenarios assume that the per capita irrigated areas will be the same in 2025 as in 1990. The difference between the scenarios is due to different assumptions about the effectiveness of the utilization of water in irrigating crops—the "crop per drop" (Keller, Keller, and Seckler 1996). Irrigation effectiveness includes water recycling within the irrigation sector. The first is a base case, or "business as usual," scenario. The second scenario assumes a high, but not unrealistic, degree of effectiveness in the utilization of irrigation water, with the consequent savings of irrigation water being used to meet the future water needs of all the sectors.

It is found that the growth in world requirements for the development of additional water supplies varies between 57 percent in the first scenario to 25 percent in the second scenario. The truth perhaps lies somewhere between. Thus increasing irrigation effectiveness reduces the need for development of additional water supplies for all the sectors in 2025 by roughly one-half. This is a substantial amount, but development of additional water supplies through

small and large dams, conjunctive use of aquifers and, in some countries, desalinization plants will still be needed.

Also, these world figures disguise enormous differences among countries (and among regions within countries). Many of the most water-scarce countries already have highly effective irrigation systems, so this will not substantially reduce their needs for development of additional water supplies. On the other hand, most of the world's gain in irrigation effectiveness would be in countries with a high percentage of rice irrigation. It is not clear how much basin irrigation effectiveness can be practically increased in rice irrigation. Also, rice irrigation tends to occur in areas with high rainfall where water supply is not a major problem. The fact that South China has a lot of water to be saved through improved irrigation effectiveness is small consolation to a farmer in Senegal who hardly has any—or for that matter to a farmer in the arid north of China (unless there are interbasin transfers from south to north). Partly for these reasons, one-half of the world's total estimated water savings from increased irrigation effectiveness is in India and China. This illustrates why the country data—and, ultimately, the data for regions within countries—are much more important than world data.

Part III presents two basic criteria of water scarcity that together comprise the overall IWMI indicator of water scarcity for countries. Using the high irrigation effectiveness scenario, these criteria are (i) the percent increase in water "withdrawals" over the 1990 to 2025 period and (ii) water withdrawals in 2025 as a percent of the "Annual Water Resources" (AWR) of the country. Because of their enormous populations and water use, combined with extreme variations between wet and dry regions within the countries, India and China are considered separately. The 116 remaining countries are classified into 5 groups according to these criteria (figure 1).

Group 1 consists of countries that are water-scarce by both criteria. These countries, which have 8 percent of the population of the countries studied, are mainly in West Asia and North Africa. For countries in this group, water scarcity will be a major constraint on food production, human health, and environmental quality. Many will have to divert water from irrigation to supply their domestic and industrial needs and will need to import more food.

The countries in the four remaining groups have sufficient water resources (AWR) to satisfy their 2025 requirements. However, variations in seasonal, interannual, and regional water supplies may cause underestimation of the severity of their water problems based on average and national water data. A major concern for many of these countries will be developing the large financial, technical, and managerial wherewithal needed to develop their water resources.

Group 2 countries, which contain 7 percent of the study population and are mainly in sub-Saharan Africa, must develop more than twice the amount of water they currently use to meet reasonable future requirements.

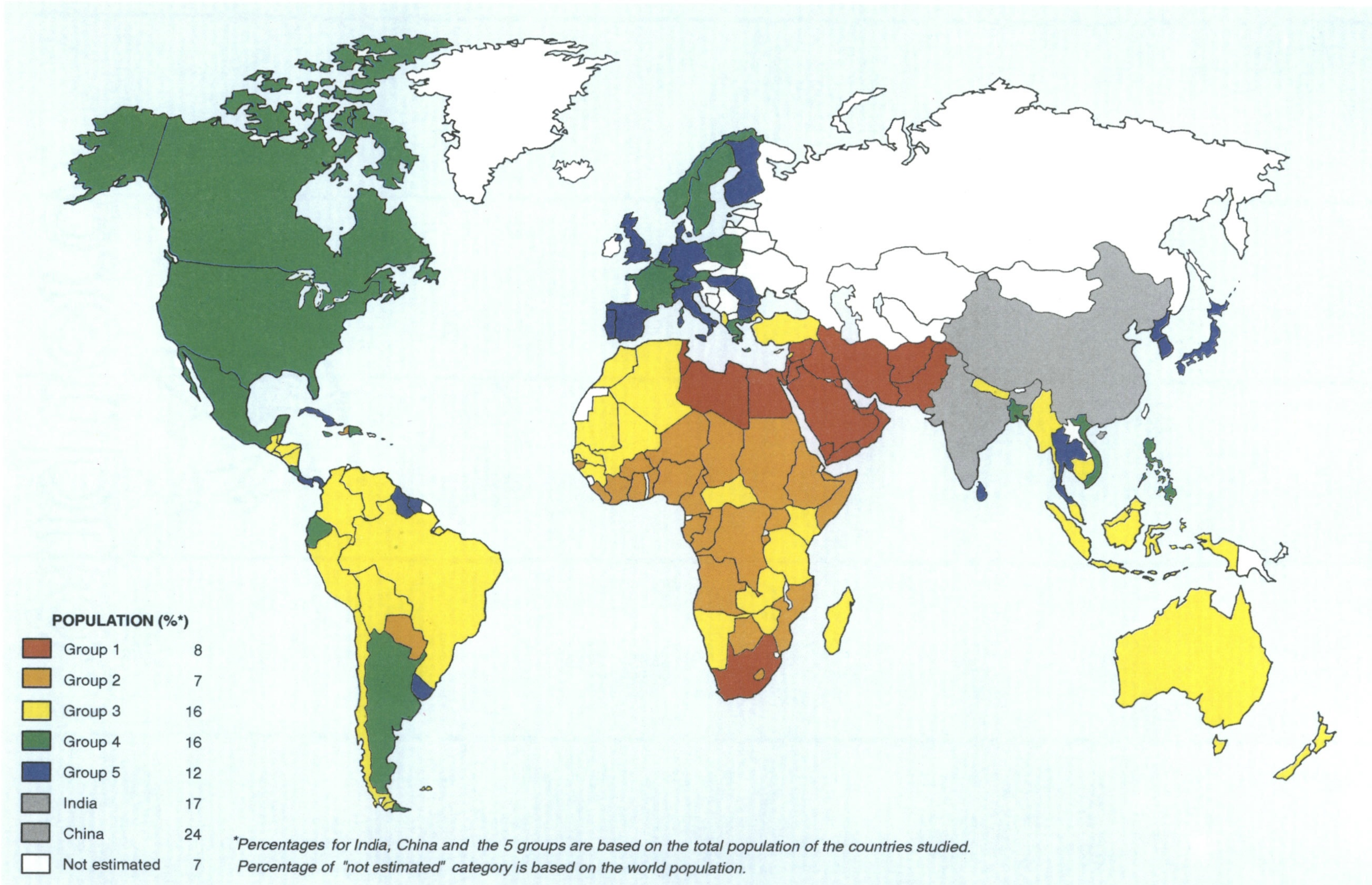
Group 3 countries, which contain 16 percent of the population and are scattered throughout the developing world, need to increase withdrawals by between 25 percent and 100 percent, with an average of 48 percent.

Group 4 countries, with 16 percent of the population, need to increase withdrawals, but by less than 25 percent.

Group 5 countries, with 12 percent of the population, require no additional withdrawals in 2025 and most will require even less water than in 1990.

We believe that the methodology used in this report may serve as a model for future studies. The analysis reveals serious problems in the international database, and much work needs to be done before the methodology can be used as a detailed planning tool. However, the work to date highlights the national and regional disparities in water resources and provides a basis from which we can begin to assess the future supply and demand for this vital natural resource.

FIGURE 1.
IWMI indicator of relative water scarcity.



World Water Demand and Supply, 1990 to 2025: Scenarios and Issues

David Seckler, Upali Amarasinghe, David Molden, Radhika de Silva, and Randolph Barker

Introduction

It is widely recognized that many countries are entering an era of severe water shortage. Several studies (referenced below) have attempted to quantify the extent of this problem so that appropriate policies and projects can be implemented. But there are formidable conceptual and empirical problems in this field. To address these problems, the International Water Management Institute (IWMI) has launched a long-term research program to improve the conceptual and empirical basis for analysis of water in major countries of the world. This study is the first step in that research program.

What do we mean when we say that one country is facing water scarcity while another country is not? At first, this might seem to be a simple question to answer. But the more one attempts actually to answer it, much less to create quantitative indicators of scarcity, the more one appreciates what a difficult question it really is. Water scarcity can be defined either in terms of the existing and potential supply of water, or in terms of the present and future demands or needs for water, or both.

For example, in their pioneering study of water scarcity, Falkenmark, Lundqvist, and Widstrand (1989) take a "supply-side" approach by ranking countries according to the per capita amount of "Annual Water Resources" (AWR), as we call it, in the country. (This and other technical terms are discussed in Part I). They define 1,700 cubic meters (m^3) per capita per year as the level of water supply above which shortages will be local and rare. Below 1,000 m^3 per capita per year, water supply begins to hamper health, economic development, and human well-being. At less than 500 m^3 per capita per year, water availability is a primary constraint to life. We shall refer to this as the "Standard" indicator of water scarcity among countries since it is by far the most widely used and referenced indicator (e.g., Engelman and Leroy 1993).

Another supply-side approach is taken in a study commissioned by the UN Commission on Sustainable Development (Raskin et al. 1997). This study defines water scarcity in terms of *the total amount of annual withdrawals as a percent of AWR*. We refer to this as the "UN" indicator. According to this criterion, if total withdrawals are greater than 40 percent of AWR, the country is considered to be water-scarce.

One of the problems with the supply-side approach is that the criterion for water scarcity is based on a country's AWR without reference to present and future *demand or needs* for water. To take an extreme example, as shown in table 1, Zaire has a very high level of AWR per capita and a very low percentage of withdrawals in relation to AWR. Thus Zaire does not rank as water-scarce by either the Standard or the UN indicators. But the people of Zaire do not presently have enough water withdrawals to satisfy any reasonable standard of water needs. Zaire must *develop* large amounts of additional water supplies to meet the present, let alone future, needs of its population. The people of Zaire, like the Ancient Mariner, have "water, water everywhere, but nor any drop to drink."

This study attempts to resolve these problems by simulating the demand for water in relation to the supply of water over the period 1990 to 2025. Two scenarios are presented. Both make the same assumptions regarding the domestic and industrial sectors. The difference between the scenarios is due to different assumptions about the effectiveness of the irrigation sector. The first scenario presents a "business as usual" base case; the second scenario assumes a high, but not unrealistic, degree of effectiveness of the irrigation sector. This enables us to estimate how much of the increase in demand for water could be met by *more* effective *use* of existing water supplies in irrigation and how much would have to be met by the *development of additional water supplies*. We then compare these estimates with the AWR for each country to determine if there are sufficient water resources in the countries to meet their needs for additional water development.

This report is divided into three parts. Part I discusses *water balance analysis,* which provides the conceptual framework underlying our estimates of water demand and supply. Part II discusses the simulation model and applies it to 118 countries containing 93 percent of the world's population. (The remainder is largely in the former Soviet Union.) Part III presents the rationale and methodology for grouping countries into five groups based on degrees of water scarcity and discusses the implications of the analysis for national and global food security.

PART I:—Water Balance Analysis

The conceptual framework of the analysis in this section is based on previous studies (Seckler 1992, 1993, 1996; J. Keller 1992; Keller, Keller, and Seckler 1996; Perry 1996; Molden 1997; and the references in these reports). It reflects what is sometimes referred to as the "IWMI Paradigm" of integrated water resource systems, which explicitly includes water recycling in the analysis of irrigation and other water sectors. In this section, we apply this basic paradigm to country-level analysis of water resource systems.

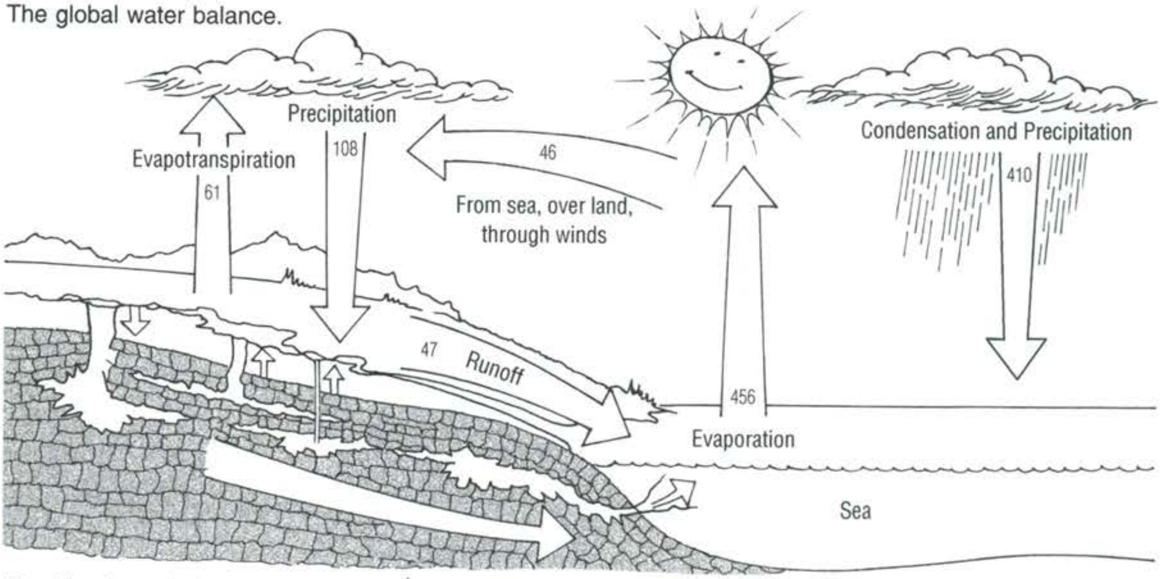
As the discussion shows, this is not an easy task because in water resources, as in many other fields, the meaning of data and functional relationships is highly dependent on the *scale* of the analysis. Thus when the analysis proceeds from the micro, through the meso, to the macro scale, care must be taken to keep the concepts and words in the appropriate context. Most of the data used in this report are from the World Resources Institute 1996, Data Table 13.1; henceforth simply "WRI." As noted below, the WRI data have some major areas of ambiguity.

The Global Water Balance

We begin the discussion with a brief view of the water balance at the ultimate scale of the globe, as illustrated in figure 2. (This section is adapted from Seckler 1993, Postel, Daily, and Ehrlich 1996, and WRI 1996).

Water is difficult to create or destroy under most natural conditions. Thus as it recycles globally through its three states of liq-

FIGURE 2.
The global water balance.



Note: All numbers are in thousands of cubic kilometers of water per year.
Source: Seckler 1993.

Winrock International, 1993

uid, solid, and vapor, virtually none is gained or lost. Indeed, the total amount of water on earth today is nearly the same as it was millions of years ago at the beginning of the earth—with the possible exception of the recent discovery of "imports" of significant amounts of water from outer space by "cosmic snowballs" (reported in Sawyer 1997).

Over 97 percent of the world's water resources is in the oceans and seas and is too salty for most productive uses. Two-thirds of the remainder is locked up in ice caps, glaciers, permafrost, swamps, and deep aquifers. About 108,000 cubic kilometers (km^3) precipitate annually on the earth's surface (figure 2). About 60 percent (61,000 km^3) evaporates directly back into the atmosphere, leaving 47,000 km^3 flowing toward the sea. If this amount were evenly distributed, it would be approximately 9,000 m^3 per person per year. However, much of the flow occurs in seasonal floods. It is estimated that only 9,000 km^3 to 14,000 km^3 may ultimately be controlled. At present, only 3,400 km^3 are withdrawn for use (table 1, column 4).

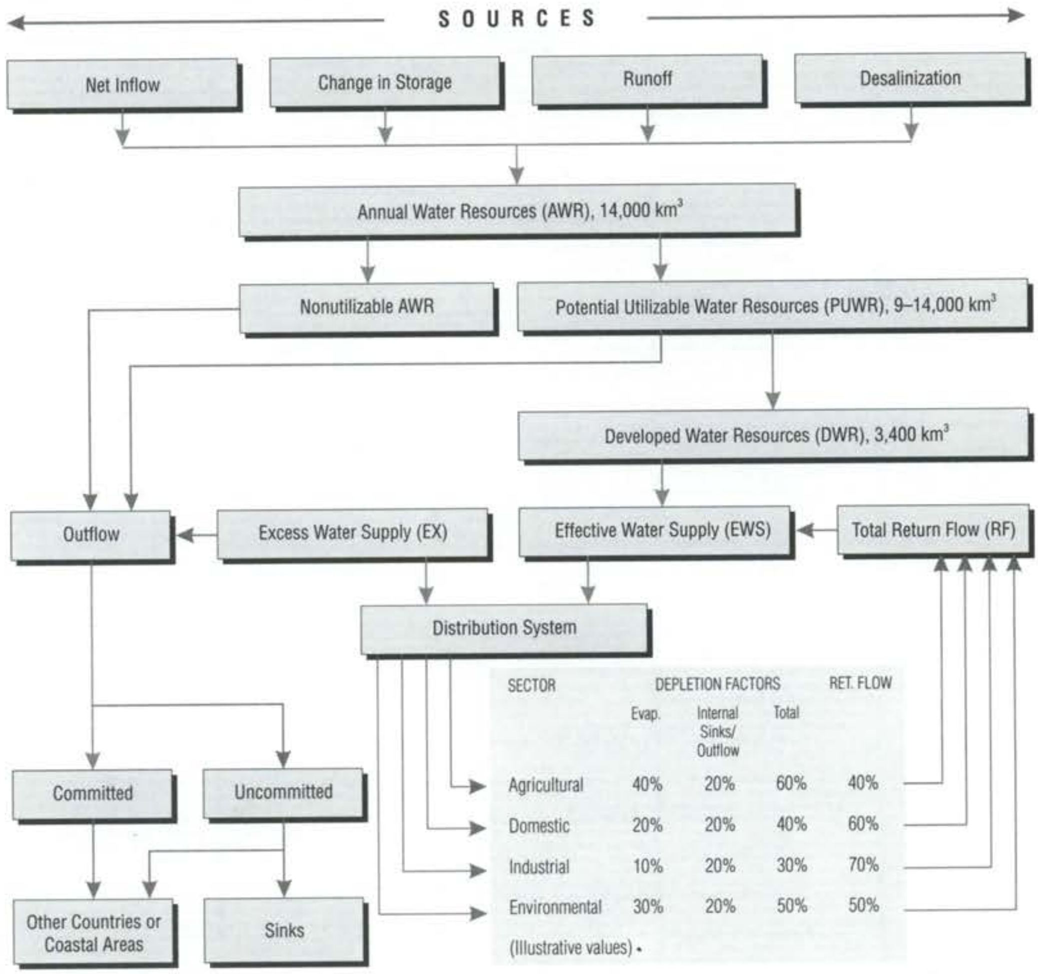
Country Water Balances

Figure 3 illustrates the water balance framework and nomenclature that form the basis for the country-level water balances (also see Molden 1997). The cubic kilometer amounts for certain categories link figure 2 to figure 3.

There are four *sources* of water:

- *Net flow of water* into a country is water inflow from rivers and aquifers minus outflows.
- *Changes in storage* are interannual changes in the amounts of water stored in snow and ice, reservoirs, lakes, aquifers, and soil-moisture. Decreasing storage levels indicate an unsustainable amount of supply from these sources, and increasing levels indicate the potential for additional annual water supplies.
- *Runoff* is the surface and subsurface flow of water. It is equal to annual precipitation minus *in situ* evaporation. Water

FIGURE 3.
Water balance analysis.



that infiltrates into soil is sometimes also subtracted for short-term analysis (e.g., floods) but infiltration eventually ends up in evaporation, storage, or runoff. Because of water recycling in the system, runoff is almost impossible to measure directly on a large scale. It is usually estimated through climatological data and simulation models.

Desalinization is from seawater or brackish water, but it is a limited and costly source.

The Annual Water Resources (AWR) of a country constitute the average annual amount of water provided by the above sources on a sustainable basis. (AWR are equal to the WRI columns: "Annual Internal Renewable Water Resources" minus "Annual River Flows to Other Countries.") Thus, for example, depletion of aquifers is not considered part of AWR because it is not sustainable. This is why certain countries in the WRI database are shown to divert more water than AWR. Another problem is that while WRI provides data on the outflow from one country to another, it does not provide data on the outflow from a country to sinks, like the oceans. This would bias estimates of AWR upward for countries with uncontrollable outflows to sinks, as noted directly below. Last, there are major errors in the outflow figures to other countries in the WRI data. According to these data, for example, Ethiopia, has no outflow while all of Canada's AWR flow to some other country! These errors are corrected wherever possible, as indicated in the notes to table 1.

Part of the AWR is *nonutilizable*. The amount of nonutilizable AWR depends on whether or not the water is available and can be controlled for use at the time and place in which it is needed. This problem is particularly important in regions that have pronounced differences in seasonal precipitation, such as monsoon-typhoon Asia. In India, for example, about 70 percent of the total annual precipitation occurs in the three summer months of the monsoon, most of which floods out to the sea.

The *potentially utilizable water resource* (PUWR) is the amount of the AWR that is potentially utilizable with technically, socially, environmentally, and economically feasible water development programs. Since most countries have not fully developed their PUWR, part of this amount of water is not actually utilized at a given point in time and goes to outflow. Unfortunately, there are no estimates of PUWR in WRI. In defining PUWR, it is important to consider the reliability of the annual supply of water. Because of climatological variations there is a large amount of interannual and seasonal variation in flows. The PUWR needs to be defined in terms of the reliability of a minimally acceptable flow in the lowest flow season of the lowest flow year. Thus only a fraction of the average AWR can be considered to be PUWR for most countries. One exception is Egypt, where fully 3 years' total AWR (about 160 km^3!) can be stored in the High Aswan Dam and released at will.

The *developed water resource* (DWR) is the amount of water from PUWR that is controlled and becomes the first, or primary, inflow of unused or "virgin" water to the supply system. Except in a few countries like Egypt, where nearly all the DWR flows from a single, easily measured point—the discharge of the High Aswan Dam—it is very difficult to measure DWR because it is difficult to know what part of the water being measured is recycled, not "virgin" water.

The *outflow* from a river basin or country may be divided into two parts (Molden 1997). The *committed* outflow is the amount of water formally or informally committed to downstream users and uses. While these users may be other countries, which have rights to certain inflows, the uses may be outflows necessary to protect coastal areas and ports, and provide wildlife habitats and the like. The *uncommitted* outflow is surplus to any of the above uses and simply flows out of the basin or country into "sinks," mainly to the oceans and seas, where it cannot be used for most purposes.

Of course, since water is a highly fungible—or, one might even say, a highly "liquid"—resource, with many different possible uses, statements about the "usability" of water must be treated cautiously. For example, highly polluted water is still usable for navigation. Salt sinks, like the Aral or Salton Seas, are considered to be valuable environmental resources. And we now understand the crucial role of swamps, wetlands, and estuaries in the ecological chain. Ultimately, the usefulness of water must be assessed through more sophisticated terms of economic, environmental, and social evaluation analyses.

If the amount of water in the outflow (and internal sinks) were known, the best indicator of physical water scarcity in river basins or countries could be constructed. **There are two kinds of river basins (Seckler 1992, 1996): "open" systems, where there is a reliable outflow of** usable water to sinks (or uncommitted flows to other countries) in the dry season (O), and "closed" systems, where there is no such dry season outflow of usable water. In open systems, additional amounts of water can be diverted for use without decreasing the physical supply available to any other user in the system. In closed systems, additional withdrawal by one user decreases the amount of withdrawal by other users: it is a zero-sum game. Thus, in terms of figure 3, the degree of scarcity (S) of river basin would be indicated by the equation: $S = O/DWR$.

Of course, closed systems can be opened by increasing DWR through such water development activities as additional storage of wet season flows for release in the dry season and desalinization. But the distinction indicates whether, from a purely physical point of view, additional water demand can be met from existing supplies (DWR) or requires development of additional supplies.

It would be even better if the monthly (or weekly) outflow were known. This could be compared to monthly demands for water, including committed outflows, to create a complete estimate of water scarcity in river basins. Information on the outflow of major river basins to other countries and to sinks has been compiled by the Global Runoff Data Centre (1989) and others. (Just as this report was going to press, we received a very interesting monograph by Alcamo et al.1997, which has an approach that is highly compatible with our own and includes hydrological simulations of the major river basins of the world.) There is also information on the committed amounts of the outflow. In future research, these data will be collected and used as the indicator of physical water scarcity, but for the present, less accurate indicators must be used.

Effective Water Supply and Distribution

As shown in figure 3, flows from DWR become part of the *effective water supply (EWS)*. The other part of EWS is provided by *return flows* (RF) from the water used by the sectors. EWS is *the amount of water actually delivered to and received by the water-using sectors.*

We have emphasized this definition of EWS because one of the most difficult problems in the WRI data is *knowing precisely what their "withdrawals" mean*. Specifically, are they the "withdrawals" from PUWR and thus equal to DWR? Or are they the "withdrawals" from EWS received by the sectors? The difference, of course, is the amount of return flows in the system, which can be a substantial amount. We have searched the WRI definitions and notes and cannot find a clear answer to this important question.

Clearly, this problem of the definition of withdrawals is another task on the research agenda. But for the present, we shall proceed on the basis of the assumption that *withdrawals are equal to DWR*. Therefore, if there are substantial amounts of return flow in the system, withdrawals are *substantially less than EWS,* that is, *the amounts of water received by the users in the sectors.*

Sectors

There are four sectors shown in figure 3: *irrigation, domestic, industrial,* and *environmental*. Unfortunately, no comprehensive data are available on environmental uses of water, even though it is rapidly becoming one of the largest sectors, with high evaporation losses and flows of rivers to sinks (Seckler 1993), and it is not considered further in our analysis.

Other important sectors that should be explicitly included in a more complete analysis are the hydropower and thermal sectors (which probably account for a large part of the high per capita water withdrawals in the industrial sector of countries like the USA and Canada shown in table 1). These sectors are especially important because they have very low evaporation losses, with low pollution rates, and thus can contribute large amounts of water to recycling. Another important sector is what may be called the "waste disposal" sector: the use of water for flushing salts, sewage, and other pollutants out of the system. The importance of this sector becomes apparent when one attempts to remove pollutants by other means.

In each of the four sectors, the water is divided into *depletion factors* and *return flows.* The percentages in figure 3 show illustrative values of these components.

- *Evaporation* (EVAP) includes the evapotranspiration of plants. This amount of water is assumed to be lost to the system—although in large-scale systems, such as countries, part of EVAP recycles to the system through precipitation. Here is another important area for future research. As more water is used and evaporated, more water returns from precipitation. That much is certain. But *where* is it available, and *when?*

- *Sinks,* as discussed before, represent flows of water to such areas as deep or saline aquifers, inland seas, or oceans where water is not economically recoverable for general uses. Sinks may be internal, within a country's or river basin's salt ponds or seas, for example, or they may be external, as in the case of oceans. Also, as in the case of EWS, some of the water from *within* the distribution system may enter outflow—as in the disposal of saline water, or through temporary spills of water due to mismatches between water demand and supply.

- *Return flow (RF)* is the drainage water from a particular withdrawal that flows back into the system where it can be captured and reused, or recycled within the system. The drainage water may either be recycled within the sector or flow into rivers and aquifers to be recaptured and reused by other sectors. For example, in rice irrigation much of the water applied to one field drains to a downstream field where it provides irrigation to that field. Or, in the domestic sector, sewage water (hopefully, treated) returns to the river where it becomes a supply of water for other downstream domestic users, or it may be utilized for irrigation. The amount of return flow also depends on the geographic location of water utilization in the system. In Egypt, for example, most of the water utilized near Cairo drains back into the Nile and is recycled downstream, but most of the water utilized near Alexandria drains directly to the sea and cannot be recycled. Return flow creates the extremely important, although largely neglected, "water multiplier effect" in water balance analysis (Seckler 1992, 1993), which is discussed in more detail in Appendix A.

PART II:—Projecting Supply and Demand

In this section, we provide an overview of the basic data and results of the simulation model of water supply and demand for the 118 countries of the study. Following a brief introduction to the database, the 1990 data and the assumptions for projecting the 2025 data are discussed in detail.

Much of the discussion in this part concerns the detailed computation process for the model and, therefore may not be of interest to many readers. We urge such readers to rapidly skim through this part to the section "Two Irrigation Scenarios," read it; again skim the section "Domestic and Industrial Projections" and then read "Growth of Total Water Withdrawals to 2025" at the end of Part II.

Introduction to the Database

The water data for most of the countries are from WRI 1996. As the authors of that publication note, many data are out of date and of questionable validity. We have chosen the 1990 date arbitrarily, since the data for individual countries are for different dates. FAO (1995, 1997 a, b) has provided more recent data for some countries in Africa and West Asia. These data have been used where available as indicated by the references to footnote 1 against the country names in table 1. Shiklomanov 1997 provides other data for some other countries, but this study has only been released electronically, and the full text has not yet been published. In the future, we plan to improve the data set by working with local experts in the major countries.

One of the advantages of a model is that it clearly indicates the kinds of data that are needed to estimate important parameters for which data may be lacking. In these cases, we have used assumed and estimated values. These values are explained in the text and clearly indicated in the full spreadsheet.

The full model, with a guide, can be downloaded on IWMI's home page (http://www.cgiar.org/iimi). It is designed so that it can easily be manipulated by others to test their own assumptions and data. We welcome observations on the model by users and contributions of better data from those who have detailed knowledge of the specific countries.

Table 1 presents a summary of the basic data and analysis of the model. The introduction to table 1 provides an alphabetical listing of countries with their identification numbers so they can easily be looked up in the table. It also defines each of the columns, the data input, and the calculations. References in the text to the columns are made as "C1" for column 1, etc.

The first page of table 1 provides world and group summaries, the remaining pages show the data and results for the 118 countries individually. The countries, with the exception of China and India, have been ordered into five groups according to their estimated degree of relative water scarcity in 2025. The criteria used in this ordering are discussed in Part III. For now, it is sufficient to note that the group numbers indicate a decreasing order of projected water scarcity taking into consideration both demand and supply.

1990 Data

The first set of columns shows the 1990 population and the UN 1994 "medium" growth projection to 2025 (UN 1994). It should be noted that Seckler and Rock

(1995, 1997) contend that the UN "low" projection is the best projection of future population growth. While the low population projection would lower 2025 water demands somewhat, its major significance is after 2025, when population is projected to stabilize by 2040 at about 8 billion, whereas in the medium projection it continues to increase.

The annual water resources is shown in C3. The next set of columns shows total withdrawals (WITH) in cubic kilometers (C4) and per capita withdrawals in cubic meters for the domestic, industrial, and irrigation sectors. (Note, all the group averages are obtained by dividing the sum of the country values, thus achieving a weighted, not a simple, average.)

Irrigation

The next set of data concerns irrigation. Column 8 shows the 1990 *net irrigated area,* which is the amount of land equipped for irrigation for at least one crop per year. The total 1990 withdrawals for irrigation are shown in C9. The estimated *annual irrigation intensity,* which represents the degree of multiple cropping on the net irrigated area each year, is given in C10. Since there is no international data on irrigation intensity, this parameter is estimated, as explained in Appendix B, and is subject to significant errors. The *gross irrigated area,* which is not shown in table 1, is obtained by multiplying C8 by C10.

The *withdrawals* of water per hectare of gross irrigated area per year (C11) are shown in terms of the depth of irrigation applied to fields (m/ha). The estimated crop water requirements are shown in C12, also in m/ha. These estimates are discussed in more detail in Appendix B. For now, it is sufficient to say that the crop water requirement is based first on estimates of the reference evapotranspiration rates (ETo) of the irrigated areas in each country during the entire crop season (see Appendix B). Once this is obtained, precipitation during the crop seasons (at the 75 percent exceedence level of probability—at least 3 out of every 4 years this amount of precipitation is obtained) is subtracted from ETo to obtain the "net evapotranspiration" (NET) requirements of the crops. This is used as an indicator of the amount of irrigation water that crops need to obtain their full yield potential.

It is notable that the average NET for Group 1 is substantially higher than that of the other groups. This means, other things being equal, that substantially more water is required to irrigate a unit of land in the hot and dry countries in this group than in the other groups. However, because radiation increases both evapotranspiration and yield potential, yields on irrigated lands are likely to also be higher—so the "crop per drop" may be similar between these groups.

Column 13 shows the results of dividing the 1990 NET (C12) values by the total irrigation withdrawals (C11). Assuming, as noted above, that withdrawals in WRI are equal to DWR in figure 3, this is the "effectiveness" of the irrigation sector for the countries (this is close to what Molden [1997] calls the "depleted fraction for irrigated agriculture" and Keller and Keller [1996] refer to as the "effective efficiency of irrigation").

The range of variation of irrigation effectiveness among the countries is enormous. Several countries have an irrigation effectiveness of 70 percent (which is the highest possible in this model due to the way cropping intensities are estimated, as discussed in Appendix B). But many are exceptionally low. For example, Germany (no. 107) has only an 11 percent irrigation effectiveness—even though most of the irrigation in Germany is with sprinkler irrigation! Such large anomalies are undoubtedly due to errors in the data on withdrawals and need to be revised.

Two irrigation scenarios

We have constructed two irrigation scenarios for this study. In both we assume that the *per capita gross irrigated area will be the same* in 2025 as it was in 1990 (or, more precisely, that the per capita NET will be the same). The implications of this assumption are discussed below and in Part III. Thus the differences between these scenarios depend exclusively on assumptions about the change in basin irrigation efficiencies over the 1990 to 2025 period.

The first, or "business as usual," scenario (S1) assumes that the effectiveness of irrigation in 2025 will be the *same* as in 1990 (C13). Thus the 2025 projection of irrigation withdrawals in this scenario is obtained simply by multiplying the 1990 irrigation withdrawals (C9) by the population growth (C2) for each country. The amount of 2025 irrigation withdrawals under this scenario is 3,376 km^3 (C15), which is equal to the 62 percent growth of population over the period.

The second, "high effectiveness" scenario (S2) assumes that most countries will achieve an irrigation effectiveness of 70 percent on their total gross irrigated area by 2025. This is the default value shown in C14. However, we have entered override values for some of the countries based on two kinds of considerations. First, we have imposed an upper limit on the increase in irrigation effectiveness of 100 percent over the 1990 to 2025 period. This has been done both in the interests of realism and to reduce the influence of data errors (e.g., Germany) on the results. Second, we have made personal judgments—based on imperfect knowledge about the hydrology, crop systems, water salinity, and technical and managerial capabilities of the countries—about the upper limits to irrigation effectiveness in certain countries. For example, for reasons explained in Appendix B, rice irrigation will generally have lower basin efficiencies, because of high drainage and mismatches of return flow, than other crops; Pakistan requires more drainage water to leach salts to sinks; and small islands are more likely to lose drainage water to the oceans. Users can, of course, change these default values as they wish to generate different results.

The 2025 projection of irrigation withdrawals for the second scenario is obtained by first multiplying the net irrigated area (C8) by the irrigation intensity (C10) to obtain the gross irrigated area (GIA). The GIA is then multiplied by NET (C12) and the population growth (C2). Dividing this product by 100 gives the 2025 total crop water requirements in km^3. Dividing this amount by the assumed basin irrigation efficiencies in C14 gives the total irrigation withdrawals required to meet the crop water requirements under this scenario (C16):

$$C16 = ((C8 \times C10 \times C12 \times C2) / 100) / C14$$

Most of the countries in Group 5 are projected to decrease irrigation withdrawals from 1990 to 2025 because of gains in irrigation effectiveness. This causes a problem in summing total withdrawals at the all-country level because water surpluses in one country rarely help solve water shortages in another country. Thus in computing the total for the countries, the 1990 withdrawals for countries in group 5 are used to maintain comparability. In any case, it is not clear that these countries would want to invest in high irrigation effectiveness (see Appendix A).

Even with this adjustment, the growth of world irrigation withdrawals in the second scenario is only 17 percent (C17), whereas in the first scenario it is equal to population growth, or 62 percent. As shown in C19, the difference in the amount of total water withdrawals for irrigation between the two scenarios is 944 km^3. This represents a 28 percent reduction in the amount of total 2025 withdrawals (C18) in the second scenario compared to the first. As shown in Part III, this amount of water could theoretically be used to meet about one-half of the increased demand for additional water supplies over the 1990 to 2025 period.

It should be emphasized that the increase to high irrigation effectiveness in the second scenario would require fundamental changes in the infrastructure and irrigation management institutions in most countries and would therefore be enormously difficult and expensive. In some of these countries, it may be easier simply to develop additional water resources than to attempt to achieve high irrigation effectiveness. Which of these alternatives is best is a question which only a detailed analysis within the countries can address.

Several other aspects of these irrigation scenarios should be briefly discussed:

- The scenarios do not directly allow for increased per capita food production from irrigation. But, with essentially the same per capita irrigation capacity in 2025, considerable increases in per capita food production would be expected due to "exogenous" increases in yield from the irrigated area because of better seeds, fertilizers, and irrigation management practices. Indeed, one of the nice things about irrigation is that once a field is adequately watered, it can support any amount of increased yield without the need for any additional water (NET for the crop is constant). Thus, the *productivity* of irrigation water—the value of the "crop per drop"—would be substantially increased.
- Most authorities would agree that irrigation must play a greater proportionate role in meeting future food needs than it has played in the past. The reasons are that most of the best rain-fed areas are either already developed or have economically and environmentally prohibitive costs of development and that the potential for rapid growth of yields in marginal rain-fed areas is low. Thus even with higher yields on irrigated land, perhaps more per capita irrigation will be needed in 2025 than in 1990.
- The projections do not provide for excess irrigation supplies for times of drought.
- The country-level analysis ignores regional differences within countries. It is small consolation to a farmer in the north of China to know that the south is very wet—unless a river basin transfer is feasible, as in this case, it might be.
- The analysis ignores trade in food and the opportunity for some water-short countries to reduce irrigation, import food instead, and transfer water out of irrigation to the domestic and agriculture sectors. As noted below, some of the most water-scarce countries are already doing this, and they will undoubtedly do more in the future. But here one runs into a composition problem: not all of the countries in the world can do this. So the question is, if some countries are to import more food, which countries are to export more—and, will this require more irrigation in those countries?

Obviously, all of these are important aspects of the problem requiring future research. But they cannot be adequately addressed here. This analysis does, however, provide the framework in which such questions can be properly addressed.

Domestic and industrial projections

We have made projections for the domestic and industrial sectors in terms of a combination of criteria relating to water as a basic need and as subject to economic demand or "willingness to pay" (Perry, Rock, and Seckler 1997).

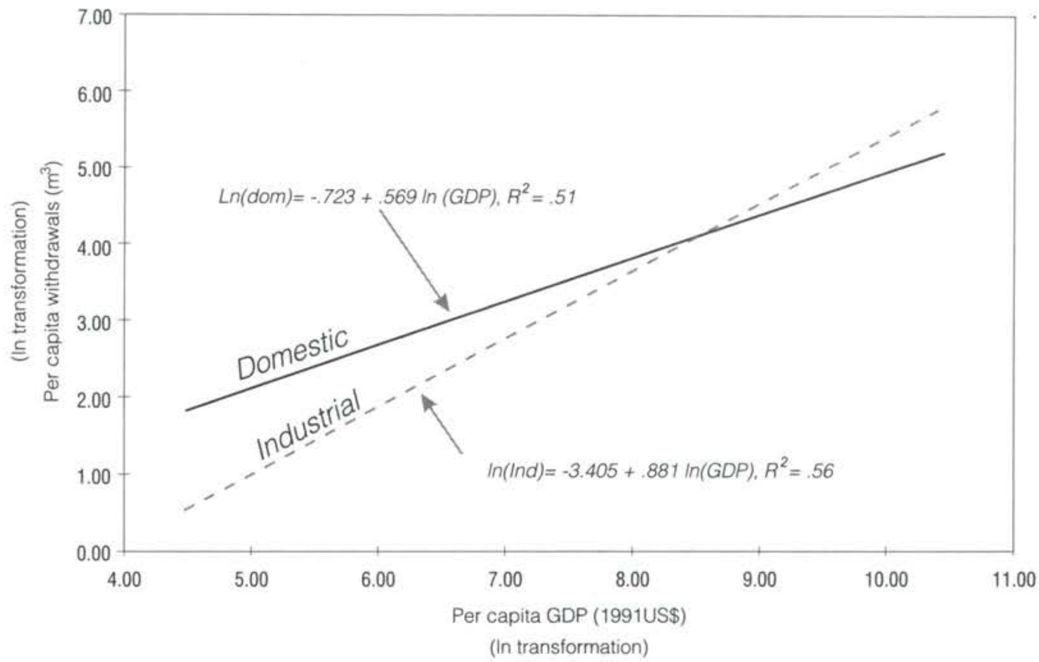
In terms of basic needs, Gleick 1996 estimates that the minimum annual per capita requirement for domestic use is about 20 m^3; we assume an equal amount for industrial use for a total per capita diversion of 40 m^3. As shown in table 1 (C5 and C6) many countries, especially in Africa, are far below this amount. For countries below 10 m^3 per capita for the domestic or the industrial sectors in 1990, we have only doubled the per capita amount for each sector in 2025. This avoids unrealistically high percentage increases for these sectors in very poor countries over the period. However, for some countries, we suspect that the per capita domestic withdrawals are greatly underestimated. In some countries, the data may be only for developed water supplies, not including the use of rivers and lakes for domestic water. Also, since we assume that withdrawals are equal to DWR, not to the utilization of water by the sectors, withdrawals exclude recycled water and are, therefore, likely to underestimate actual per capita utilization in these sectors.

For countries above 10 m^3 per capita for domestic or industrial sectors in 1990, we project 2025 demands for these sectors on the basis of the relationship between per capita GDP (provided for this study by Mark Rosegrant of the International Food Policy Research Institute [IFPRI]) and the per capita water withdrawals shown in figure 4.

Because of variations of individual countries around the regression lines in figure 4, this procedure results in some complications that have been handled as follows. For those countries whose projections for 2025 are below 20 m^3 per capita, we assume 20 m^3 or the 1990 per capita level, whichever is higher. For those countries with 1990 withdrawals greater than the projected 2025 level, we assume their 1990 level. However, for countries with 2025 projections twice the 1990 level or greater, we assume only twice the 1990 level. Countries with very high per capita domestic and industrial consumption are likely to be able to make better use of their water by 2025. Accordingly, we have placed a ceiling on per capita withdrawals for these sectors. This ceiling is set at 1990 levels of per capita withdrawals for all countries at or above the level of US$17,500, and it is set at the projected withdrawals up to this amount for countries whose 1990 per capita GDP is below this amount. The per capita projections for domestic and industrial sectors in 2025 are shown in C20 and C21. These may be compared with the corresponding figures for 1990 in C5 and C6. The total 2025 withdrawals to these sectors are 1,193 km^3 (C22), representing an increase of 45 percent over 1990 (C23). Since this is less than population growth, the reductions in per capita use of water by the high water-consuming countries thus more than offset the per capita increases by the low water-consuming countries at the world level.

It should be noted that recycling water from the domestic and industrial sectors has not been included in the projections. The major reason for this is that with high effec-

FIGURE 4.
Per capita domestic and industrial withdrawals.



tiveness in the irrigation sector, the amount of committed outflows from the system and the environmental needs for water within the system could be reduced to unacceptable levels for many countries. This needs further research.

Growth of Total Water Withdrawals to 2025

In the second, high irrigation effectiveness scenario, total water withdrawals by all the sectors in 2025 are 3,625 km^3 (C24). This is an increase of 720 km^3 (C25) or 25 percent (C28). Under the first, "business as usual" scenario, the withdrawals would increase by 57 percent, or by 1,664 km^3. The truth perhaps lies somewhere between these two scenarios. If so, increased irrigation effectiveness would reduce the need for development of additional water resources (DWR) by about one-half.

However, these world figures must be interpreted with care. For example, exactly one-half of the gains in irrigation due to high effectiveness occur in China and India (see the percentage figures in C19), and only a few more countries would account for most of the balance. Also, the most water-scarce countries tend to have the highest irrigation effectiveness and, therefore, the least potential for gains in effectiveness. Part III provides a more accurate view of these matters on a group- and country-wise basis.

Part III:—Country Groups

In this part, we explain how the countries can be grouped to reflect different kinds and degrees of water scarcity. We then discuss the alternatives measures for increasing the productivity of water and the problems associated with developing new water resources. We conclude by indicating the implications of our analysis for global food security.

Country Grouping

Two basic indicators are used to group countries in terms of relative water scarcity under the second, high irrigation effectiveness scenario. These are (i) the projected percentage increase in total withdrawals from 1990 to 2025 (C28) and (ii) the total withdrawals in 2025 as a percentage of the AWR (C29). The latter is conceptually the same as the UN indicator, but because of the importance of recycling we consider only those countries with a value greater than 50 percent to be water-scarce, based on this indicator. The logic behind these two indicators is that, other things being equal, the *marginal cost of a percentage increase in withdrawals* rapidly increases after withdrawals as the percentage of AWR (C29) exceeds 50 percent. For example, at 50 percent or below it may be one unit of cost per percentage increase, but at 70 percent it may be three units of cost per percentage increase. If we knew what the cost curve is, we could have only one, continuous, scarcity indicator that would be calculated by multiplying the percentage increase in withdrawals for each country times the relevant points on the cost curve. But we do not, hence the division between Group I and the other groups.

For purposes of comparison with the IWMI indicators, we have also shown the 2025 values of the Standard indicator (C26), but this is not used here.

Group 1 countries consist of all those countries for which the withdrawals as percentage of annual water resources are greater than 50. Belgium (no. 94) presents a curious anomaly. Withdrawals as a percent of AWR are 73, thus Belgium should be in Group 1. But its growth in withdrawals is very small, at .4 percent. Thus, we have put it in Group 4!

The remaining four groups have sufficient water resources that presumably can be developed at reasonable cost to supply the projected demand. Thus, excluding countries that are already in Group 1, the countries are grouped according to their percentage increase in withdrawals.

Group 2 countries are those with an increase in projected 2025 water withdrawals of 100 percent or more. Group 3 countries are those with an increase in projected water withdrawals in the range of 25 percent to 99 percent. Group 4 countries are those with an increase in projected water withdrawals below 25 percent, and Group 5 are countries those with no, or negative, increase in projected water withdrawals. The situations of these countries may be briefly described as follows.

Group 1 consists of countries that are water-scarce by both criteria. They contain 8 percent of the population of the 118 countries studied. Their 2025 withdrawals are 191 percent of 1990 withdrawals and 91 percent of AWR. Short of desalinization, many of these countries either have reached or will reach the absolute limit in the development of their water supplies—with some already drawing down limited groundwater supplies. It can be expected that cereal grain imports will increase in most of these countries as growing domestic and industrial water needs are met by reducing withdrawals to irrigation.

Group 2 countries account for 7 percent of the study population. These countries are principally in sub-Saharan Africa where conditions are often unfavorable for crop production. In the development of water resources, emphasis must be given to expanding small-scale irrigation and increasing the productivity of rain-fed agriculture with supplemental irrigation.

Group 3 countries account for 16 percent of the population and are scattered throughout the developing world.

Group 4 countries are mainly developed and have 16 percent of the total study population. Future water demands are modest, and available water resources appear to be adequate. This group contains two of the world's largest food grain exporters, USA and Canada. If import demands were to rise significantly in the other groups, one might expect to see an expansion of irrigated agriculture in Group 4 countries to meet the growing export demand.

In light of its massive per capita water withdrawals for the industrial sector (presumably for hydropower and cooling water for thermal energy), we reclassified Canada from Group 3 to Group 4 on grounds that reasonable demand management and water conservation techniques should reduce future water demands for these purposes.

Group 5 countries account for 12 percent of the study population. With increased irrigation effectiveness, these countries require no more water than they used in 1990 and most, indeed, require less. But it is doubtful if they would make heavy investments in increased irrigation effectiveness under these conditions—except, possibly, for environmental purposes.

We have considered India and China separately from the five groups. Together they contain 41 percent of the study population. In countries such as these, which have both wet and dry areas, national statistics underestimate the degree of water scarcity and thus can be very misleading. Cereal grain is now being produced in water-deficit areas where withdrawals exceed recharge and water tables are falling. For example, northern China has approximately half of China's population but only 20 percent of China's water resources (World Bank 1997). Growing demand for water in the north will be met with some combination of the following options: further development of water resources and water storage facilities; increased productivity of existing water supplies (e.g., through wider adoption of technologies such as trickle irrigation); regional diversion of water (e.g., south to north China); and increase in food imports. The capacity of India and China to efficiently develop and manage water resources, especially on a regional basis, is likely to be one of the key determinants of global food security as we enter the next century.

Increasing the Productivity of Irrigation Water

The degree to which the increased demand for water in 2025 is projected to be met by increasing water productivity in agriculture, as opposed to developing more water supplies, varies among countries. But as opportunities for development of new water resources diminish and costs rise, increasing the productivity of existing water resources, both irrigation and rainwater, becomes a more attractive alternative.

The productivity of irrigation water can be increased in essentially four ways: (i) increasing the productivity per unit of evapotranspiration (or, more precisely, transpiration) by reducing evaporation losses; (ii) reducing flows of usable water to sinks; (iii) controlling salinity and pollution; and (iv) reallocating water from lower-valued to higher-valued crops. There is a wide range of irrigation practices and technologies available to increase irrigation water productivity ranging from the conjunctive use of aquifers and better management of water in canal systems, to the use of basin-level sprinkler and drip irrigation systems. The suitability of any given technology or practice will vary according to the particular physical, institutional, and economic environment.

In addition, water productivity in irrigated and rain-fed areas can be increased by genetic improvements that would lead to increases in yield per unit of water. This would include increases in crop yields due to development of crop varieties with better tolerance for drought, cool seasons (which reduce evapotranspiration), or saline conditions.

Developing More Water Supplies —Environmental Concerns

The benefits of irrigation have resulted in lower food prices, higher employment and more rapid agricultural and economic development. But irrigation and water resource development can also cause social and environmental problems. These include soil degradation through salinity, pollution of aquifers by increased use of agricultural chemicals, loss of wildlife habitats, and the enforced resettlement of those previously living in areas submerged by reservoirs. The result has been a growing conflict between those who see the potential benefits of further water resource development and those who view it as a threat to the environment.

Environmentalists have focused their attack on large dam projects such as the Narmada Project in India and the Three Gorges Dam in China. There are valid arguments to support the views of both the promoters and detractors. The long-term diverse and complex nature of the effects of water development makes it especially hard to balance these views within a simple cost-benefit framework. In our view, however, those who oppose development of all medium and large dams overlook the benefits to human welfare that in some instances may outweigh the costs severalfold. On the other hand, the water development community has often committed social and economic crimes in their passion for construction works. Rational alternatives to both extremes exist and must be adopted.

Global Food Security

For most of modern history, the world's irrigated area grew faster than population, but since 1980 the irrigated area per person has declined and per capita cereal grain production has stagnated. The debate regarding the world's capacity to feed a growing population, brought to the fore in the writings of Malthus two centuries ago, continues. But the growing scarcity and competition for water add a new element to this debate over food security.

In a growing number of countries and regions of the world, *water has become the single most important constraint to increased food production*. The rapid growth in food production during the green revolution from the mid-1960s to the present was accomplished in large part on irrigated land.

Most authorities would agree that irrigation must continue to play even a greater proportionate role in meeting future food needs than it has played in the past.

Our projections ignore international trade in food and the opportunity for some water-short countries to reduce irrigation, import food instead, and transfer water out of irrigation to the domestic and agriculture sectors. But as noted above, some of the water-scarce countries are already doing this and undoubtedly they will do more in the future. The question seems to be, which countries will import more food and which countries will export more? The exporters are likely to require more irrigation. IWMI and IFPRI are collaborating in research on this problem.

Conclusions

Many countries are entering a period of severe water shortage. None of the global food projection models such as those of the World Bank, FAO, and IFPRI have explicitly incorporated water as a constraint. There will be an increasing number of water-deficit countries and regions including not only West Asia and North Africa but also some of the major breadbaskets of the world such as the Indian Punjab and the central plain of China. There are likely to be some major shifts in world cereal grain trade as a result.

One of the most important conclusions from our analysis is that around 50 percent of the increase in demand for water by the year 2025 can be met by increasing the effectiveness of irrigation. While some of the remaining water development needs can be met by small dams and conjunctive use of aquifers, medium and large dams will almost certainly also be needed.

We believe that the methodology used in this report is appropriate and, with refinements, may serve as a model for future studies. However, the analysis reveals serious problems with the international database. Furthermore, the dependency on national-level data for our analysis tends to underestimate scarcity problems associated with regional, intra-annual, and seasonal variations in water supplies. Much work needs to be done before the methodology can be used as a basin planning tool. In the future, we plan to update and improve the data set using information from special surveys, studies of the special countries, and other information. The database has been designed so that it can easily be manipulated by others to test their own assumptions. We welcome observations on the model by users and especially contributions of better data from those who have detailed knowledge of specific countries.

Recycling, the Water Multiplier, and Irrigation Effectiveness

When water is diverted for a particular use it is almost never wholly "used up." Rather, most of that water from the particular use drains away and it can be captured and reused by others. As water recycles through the system, a "water multiplier effect" (Seckler 1992; Keller, Keller, and Seckler 1996) develops where *the sum of all the withdrawals in the system can exceed the amount of the "initial water withdrawals" (DWR) to the system by a substantial amount.*

A numerical example may help make this important concept clear in the context of figure 3. Assume that there is no water pollution, that all the drainage water in the system is recycled and, for simplicity, that the percentage of evaporation losses from each diversion is constant. Then, out of a given amount of DWR, the effective water supply (EWS) could be as high as:

$$EWS = DWR \times (1/E),$$

where, E = the percentage evaporation losses of all the withdrawals.

For example, if E = 0.25, the water multiplier would be 4.00; and four times the DWR could be diverted for use. Appendix table A1 provides a simple illustration of the water multiplier. The recycling process starts with an initial diversion of water that has a pollution concentration of 1,000 parts per million or 0.1 percent. It is assumed that 20 percent of the water is evaporated in each cycle and that each use in the cycle adds 0.1 percent of pollution to the drainage water. Because of additional pollutants and the concentration of past pollutants in the water due to evaporation losses, the pollution load of the water increases rapidly. By the fifth cycle, it may be too high for most uses and the drainage would be either diluted with additional initial water supplies or discharged into sinks. At this point, the water multiplier would be 2.4. But assuming that the cycle runs its course through 10 recyclings, EWS would increase to 3,199 units, over three times the DWR.

There are three major implications of the water multiplier effect. The first is that where recycling is possible, *pollution control is one of the most basic ways of increasing water supply.* With the notable exception of salinity in the case of irrigation water, most pollutants can be economically removed from drainage water. In areas of extreme water scarcity, where water for urban and industrial uses is high-valued, even salinity can be removed by desalinization processes.

The second major implication is that insofar as recycling processes are not accounted for in the estimates of the water supply for countries, it is likely that *the amount of actual water supply in a system will be underestimated.* It should be noted that most of the recycling occurs naturally—that it is built into the system, so to speak—by flows of drainage water to rivers and aquifers where it reenters the supply system. As noted in the text, it appears to us that all the international data sets on the water supply of countries, on which all the indicators of water scarcity are based, ignore water recycling effects. It is *simply assumed that once water is withdrawn it is lost to further use.* Insofar as this is true, the international data sets and the indictors based on these data seriously underestimate the amount of water actually available for withdrawals in most countries.

Appendix table A1. Water multiplier.

Cycle	DIV	EVAP 20%	Sinks 10%	Return flow (RF) 70%	Pollutants: Sinks	Pollutants: RF 0.1%	Pollutants: Total	Pollutants: Total as % of RF
0	1000.0						1.000	
1	1000.0	200.0	100.0	700.0	0.10	0.70	1.700	.21
2	700.0	140.0	70.0	490.0	0.07	0.49	2.190	.39
3	490.0	98.0	49.0	343.0	0.05	0.34	2.533	.65
4	342.0	68.6	34.3	240.1	0.03	0.24	2.773	1.01
5	240.1	48.0	24.0	168.1	0.02	0.17	2.941	1.53
6	168.1	33.6	16.8	117.6	0.01	0.12	3.059	2.27
7	117.6	23.5	11.8	82.4	0.01	0.08	3.141	3.34
8	82.4	16.5	8.2	57.6	0.01	0.06	3.199	4.86
9	57.6	11.5	5.8	40.4	0.01	0.04	3.239	7.02
Total	3198	639.8	319.9	2239.2	0.30	2.20	22.355	

Water Multiplier

Third, of course, recycling does not create water. If the first withdrawal of 1,000 units were applied with 100 percent effectiveness (EVAP = 100 percent), the *same irrigation needs would be met*, with no return flow, and the multiplier would be 1.00.

Clearly, there are two distinct paths to increasing irrigation effectiveness (or any other kind of water use effectiveness). The first is by increasing the effectiveness of the specific application of water to a use, as in the example of 100 percent effectiveness directly above, which *reduces return flow*. The second is by *increasing return flows* by recycling drainage water that would otherwise flow to sinks. Theoretically, there is an optimal combination of these two paths of application effectiveness and recycling effectiveness, as they may be called, that leads to optimal effectiveness in the irrigation sector as a whole.

Which of these paths is optimal depends on complex hydrological, managerial, and economic considerations. For example, high application effectiveness may increase the productivity of water by providing more precise management of plant, fertilizer, and water relationships. On the other hand, high recycling effectiveness may be better when part of the objective is to recharge aquifers. An important research task that IWMI is now undertaking, is to specify what combination of these paths, under which conditions, optimally leads to high irrigation sector effectiveness.

Estimating Irrigation Requirements

The task of estimating requirements for irrigated agriculture has been one of the most difficult parts of this study. The reason is that much of the basic data needed for this task is either not available or is not compiled in a readily accessible form. One of the future tasks of IWMI's long-term research program is to solve this data problem through the World Water and Climatic Atlas (IIMI and Utah State University 1997), remote sensing, and by special studies of the countries. But in the meantime, approximations of the important variables are made.

Appendix table B2 presents the data for this section. Column 1 shows the net reported irrigated area of the countries (FAO 1994). This is the area that is irrigated at least once per year. Column 2 shows total withdrawals for irrigation in 1990. Dividing agricultural withdrawal by net irrigated area, one obtains the depth of irrigation water applied (C3) to net irrigated area—not considering losses of water in the distribution system.

To estimate the need for water in irrigation, we begin with Hargreaves and Samani 1986, which provides basic climatic data for most of the countries of the world. An example from Mali is shown in table B1. This table shows precipitation (P) at the 95, 75, 50, and 5 percent probability levels; mean precipitation (PM); temperature; potential evapotranspiration (ETP) for a reference crop (grass); and net evapotranspiration (NET), which is ETP minus precipitation at the 75 percent exceedence level of probability (here we do not adjust for "basin precipitation"). The irrigation requirement of the crop (IR) is defined as NET divided by the irrigation effectiveness—in this case, assumed to be 70 percent. Negative values of NET and IR are set at zero for purposes of these estimations.

For technical readers it should be noted that we have used potential ET, not actual ET, which may cause an upward bias in NET, depending on the extent of rice irrigation. On the other hand, we have used full

Appendix table B1. Climatic data of Station Kita, Mali (lat. 13 6 N, long. 9 30 W; elevation 329.0 m), 1960–85.

P: Prob	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
95	0	0	0	0	12	63	137	163	114	8	0	0	761
75	0	0	0	0	26	104	192	237	171	27	0	0	930
50	0	0	0	2	40	143	237	301	220	53	1	0	1061
5	0	2	3	53	95	272	378	502	378	174	52	5	1431
PM	0	0	1	11	45	152	245	312	230	67	10	1	1074
Tem C	26	29	31	33	32	29	26	26	26	27	27	25	28
ETP	141	156	189	194	194	176	161	156	152	161	123	124	1927
NET	141	156	189	194	168	72	0	0	0	134	123	124	1301
IR	176	195	236	243	210	90	0	0	0	168	154	155	1626

Notes: Prob = probability. PM = Mean precipitation in mm. Tem C = Mean temperature in Celcius. ETP = Potential evapotranspiration in mm. NET = ETP - Precipitation at 75 percent probability in mm. IR = irrigation requirement in mm.

precipitation, not effective precipitation, which would cause a downward bias in NET. We hope these factors balance out to a reasonable approximation.

Agricultural maps (FAO 1987; Framji, Garg, and Luthra 1981; USDA 1987) of different countries were consulted to identify climatic stations located within agricultural areas. (Unfortunately, there are no international maps of major irrigated areas). Then tables similar to the one above were analyzed for the stations in all the countries. From these data, a representative table for the country as a whole was developed. When the irrigated area of different regions within a country is known (here only the USA and India) on a state or provincial basis, the representative table is compiled as a weighted average; otherwise a simple average of the stations is used.

Given these data, the *potential crop season* (C4) is defined as the number of months with an average temperature of over 10 °C. In table B1, for example, the temperature is above 10 °C in all 12 months, thus the potential crop season for this station is 12 months.

A crop season is assumed to be 4 months long. The NET in the "first" season is the sum of the NET in the 4 consecutive months when the irrigation requirement is lowest (C5). In table B1, for example, it is assumed that irrigation for the first crop starts in June and extends through September. The irrigation effectiveness is assumed to be 70 percent (C6). The irrigation requirement at 70 percent irrigation effectiveness is given in C7. The surplus or deficit (C3-C7) of the withdrawals after the first season irrigation is in C8. The irrigation intensity of the first season is in C9. If there is a surplus after the first season irrigation, it is assumed to be used for multiple cropping of the irrigated area (the "gross" irrigated area). However, we assume that 50 percent (C10), default value, of the agriculture withdrawals remaining after the first season is not available for the second season because of evaporation losses and lack of storage facilities. This average loss figure should be increased for areas with highly peaked seasonal water supplies, such as monsoonal Asia, and with inadequate storage facilities. It should be decreased for areas with the reverse conditions, such as in Egypt, which can store several years of water supply in the High Aswan Dam. The withdrawals carried over to the second season (max {0,C8 x [1-C10]}) are in C11.

Then the second consecutive low-irrigation requirement period (of 4 months) is chosen from table B1, after leaving a harvesting and land preparation period of at least a month following the first season, to utilize the remainder of the agricultural water. The country's NET for the "second" season is given in C12. The amount required at 70 percent basin effectiveness is given in C13. The surplus of withdrawals after the second season irrigation is in C13. It should be noted that while changes in the percentage of water carried over to the second season will change the estimated irrigation intensity of the country, it will not affect the *proportional* change in irrigation required over the period, since the same figure is applied to both 1990 and 2025.

If a country has sufficient water to irrigate for up to 8 months, it is assumed that this is done. A limit of 8 months for the gross irrigation requirement is assumed. The annual irrigation intensity is shown in C15. For a few countries, the annual irrigation intensity was found to be less than 100 percent. This may be due to discrepancies and errors in the reported net irrigated area in the database or insufficient water to provide full irrigation.

The NET for the gross irrigated area in 1990 is in C16. The depth of annual NET over gross irrigated area is in C17.

A Note on Rice Irrigation

Estimating the irrigation requirement for rice is exceptionally difficult. First, the actual evapotranspiration (ETa) for nearly all the major crops is about 90 percent of the reference crop of grass (ETP, in table B1), but for rice, due mainly to land preparation by flooding and the consequent exposed surface of water, the ETa is about 110 percent of grass. Thus, if the irrigated area of a country is one-half rice, the country average estimate is about right, but otherwise there is a corresponding error. Unfortunately, there are no international data on irrigated area by crop, so adjustments for this factor cannot be made. About 80 percent of the irrigated area of Asia is in rice—so the error could be significant, especially in Asia.

Second, an even more difficult problem is that net evapotranspiration (NET) is not the only—or, in many cases, not even the most—important determinant of the irrigation requirement for rice. Rice fields are kept flooded primarily for weed control. This creates high percolation "losses" from the fields. Thus in order to keep the fields flooded, an amount of water that is several times NET is often applied to the field. As if this were not enough, many farmers also like to have fresh water running through their rice fields, rather than simply holding stagnant water, in the belief that this increases yield (and perhaps taste). There is no scientific evidence for this belief except that during very hot days running water may beneficially cool the plant. On the other hand, this practice flushes fertilizers out of the rice fields and contributes to water pollution. Whatever the reason, this common practice leads to very high withdrawals of water for rice irrigation—and, even with recycling, a considerable amount of mismatching between water supply and demand.

Technological and managerial advances in rice irrigation, especially with the use of herbicides, have created the potential for irrigating rice at much higher effectiveness; but the problem lies in convincing farmers to adopt these new methods.

Also, in light of recycling, one wonders how the water withdrawals for irrigation are actually estimated in the WRI database. If the estimated "withdrawals" for irrigation in a country are based on a field irrigation requirement for rice that is several times NET for the gross irrigated area in rice, which may in fact be the case, this could lead to a serious overestimation of actual net withdrawals of water for irrigation in the country. If this overestimation possibility is true (and we suspect it is), then the imputed ineffectiveness of irrigated agriculture and hence the potential for water savings in rice-intensive countries are not as large as the data would indicate. Of course, this same recycling effect may be true for other crops as well, but the magnitude of the error would not be nearly so great. Clearly, this is an important area for further research into the data set. In the meantime, the calculations of potential water savings from the irrigation sector, especially in countries that have a high percentage of their area in rice, must be treated cautiously. Water requirements for crops should be made on the basis of NET, in the first approximation, with the difference between this and the irrigation requirement considered in light of recycling within the basin. Perhaps the best way to regard this problem is by saying that countries with intensive rice irrigation may have high *potential* for transferring water from agriculture, *if rice irrigation is, in fact, highly ineffective from a basin perspective.*

Introduction to table 1. Country names and identification numbers.

Country	ID	Country	ID	Country	ID
Afghanistan(1)	9	Ghana(1)	30	Norway(2)	85
Albania	68	Greece(2)	90	Oman(1)	5
Algeria(1)	60	Guatemala	49	Pakistan(1)	16
Angola(1)	32	Guinea(1)	45	Panama	100
Argentina	89	Guinea-Bissau(1)	27	Paraguay	38
Australia	61	Guyana	115	Peru	47
Austria(2)	91	Haiti	33	Philippines	79
Bangladesh	92	Honduras	70	Poland	86
Belgium(2,3)	93	Hungary	113	Portugal(2)	111
Belize	67	Indonesia	65	Romania(2)	102
Benin(1)	31	Iran(1)	14	Saudi Arabia(1)	2
Bolivia	52	Iraq(1)	12	Senegal(1)	50
Botswana(1)	24	Israel	8	Singapore	13
Brazil	58	Italy	116	Somalia(1)	36
Bulgaria	108	Jamaica	80	South Africa(1)	17
Burkina Faso(1)	41	Japan	114	South Korea	96
Burundi(1)	26	Jordan(1)	6	Spain	105
Cambodia	62	Kenya(1)	48	Sri Lanka	101
Cameroon(1)	22	Kuwait(1)	4	Sudan(1)	37
Canada(2,3)	77	Lebanon(1)	75	Surinam	110
Cen. African Rep.(1)	43	Lesotho(1)	25	Sweden	82
Chad(1)	40	Liberia(1)	35	Switzerland	81
Chile	76	Libya(1)	1	Syria(1)	15
Colombia	56	Madagascar(1)	64	Tanzania(1)	44
Congo(1)	18	Malaysia	66	Thailand	104
Costa Rica	94	Mali(1)	51	Tunisia(1)	11
Cote d'Ivoire(1)	23	Mauritania(1)	73	Turkey(1)	53
Cuba	106	Mexico	87	UAE(1)	3
Denmark(2)	97	Morocco(1)	69	Uganda(1)	28
Dominican Rep.	95	Mozambique(1)	34	UK(2)	98
Ecuador	84	Myanmar	72	Uruguay	112
Egypt(1)	10	Namibia(1)	55	USA(2)	78
El Salvador	74	Nepal	46	Venezuela	59
Ethiopia(4)	39	Netherlands(2)	103	Vietnam	83
Finland(2)	109	New Zealand(2)	71	Yemen(1)	7
France(2)	88	Nicaragua	42	Zaire(1)	19
Gabon(1)	20	Niger(1)	21	Zambia(1)	57
Gambia(2)	63	Nigeria(1)	29	Zimbabwe(1)	54
Germany	107	North Korea	99		

1. AWR, total WITH and per capita WITH data are from FAO 1995, FAO 1997a, and FAO 1997b.
2. AWR of these countries are equal to internally renewable water resources of WRI data.
3. Canada and Belgium are moved to group 4.
4. AWR of Ethiopia are 80 percent of internally renewable water resources of WRI data.

Introduction to table 1. Description of columns in table 1.

Column	Description	Data input or Calculation	Units
C1	1990 population	Data	(million)
C2	Population growth from 1990 to 2025	Data	%
C3	Annual water resources (AWR)	Data	km^3
C4	Total withdrawals in 1990	Data	km^3
C5	Per capita domestic withdrawals in 1990	Data	m^3
C6	Per capita industrial withdrawals in 1990	Data	m^3
C7	Per capita irrigation withdrawals in 1990	Data	m^3
C8	Net irrigated area in 1990	Data	1,000 ha
C9	Total irrigation withdrawals in 1990	C7xC1/1,000	km^3
C10	Annual irrigation intensity	C15 in Appendix table B2	%
C11	Irr. WITH as a depth on gross irrigated area	C9/(C8xC10) x100	m
C12	NET as a depth on gross irrigated area	C17 in Appendix table B2	m
C13	Estimated irrigation effectiveness in 1990	C12/C11	%
C14	Assumed irrigation effectiveness	min(2xC13,70%)	%
C15	Total irr. WITH in 2025 under scenerio 1 (S1)	C9xC2	km^3
C16	Total irr. WITH in 2025 under scenerio 2 (S2)	C8xC10xC2xC12/C14/100	km^3
C17	S2: % change from 1990 irr. WITH	C16/C9–1	%
C18	S2 as a % of S1	C16/C15	%
C19	Total savings from S2	C15-C16	km^3
C20	Per capita domestic WITH in 2025	See figure 3	m^3
C21	Per capita industrial WITH in 2025	See figure 3	m^3
C22	Total domestic and industrial WITH in 2025	(C19+C20) xC1xC2/1,000	km^3
C23	% change from 1990 D&I WITH	C22/([C5+C6]xC1/1,000)–1	%
C24	Total WITH in 2025	C16+C22	km^3
C25	Total additional withdrawals in 2025	C24-C4	km^3
C26	Per capita internal renewable water supply in 2025	C3/(C1xC2) x1,000	m^3
C27	S1: % change from 1990 total WITH	(C15+C22)/C4–1	%
C28	S2: % change from 1990 total WITH	C24/C4–1	%
C29	2025 total withdrawal as % of IRWR	C24/C3	%

		1990 Data							1990 Irrigation						2025 Irrigation Scenerios (S1 and S2)						2025 Domestic and Industrial				2025 Total		Indicators IWMI				
Country	ID	Population 1990 2025 (millions)	Population Growth 1990- %	Annual Water Resou. (AWR) km^3	Total With-drawals (=DWR) km^3	Per capita WITH Dom. m^3	Per capita WITH Ind. m^3	Per capita WITH Irr. m^3	Net irrigated area (NIA) (1,000 ha)	Total Irr WITH km^3	Annual irr int. %	WITH gross irr. area m/ha/ year	NET gross irr. area m/ha/ year	Effec eff. %	Assum effec eff. 70% %	S1 tot irr WITH km^3	S2 tot irr WITH km^3	S2 % chan from 1990 %	S2/S1 %	S1-S2 km^3	Per capita Dom. m^3	Per capita Ind. m^3	Total D&I WITH km^3	% chan. from 1990 %	S2 2025 Total WITH km^3	S2 Add'l WITH in 2025 km^3	IRWR Per Cap (Stand-dard) m^3	2025 WITH (S1) % chan from 1990 %	2025 WITH (S2) % chan from 1990 %	2025 WITH (S2) % of AWR %	Country
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
World		5,285	160%	47,196	3,410				245,067																		5,571				World
Countries		4,892	160%	41,463	2,905	54	114	426	220,376	2,086	146%	0.65	0.28	43%	60%	3,376	2431	17%	72%	944	58	96	1,193	45%	3,625	720	5,310	57%	25%	9%	Countries
% of total		93%		88%	85%	9%	19%	72%	90%																						% of Total
Group	1	377	222%	857	407	55	39	985	37,507	371	138%	0.72	0.39	54%	66%	847	698	88%	82%	149	56	39	79	122%	777	370	1,026	128%	91%	91%	Group 1
% of total		8%		2%	14%	5%	4%	91%	17%	18%						25%	29%			16%			7%		21%						% of Total
Group	2	348	257%	4,134	28	10	4	67	3,101	23	148%	0.51	0.30	58%	62%	57	48	105%	84%	9	17	7	21	335%	69	41	4,629	178%	145%	2%	Group 2
% of total		7%		10%	1%	13%	5%	82%	1%	1%						2%	2%			1%			2%		2%						% of Total
Group	3	777	176%	17,358	220	59	33	192	23,301	149	156%	0.41	0.18	43%	62%	275	179	20%	65%	95	63	45	147	107%	327	106	12,709	92%	48%	2%	Group 3
% of total		16%		42%	8%	21%	12%	68%	11%	7%						8%	7%			10%			12%		9%						% of Total
Group	4	796	146%	11,261	800	126	397	482	38,735	383	144%	0.69	0.31	45%	58%	561	371	-3%	66%	190	122	358	557	34%	929	129	9,688	40%	16%	8%	Group 4
% of total		16%		27%	28%	13%	39%	48%	18%	18%						17%	15%			20%			47%		26%						% of Total
Group	5	589	108%	2,968	399	80	239	359	24,623	211	130%	0.66	0.20	31%	49%	232	138	-34%	60%	93	84	227	197	5%	335	0	4,688	7%	-16%	11%	Group 4
% of total		12%		7%	14%	12%	35%	53%	11%	10%						7%	6%			10%			16%		9%						% of Total
China		1,155	132%	2,800	533	28	32	401	47,965	463	184%	0.53	0.21	39%	60%	612	399	-14%	65%	213	46	38	128	84%	527	0	1,835	39%	-1%	19%	China
% of total		24%		7%	18%	6%	7%	87%	22%	22%						18%	16%			23%			11%		15%						% of Total
India		851	164%	2,085	518	18	24	569	45,144	484	145%	0.74	0.29	40%	60%	792	525	8%	66%	267	28	24	73	100%	598	80	1,498	67%	15%	29%	India
% of total		17%		5%	18%	3%	4%	93%	20%	23%						23%	22%			28%			6%		16%						% of Total

Country	ID	1990 Data							1990 Irrigation						2025 Irrigation Scenerios (S1 and S2)						2025 Domestic and Industrial				2025 Total		Indicators IWMI				Country
		Population 1990 2025 (millions)	Population Growth 1990- %	Annual Water Resou. (AWR) km³	Total With-drawals (=DWR) km³	Per capita WITH Dom. m³	Per capita WITH Ind. m³	Per capita WITH Irr. m³	Net irrigated area (NIA) (1,000 ha)	Total Irr WITH km³	Annual irr int. %	WITH gross irr. area m/ha/year	NET gross irr. area m/ha/year	Effec eff. %	Assum effec eff. 70% %	S1 tot irr WITH km³	S2 tot irr WITH km³	S2 % chan from 1990 %	S2/S1 %	S1-S2 km³	Per capita Dom. m³	Per capita Ind. m³	Total D&I WITH km³	% chan. from 1990 %	S2 2025 Total WITH km³	S2 Add'l WITH in 2025 km³	IRWR Per Cap (Stand-dard) m³	2025 WITH (S1) % chan from 1990 %	2025 WITH (S2) % chan from 1990 %	2025 WITH (S2) % of AWR %	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
GROUP 1																															
Libya (1)	1	4.5	283%	0.6	4.0	96	19	765	470	3.5	117%	0.63	0.34	53%	70%	9.9	7.5	116%	76%	2.3	96	20	1.5	186%	9.0	5.0	47	184%	125%	999%	Libya
Saudi Arabia(1)	2	16.0	266%	2.4	16.7	94	10	936	900	15.0	150%	1.12	0.52	47%	70%	39.9	26.6	77%	67%	13.4	94	21	4.9	193%	31.4	14.8	56	169%	88%	999%	Saudi Arabia
UAE(1)	3	1.7	177%	0.2	1.8	266	100	742	63	1.2	158%	1.24	0.56	45%	70%	2.2	1.4	14%	64%	0.8	266	100	1.1	77%	2.5	0.6	51	77%	35%	999%	UAE
Kuwait(1)	4	2.1	131%	0.2	0.7	129	7	212	3	0.5	200%	7.58	0.49	6%	13%	0.6	0.3	-35%	50%	0.3	129	14	0.4	38%	0.7	0.0	71	34%	-6%	349%	Kuwait
Oman(1)	5	1.8	348%	1.0	1.3	36	15	677	58	1.2	160%	1.27	0.60	47%	70%	4.1	2.8	132%	67%	1.4	73	29	0.6	596%	3.4	2.1	162	272%	165%	343%	Oman
Jordan(1)	6	4.3	283%	0.9	1.0	54	7	185	63	0.8	132%	0.95	0.52	55%	70%	2.2	1.7	121%	78%	0.5	54	15	0.8	217%	2.6	1.5	73	191%	145%	292%	Jordan
Yemen(1)	7	11.3	298%	4.1	2.8	18	3	231	348	2.6	96%	0.78	0.55	70%	70%	7.8	7.8	198%	100%	0.0	20	5	0.8	271%	8.6	5.8	122	204%	204%	210%	Yemen
Israel	8	4.7	168%	2.2	1.9	65	20	322	206	1.5	121%	0.60	0.30	50%	70%	2.5	1.8	19%	71%	0.7	126	41	1.3	227%	3.1	1.2	282	101%	63%	141%	Israel
Afghanistan(1)	9	15.0	301%	65.0	25.6	102	34	1566	3,000	23.6	84%	0.94	0.66	70%	70%	70.9	70.9	201%	100%	0.0	102	1	4.7	128%	75.5	49.9	1,436	195%	195%	116%	Afghanistan
Egypt(1)	10	56.3	173%	68.5	51.4	53	79	781	2,648	44.0	189%	0.88	0.52	60%	70%	76.0	64.6	47%	85%	11.3	53	79	12.9	73%	77.5	26.1	704	73%	51%	113%	Egypt
Tunisia(1)	11	8.1	164%	3.9	3.1	32	11	339	300	2.7	131%	0.70	0.35	51%	70%	4.5	3.2	19%	72%	1.3	49	21	0.9	169%	4.2	1.1	296	76%	36%	106%	Tunisia
Iraq(1)	12	18.1	236%	75.4	42.8	71	118	2178	3,525	39.4	129%	0.86	0.46	53%	70%	92.9	70.9	80%	76%	22.0	71	118	8.1	136%	79.0	36.2	1,768	136%	85%	105%	Iraq
Singapore	13	2.7	124%	0.6	0.2	41	43	0	–	–	NA	NA	NA	NA	NA	0.0	0.0	–	NA	0.0	82	86	0.6	148%	0.6	0.3	179	148%	148%	94%	Singapore
Iran(1)	14	58.9	210%	137.5	64.3	65	22	1004	7,000	59.2	105%	0.81	0.53	65%	70%	124.0	115.9	96%	93%	8.1	65	36	12.5	143%	128.4	64.1	1,113	112%	100%	93%	Iran
Syria(1)	15	12.3	271%	26.3	12.6	41	20	956	693	11.8	166%	1.03	0.48	47%	70%	32.0	21.5	82%	67%	10.5	41	23	2.1	183%	23.6	11.1	784	172%	88%	90%	Syria
Pakistan(1)	16	121.9	234%	418.3	155.7	26	26	1226	16,940	149	116%	0.76	0.37	49%	60%	349.2	282.7	89%	81%	66.4	26	26	14.5	134%	297.3	141.6	1,469	134%	91%	71%	Pakistan
South Africa(1)	17	37.1	191%	50.0	20.8	96	61	404	1,290	15.0	160%	0.72	0.33	45%	70%	28.7	18.6	24%	65%	10.0	96	61	11.2	91%	29.8	9.0	705	91%	43%	60%	South Africa
GROUP 2																															
Congo(1)	18	2.2	254%	832.0	0.0	12	5	2	1	0.0	200%	0.25	0.09	37%	70%	0.0	0.0	34%	53%	0.0	25	11	0.2	409%	0.2	0.2	99,999	381%	367%	0%	Congo
Zaire(1)	19	37.4	280%	1019.0	0.3	5	1	2	9	0.1	200%	0.44	0.11	26%	51%	0.2	0.1	40%	50%	0.1	11	3	1.4	459%	1.6	1.2	9,738	394%	362%	0%	Zaire
Gabon(1)	20	1.1	235%	164.0	0.1	41	13	3	4	0.0	117%	0.08	0.04	47%	70%	0.0	0.0	58%	67%	0.0	77	25	0.3	347%	0.3	0.2	60,808	334%	329%	0%	Gabon
Niger(1)	21	7.7	290%	32.5	0.5	11	1	57	66	0.4	100%	0.67	0.47	70%	70%	1.3	1.3	190%	100%	0.0	20	3	0.5	431%	1.8	1.2	1,452	233%	233%	5%	Niger
Cameroon(1)	22	11.5	253%	268.0	0.4	14	6	11	21	0.1	200%	0.30	0.08	25%	51%	0.3	0.2	27%	50%	0.2	23	12	1.0	331%	1.2	0.8	9,187	269%	224%	0%	Cameroon
Cote d'Ivoire(1)	23	12.0	307%	77.7	0.8	14	7	43	66	0.5	164%	0.48	0.19	40%	70%	1.6	0.9	77%	57%	0.7	28	14	1.6	515%	2.5	1.7	2,110	309%	221%	3%	Cote d'lvorie

Country	ID	1990 Data: Population 1990 2025 (millions)	1990 Data: Population Growth 1990-2025 %	1990 Data: Annual Water Resou. (AWR) km³	1990 Data: Total With-drawals (=DWR) km³	1990 Data: Per capita WITH Dom. m³	1990 Data: Per capita WITH Ind. m³	1990 Data: Per capita WITH Irr. m³	1990 Irrigation: Net irrigated area (NIA) (1,000 ha)	1990 Irrigation: Total Irr WITH km³	1990 Irrigation: Annual irr int. %	1990 Irrigation: WITH gross irr. area m/ha/year	1990 Irrigation: NET gross irr. area m/ha/year	1990 Irrigation: Effec eff. %	2025 Irrigation Scenerios (S1 and S2): Assum effec eff. 70% %	2025 Irrigation Scenerios (S1 and S2): S1 tot irr WITH km³	2025 Irrigation Scenerios (S1 and S2): S2 tot irr WITH km³	2025 Irrigation Scenerios (S1 and S2): S2 % chan from 1990 %	2025 Irrigation Scenerios (S1 and S2): S2/S1 %	2025 Irrigation Scenerios (S1 and S2): S1-S2 km³	2025 Domestic and Industrial: Per capita Dom. m³	2025 Domestic and Industrial: Per capita Ind. m³	2025 Domestic and Industrial: Total D&I WITH km³	2025 Domestic and Industrial: % chan. from 1990 %	2025 Total: S2 2025 Total WITH km³	2025 Total: S2 Add'l WITH in 2025 km³	Indicators: IRWR Per Cap (Standard) m³	IWMI 2025 WITH: (S1) % chan from 1990 %	IWMI 2025 WITH: (S2) % chan from 1990 %	IWMI 2025 WITH: (S2) % of AWR %	Country
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
Botswana(1)	24	1.3	234%	14.7	0.1	27	17	41	2	0.1	200%	1.10	0.44	40%	70%	0.1	0.1	32%	57%	0.1	54	35	0.3	367%	0.3	0.2	4,933	255%	207%	2%	Botswana
Lesotho(1)	25	1.8	233%	5.2	0.1	7	7	17	3	0.0	135%	0.77	0.40	52%	70%	0.1	0.1	73%	74%	0.0	14	14	0.1	366%	0.2	0.1	1,246	235%	201%	3%	Lesotho
Burundi(1)	26	5.5	245%	3.6	0.1	7	0	13	14	0.1	134%	0.37	0.18	48%	70%	0.2	0.1	66%	68%	0.1	14	1	0.2	424%	0.3	0.2	267	246%	195%	9%	Burundi
Guinea-Bissau(1)	27	1.0	205%	27.0	0.0	10	1	6	17	0.0	102%	0.03	0.01	36%	70%	0.0	0.0	7%	52%	0.0	20	1	0.0	301%	0.0	0.0	13,650	230%	195%	0%	Guinea-Bissau
Uganda(1)	28	18.0	267%	66.0	0.4	6	2	12	9	0.2	200%	1.18	0.13	11%	22%	0.6	0.3	34%	50%	0.3	13	3	0.8	435%	1.1	0.7	1,373	274%	194%	2%	Uganda
Nigeria(1)	29	96.2	248%	280.0	3.6	11	6	20	230	1.9	148%	0.57	0.23	40%	70%	4.8	2.7	42%	57%	2.0	20	11	7.4	353%	10.1	6.6	1,175	242%	185%	4%	Nigeria
Ghana(1)	30	15.0	253%	53.2	0.5	12	5	18	6	0.3	200%	2.28	0.39	17%	34%	0.7	0.3	26%	50%	0.3	20	9	1.1	338%	1.5	0.9	1,400	242%	176%	3%	Ghana
Benin(1)	31	4.6	264%	25.8	0.1	6	3	19	6	0.1	187%	0.73	0.28	39%	70%	0.2	0.1	46%	55%	0.1	13	6	0.2	429%	0.4	0.2	2,106	252%	172%	1%	Benin
Angola(1)	32	9.9	268%	184.0	0.6	8	6	43	75	0.4	134%	0.43	0.20	48%	70%	1.2	0.8	82%	68%	0.4	16	11	0.7	437%	1.5	0.9	6,912	233%	167%	1%	Angola
Haiti	33	6.5	202%	11.0	0.0	2	1	5	75	0.0	13%	0.32	0.23	70%	70%	0.1	0.1	102%	100%	0.0	3	1	0.1	305%	0.1	0.1	838	167%	167%	1%	Haiti
Mozambique(1)	34	14.2	248%	208.0	0.6	6	3	30	105	0.4	114%	0.35	0.20	56%	70%	1.1	0.8	98%	80%	0.2	13	5	0.6	395%	1.5	0.9	5,919	205%	167%	1%	Mozambique
Liberia(1)	35	2.6	281%	232.0	0.1	15	7	33	2	0.1	200%	2.12	0.07	3%	6%	0.2	0.1	41%	50%	0.1	20	14	0.2	338%	0.4	0.2	32,044	244%	160%	0%	Liberia
Somalia(1)	36	8.7	245%	13.5	0.9	3	0	96	180	0.8	57%	0.81	0.57	70%	70%	2.0	2.0	145%	100%	0.0	6	1	0.1	473%	2.2	1.3	635	155%	155%	16%	Somalia
Sudan(1)	37	24.6	237%	154.0	15.6	28	7	597	1,946	14.7	104%	0.73	0.48	67%	70%	34.9	33.2	126%	95%	1.7	28	1	1.7	97%	34.9	19.3	2,638	135%	124%	23%	Sudan
Paraguay	38	4.3	209%	314.0	0.5	16	8	85	67	0.4	128%	0.43	0.22	51%	70%	0.8	0.6	53%	73%	0.2	33	15	0.4	318%	1.0	0.5	34,823	155%	112%	0%	Paraguay
Ethiopia(4)	39	47.4	268%	88.0	2.4	6	2	44	162	2.1	189%	0.68	0.27	40%	70%	5.6	3.2	53%	57%	2.4	11	3	1.8	435%	5.0	2.6	694	205%	106%	6%	Ethiopia
Chad(1)	40	5.6	232%	43.0	0.2	5	1	28	14	0.2	146%	0.76	0.34	45%	70%	0.4	0.2	49%	64%	0.1	11	1	0.2	365%	0.4	0.2	3,332	174%	106%	1%	Chad
Burkina Faso(1)	41	9.0	241%	17.5	0.4	8	0	32	20	0.3	180%	0.81	0.30	37%	70%	0.7	0.4	27%	53%	0.3	16	1	0.4	413%	0.7	0.4	808	194%	102%	4%	Burkina Faso
GROUP 3																															
Nicaragua	42	3.7	247%	175.0	1.3	92	77	198	85	0.7	155%	0.55	0.24	44%	70%	1.8	1.1	55%	63%	0.7	92	77	1.5	147%	2.7	1.3	19,275	147%	98%	2%	Nicaragua
Cen. Afr. Rep.(1)	43	2.9	217%	141.0	0.1	5	1	19	1	0.1	200%	4.43	0.26	6%	12%	0.1	0.1	9%	50%	0.1	11	3	0.1	335%	0.1	0.1	22,170	174%	93%	0%	Cen. Afr. Rep.
Tanzania(1)	44	25.6	246%	89.0	1.0	3	1	36	144	0.9	138%	0.46	0.20	44%	70%	2.2	1.4	56%	64%	0.8	7	2	0.5	391%	2.0	0.9	1,415	172%	92%	2%	Tanzania
Guinea(1)	45	5.8	262%	226.0	0.8	14	4	121	90	0.7	153%	0.51	0.21	41%	70%	1.8	1.1	53%	58%	0.8	21	8	0.4	328%	1.5	0.7	14,979	184%	89%	1%	Guinea
Nepal	46	19.3	211%	170.0	2.9	6	2	143	900	2.7	109%	0.28	0.16	58%	70%	5.8	4.8	75%	83%	1.0	12	3	0.6	323%	5.4	2.5	4,178	122%	87%	3%	Nepal
Peru	47	21.6	170%	40.0	6.5	57	27	216	1,450	4.7	80%	0.40	0.28	70%	70%	7.9	7.9	70%	100%	0.0	58	54	4.1	128%	12.1	5.6	1,090	86%	86%	30%	Peru

Country	ID	1990 Data							1990 Irrigation						2025 Irrigation Scenerios (S1 and S2)						2025 Domestic and Industrial				2025 Total		Indicators IWMI				Country
		Population 1990 2025 (millions)	Population Growth 1990- %	Annual Water Resou. (AWR) km^3	Total With-drawals (=DWR) km^3	Per capita WITH Dom. m^3	Per capita WITH Ind. m^3	Per capita WITH Irr. m^3	Net irrigated area (NIA) (1,000 ha)	Total Irr WITH km^3	Annual irr int. %	WITH gross irr. area m/ha/year	NET gross irr. area m/ha/year	Effec eff. %	Assum effec eff. 70% %	S1 tot irr WITH km^3	S2 tot irr WITH km^3	S2 % chan from 1990 %	S2/S1 %	S1-S2 km^3	Per capita Dom. m^3	Per capita Ind. m^3	Total D&I WITH km^3	% chan. from 1990 %	S2 2025 Total WITH km^3	S2 Add'l WITH in 2025 km^3	IRWR Per Cap (Stand-dard) m^3	2025 WITH (S1) % chan from 1990 %	2025 WITH (S2) % chan from 1990 %	2025 WITH (S2) % of AWR %	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
Kenya(1)	48	23.6	268%	30.2	2.1	17	3	66	54	1.6	200%	1.45	0.39	27%	54%	4.2	2.1	34%	50%	2.1	20	7	1.7	252%	3.8	1.8	477	188%	85%	13%	Kenya
Guatemala	49	9.2	236%	116.0	1.3	13	24	103	117	0.9	182%	0.44	0.18	40%	70%	2.2	1.3	35%	57%	1.0	25	25	1.1	228%	2.4	1.1	5,349	160%	85%	2%	Guatemala
Senegal(1)	50	7.3	231%	39.4	1.5	10	6	185	94	1.4	161%	0.89	0.40	45%	70%	3.1	2.0	49%	65%	1.1	20	12	0.5	361%	2.6	1.1	2,332	149%	74%	7%	Senegal
Mali(1)	51	9.2	267%	100.0	1.5	3	2	156	78	1.4	191%	0.96	0.40	42%	70%	3.8	2.3	59%	60%	1.5	6	3	0.2	434%	2.5	1.0	4,069	175%	71%	3%	Mali
Bolivia	52	6.6	200%	300.0	1.3	20	10	171	110	1.1	151%	0.68	0.33	48%	70%	2.2	1.6	38%	69%	0.7	29	20	0.6	226%	2.2	0.9	22,847	119%	66%	1%	Bolivia
Turkey(1)	53	56.1	162%	183.7	30.3	87	60	395	3,800	22.2	103%	0.57	0.38	67%	70%	35.9	34.6	56%	96%	1.3	87	86	15.6	91%	50.2	19.9	2,020	70%	66%	27%	Turkey
Zimbabwe(1)	54	9.9	198%	20.0	1.3	19	9	107	100	1.1	182%	0.58	0.26	45%	70%	2.1	1.3	28%	64%	0.7	23	19	0.8	194%	2.2	0.8	1,019	118%	63%	11%	Zimbabwe
Namibia(1)	55	1.3	226%	45.5	0.2	49	5	117	4	0.2	200%	1.97	0.50	25%	51%	0.4	0.2	13%	50%	0.2	49	11	0.2	149%	0.4	0.1	14,923	133%	56%	1%	Namibia
Colombia	56	32.3	153%	1070.0	5.6	71	28	75	680	2.4	130%	0.26	0.13	49%	70%	3.7	2.6	8%	71%	1.1	71	53	6.1	91%	8.7	3.1	21,678	75%	55%	1%	Colombia
Zambia(1)	57	8.2	235%	116.0	1.5	29	13	144	30	1.2	200%	1.95	0.26	13%	27%	2.7	1.4	17%	50%	1.4	29	20	0.9	174%	2.3	0.8	6,064	144%	53%	2%	Zambia
Brazil	58	148.5	155%	6950.0	36.5	54	47	145	2,700	21.5	171%	0.47	0.18	39%	70%	33.4	18.8	-13%	56%	14.6	77	84	37.0	147%	55.8	19.3	30,185	93%	53%	1%	Brazil
Venezuela	59	19.5	178%	1317.0	7.4	164	42	176	180	3.4	200%	0.95	0.33	35%	70%	6.1	3.1	-11%	50%	3.1	164	71	8.2	104%	11.2	3.8	37,872	92%	51%	1%	Venezuela
Algeria(1)	60	24.9	182%	14.3	4.5	45	27	108	384	2.7	130%	0.54	0.26	49%	70%	4.9	3.4	26%	69%	1.5	45	27	3.3	82%	6.7	2.2	314	82%	49%	47%	Algeria
Australia	61	16.9	146%	343.0	15.8	606	19	308	1,832	5.2	101%	0.28	0.19	68%	70%	7.6	7.4	41%	97%	0.2	606	37	15.9	50%	23.2	7.5	13,905	49%	47%	7%	Australia
Cambodia	62	8.8	223%	498.1	0.6	3	1	60	160	0.5	122%	0.27	0.11	40%	70%	1.2	0.7	28%	58%	0.5	6	1	0.2	345%	0.8	0.3	25,302	136%	47%	0%	Cambodia
Gambia(2)	63	0.9	228%	8.0	0.0	2	1	26	1	0.0	200%	1.22	0.32	26%	53%	0.1	0.0	14%	50%	0.0	4	1	0.0	355%	0.0	0.0	3,806	148%	45%	0%	Gambia
Madagascar(1)	64	12.6	274%	337.0	20.6	16	0	1622	1,000	20.4	200%	1.02	0.24	23%	47%	55.8	27.9	37%	50%	27.9	20	1	0.7	251%	28.6	8.0	9,791	175%	39%	8%	Madagascar
Indonesia	65	182.8	151%	2530.0	17.5	12	11	73	4,410	13.3	137%	0.22	0.08	34%	60%	20.1	11.5	-13%	57%	8.6	25	21	12.7	202%	24.2	6.7	9,180	87%	38%	1%	Indonesia
Malaysia	66	17.9	176%	456.0	13.7	177	230	361	335	6.5	200%	0.96	0.08	8%	16%	11.4	5.7	-12%	50%	5.7	177	230	12.9	76%	18.6	4.8	14,441	76%	35%	4%	Malaysia
Belize	67	0.2	204%	16.0	0.0	11	0	98	2	0.0	196%	0.41	0.15	35%	70%	0.0	0.0	2%	50%	0.0	22	1	0.0	327%	0.0	0.0	41,451	127%	35%	0%	Belize
Albania	68	3.8	122%	21.3	0.4	6	17	71	423	0.3	22%	0.29	0.20	70%	70%	0.3	0.3	22%	100%	0.0	11	20	0.1	69%	0.5	0.1	4,563	33%	33%	2%	Albania
Morocco(1)	69	24.3	167%	30.0	10.6	21	13	402	1,258	9.8	131%	0.59	0.29	49%	70%	16.3	11.3	16%	69%	5.0	42	25	2.7	228%	14.1	3.4	738	80%	32%	47%	Morocco
Honduras	70	4.9	218%	63.4	1.4	12	15	268	74	1.3	200%	0.89	0.20	23%	45%	2.9	1.4	9%	50%	1.4	24	20	0.5	258%	1.9	0.4	5,950	130%	31%	3%	Honduras
New Zealand(2)	71	3.4	130%	327.0	2.0	271	59	259	280	0.9	122%	0.25	0.14	53%	70%	1.1	0.9	-1%	76%	0.3	271	118	1.7	53%	2.6	0.6	74,726	43%	29%	1%	New Zealand
Myanmar	72	41.8	181%	1082.0	4.2	7	3	91	1,005	3.8	118%	0.32	0.12	39%	70%	6.9	3.8	1%	56%	3.0	14	6	1.5	261%	5.4	1.1	14,319	99%	27%	0%	Myanmar

Country	ID	1990 Data: Population 1990 2025 (millions)	1990 Data: Population Growth 1990-2025 %	1990 Data: Annual Water Resou. (AWR) km³	1990 Data: Total With-drawals (=DWR) km³	1990 Data: Per capita WITH Dom. m³	1990 Data: Per capita WITH Ind. m³	1990 Data: Per capita WITH Irr. m³	1990 Irrigation: Net irrigated area (NIA) (1,000 ha)	1990 Irrigation: Total Irr WITH km³	1990 Irrigation: Annual irr int. %	1990 Irrigation: WITH gross irr. area m/ha/year	1990 Irrigation: NET gross irr. area m/ha/year	1990 Irrigation: Effec eff. %	2025 Irrigation Scenerios (S1 and S2): Assum effec eff. 70% %	S1 tot irr WITH km³	S2 tot irr WITH km³	S2 % chan from 1990 %	S2/S1 %	S1-S2 km³	2025 Domestic and Industrial: Per capita Dom. m³	Per capita Ind. m³	Total D&I WITH km³	% chan. from 1990 %	2025 Total: S2 2025 Total WITH km³	S2 Add'l WITH in 2025 km³	Indicators IWMI: IRWR Per Cap (Stand-dard) m³	2025 WITH (S1) % chan from 1990 %	2025 WITH (S2) % chan from 1990 %	2025 WITH (S2) % of AWR %	Country
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
Mauritania(1)	73	2.0	222%	11.4	1.8	57	17	849	49	1.7	200%	1.74	0.64	37%	70%	3.8	2.0	16%	52%	1.8	57	20	0.3	132%	2.3	0.5	2,566	123%	25%	20%	Mauritania
El Salvador	74	5.2	188%	19.0	1.3	17	10	218	120	1.1	185%	0.51	0.18	35%	70%	2.1	1.1	-6%	50%	1.1	34	20	0.5	276%	1.6	0.3	1,952	109%	25%	8%	El Salvador
Lebanon(1)	75	2.6	173%	4.4	1.1	124	18	302	86	0.8	142%	0.63	0.23	37%	70%	1.3	0.7	-8%	53%	0.6	124	36	0.7	95%	1.4	0.3	996	80%	25%	32%	Lebanon
Chile	76	13.2	150%	468.0	21.4	358	309	959	1,265	12.6	137%	0.73	0.36	50%	70%	19.0	13.5	7%	71%	5.5	358	309	13.2	50%	26.7	5.3	23,666	50%	25%	6%	Chile
GROUP 4																															
Canada(2,3)	77	27.8	138%	2901.0	44.5	288	1121	192	718	5.3	100%	0.74	0.19	26%	51%	7.4	3.7	-31%	50%	3.7	288	1121	53.9	38%	57.6	13.1	75,811	38%	29%	2%	Canada
USA(2)	78	249.9	133%	2478.0	467.4	243	842	785	20,900	196	163%	0.58	0.31	54%	70%	260.1	200.5	2%	77%	59.6	243	842	359.2	33%	559.6	92.3	7,483	33%	20%	23%	USA
Philippines	79	60.8	172%	323.0	41.7	123	144	418	1,560	25.4	200%	0.82	0.14	18%	35%	43.7	21.9	-14%	50%	21.9	123	144	28.0	72%	49.8	8.1	3,090	72%	20%	15%	Philippines
Jamaica	80	2.4	140%	8.3	0.4	11	11	137	33	0.3	152%	0.65	0.29	45%	70%	0.5	0.3	-10%	65%	0.2	22	22	0.1	179%	0.4	0.1	2,514	59%	17%	5%	Jamaica
Switzerland	81	6.8	114%	50.0	1.2	40	126	7	25	0.0	86%	0.22	0.16	70%	70%	0.1	0.1	14%	100%	0.0	40	126	1.3	14%	1.3	0.2	6,422	14%	14%	3%	Switzerland
Sweden	82	8.6	114%	180.0	2.9	123	188	31	114	0.3	84%	0.27	0.19	70%	70%	0.3	0.3	14%	100%	0.0	123	188	3.0	14%	3.3	0.4	18,460	14%	14%	2%	Sweden
Vietnam	83	66.7	177%	376.0	27.6	54	37	323	1,840	21.5	183%	0.64	0.21	32%	60%	38.2	20.4	-5%	54%	17.7	54	37	10.8	77%	31.2	3.6	3,182	77%	13%	8%	Vietnam
Ecuador	84	10.3	173%	314.0	6.0	41	17	523	290	5.4	200%	0.93	0.37	39%	70%	9.3	5.2	-2%	56%	4.1	45	35	1.4	138%	6.7	0.7	17,648	80%	12%	2%	Ecuador
Norway(2)	85	4.2	111%	392.0	2.1	98	351	39	97	0.2	100%	0.17	0.09	52%	70%	0.2	0.1	-17%	74%	0.0	98	351	2.1	11%	2.3	0.2	83,068	11%	9%	1%	Norway
Poland	86	38.1	109%	56.2	12.2	42	244	35	100	1.3	100%	1.35	0.20	15%	30%	1.5	0.7	-46%	50%	0.7	58	244	12.5	15%	13.3	1.0	1,353	14%	8%	24%	Poland
Mexico	87	84.5	162%	357.4	76.0	54	72	773	5,600	65.3	167%	0.70	0.29	42%	70%	105.6	63.8	-2%	60%	41.8	58	72	17.7	67%	81.5	5.5	2,617	62%	7%	23%	Mexico
France(2)	88	56.7	108%	198.0	37.7	106	459	100	1,300	5.7	100%	0.44	0.25	58%	70%	6.1	5.0	-11%	82%	1.1	106	459	34.6	8%	39.7	1.9	3,233	8%	5%	20%	France
Argentina	89	32.5	142%	994.0	33.9	94	188	761	1,680	24.8	200%	0.74	0.31	43%	70%	35.1	21.3	-14%	61%	13.8	109	188	13.7	49%	35.0	1.1	21,546	44%	3%	4%	Argentina
Greece(2)	90	10.2	96%	58.7	5.4	42	152	329	1,195	3.4	104%	0.27	0.17	62%	70%	3.3	2.9	-14%	89%	0.4	84	180	2.6	31%	5.5	0.1	5,949	9%	3%	9%	Greece
Austria(2)	91	7.7	107%	90.3	2.3	100	176	27	4	0.2	100%	5.27	0.11	2%	4%	0.2	0.1	-46%	50%	0.1	100	176	2.3	7%	2.4	0.1	19,930	7%	2%	3%	Austria
Bangladesh	92	108.1	181%	2357.0	23.8	7	2	211	2,936	22.8	161%	0.48	0.15	30%	60%	41.4	20.8	-9%	50%	20.7	13	4	3.5	263%	24.2	0.4	12,018	89%	2%	1%	Bangladesh
Belgium(2,3)	93	10.0	105%	12.5	9.1	101	779	37	–	–	NA	NA	NA	NA	NA	0.0	0.0	-	NA	0.0	101	779	9.2	5%	9.2	0.0	1,201	0%	0%	73%	Belgium
Costa Rica	94	3.3	170%	95.0	2.6	31	55	694	118	2.3	200%	0.97	0.15	15%	31%	3.9	1.9	-15%	50%	1.9	57	55	0.6	121%	2.6	0.0	16,940	75%	0%	3%	Costa Rica
Dom. Rep.	95	7.1	157%	20.0	3.2	22	27	397	225	2.8	200%	0.63	0.20	32%	64%	4.4	2.2	-21%	50%	2.2	45	40	0.9	172%	3.2	0.0	1,791	70%	0%	16%	Dom. Rep.

Country	ID	1990 Data: Population 1990 2025 (millions)	Population Growth 1990- %	Annual Water Resou. (AWR) km³	Total With-drawals (=DWR) km³	Per capita WITH Dom. m³	Per capita WITH Ind. m³	Per capita WITH Irr. m³	1990 Irrigation: Net irrigated area (NIA) (1,000 ha)	Total Irr WITH km³	Annual irr int. %	WITH gross irr. area m/ha/year	NET gross irr. area m/ha/year	Effec eff. %	2025 Irrigation Scenerios (S1 and S2): Assum effec eff. 70% %	S1 tot irr WITH km³	S2 tot irr WITH km³	S2 % chan from 1990 %	S2/S1 %	S1-S2 km³	2025 Domestic and Industrial: Per capita Dom. m³	Per capita Ind. m³	Total D&I WITH km³	% chan. from 1990 %	2025 Total: S2 2025 Total WITH km³	S2 Add'l WITH in 2025 km³	Indicators IWMI: IRWR Per Cap (Stand-dard) m³	2025 WITH (S1) % chan from 1990 %	2025 WITH (S2) % chan from 1990 %	2025 WITH (S2) % of AWR %	Country
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
GROUP 5																															
South Korea	96	42.9	127%	66.1	27.1	120	221	291	1,345	12.5	100%	0.93	0.15	16%	33%	15.8	7.9	-37%	50%	7.9	126	221	18.9	29%	26.8	0.0	1,215	28%	-1%	41%	South Korea
Denmark(2)	97	5.1	99%	13.0	1.2	70	63	100	430	0.5	40%	0.30	0.21	70%	70%	0.5	0.5	-1%	100%	0.0	70	63	0.7	-1%	1.2	0.0	2,559	-1%	-1%	9%	Denmark
UK(2)	98	57.4	107%	71.0	11.8	4	158	43	164	2.5	100%	1.51	0.13	9%	17%	2.6	1.3	-46%	50%	1.3	8	158	10.2	10%	11.5	0.0	1,155	9%	-2%	16%	UK
North Korea	99	21.8	153%	67.0	15.0	76	110	502	1,420	10.9	100%	0.77	0.12	15%	31%	16.7	8.4	-23%	50%	8.4	76	110	6.2	53%	14.6	0.0	2,007	53%	-3%	22%	North Korea
Panama	100	2.4	157%	144.0	1.8	90	83	581	31	1.4	200%	2.25	0.16	7%	14%	2.2	1.1	-21%	50%	1.1	90	83	0.7	57%	1.7	0.0	36,227	57%	-3%	1%	Panama
Sri Lanka	101	17.2	145%	43.2	8.7	10	10	483	520	8.3	178%	0.90	0.33	36%	60%	12.1	7.3	-12%	61%	4.8	20	20	1.0	191%	8.3	0.0	1,726	51%	-4%	19%	Sri Lanka
Romania(2)	102	23.2	94%	208.0	26.3	91	374	669	3,109	15.5	98%	0.51	0.36	70%	70%	14.5	14.5	-6%	100%	0.0	91	374	10.1	-6%	24.6	0.0	9,570	-6%	-6%	12%	Romania
Netherlands(2)	103	15.0	109%	90.0	7.7	26	316	176	555	2.6	100%	0.47	0.18	38%	70%	2.9	1.6	-41%	54%	1.3	26	316	5.6	9%	7.1	0.0	5,530	9%	-8%	8%	Netherlands
Thailand	104	55.6	132%	179.0	33.5	24	36	542	4,238	30.1	143%	0.50	0.16	31%	60%	39.9	20.9	-31%	52%	19.0	48	72	8.9	165%	29.7	0.0	2,433	46%	-11%	17%	Thailand
Spain	105	39.3	96%	94.3	30.7	94	203	484	3,402	49.0	117%	0.48	0.27	57%	70%	18.2	14.9	-22%	82%	3.3	126	203	12.4	6%	27.2	0.0	2,510	0%	-11%	29%	Spain
Cuba	106	10.6	119%	34.5	9.2	78	17	774	900	8.2	143%	0.64	0.31	48%	70%	9.8	6.8	-18%	69%	3.0	78	26	1.3	31%	8.1	0.0	2,726	21%	-12%	23%	Cuba
Germany	107	79.4	96%	171.0	46.0	64	405	110	482	8.7	100%	1.81	0.19	11%	21%	8.4	4.2	-52%	50%	4.2	64	405	35.9	-4%	40.1	0.0	2,237	-4%	-13%	23%	Germany
Bulgaria	108	9.0	86%	205.0	13.9	46	1173	324	1,263	2.9	51%	0.45	0.32	70%	70%	2.5	2.5	-14%	100%	0.0	46	1173	9.5	-14%	12.0	0.0	26,390	-14%	-14%	6%	Bulgaria
Finland(2)	109	5.0	108%	113.0	2.2	53	198	189	64	0.9	100%	1.47	0.16	11%	21%	1.0	0.5	-46%	50%	0.5	53	198	1.4	8%	1.9	0.0	20,899	8%	-15%	2%	Finland
Surinam	110	0.4	150%	200.0	0.5	71	59	1058	59	0.4	200%	0.36	0.08	23%	45%	0.6	0.3	-25%	50%	0.3	71	59	0.1	50%	0.4	0.0	99,999	50%	-17%	0%	Surinam
Portugal(2)	111	9.9	98%	69.6	7.3	111	273	355	630	3.5	135%	0.41	0.18	43%	70%	3.4	2.1	-40%	61%	1.3	126	273	3.9	2%	6.0	0.0	7,186	0%	-18%	9%	Portugal
Uruguay	112	3.1	119%	124.0	0.7	14	7	219	120	0.7	142%	0.40	0.15	39%	70%	0.8	0.4	-34%	55%	0.4	29	14	0.2	139%	0.6	0.0	33,595	30%	-19%	0%	Uruguay
Hungary	113	10.4	91%	120.0	6.9	59	364	238	204	2.5	100%	1.21	0.32	26%	53%	2.2	1.1	-55%	50%	1.1	80	364	4.2	-5%	5.3	0.0	12,770	-7%	-23%	4%	Hungary
Japan	114	123.5	98%	547.0	90.8	125	243	368	2,846	485.4	200%	0.80	0.03	4%	7%	44.7	22.3	-51%	50%	22.3	125	243	44.7	-2%	67.0	0.0	4,499	-2%	-26%	12%	Japan
Guyana	115	0.8	143%	241.0	1.4	18	0	1794	130	1.4	200%	0.55	0.07	14%	27%	2.0	1.0	-28%	50%	1.0	33	1	0.0	171%	1.1	0.0	99,999	45%	-26%	0%	Guyana
Italy	116	57.0	92%	167.0	56.2	138	266	582	2,711	33.2	188%	0.65	0.28	43%	70%	30.4	18.7	-44%	61%	11.8	138	266	21.2	-8%	39.8	0.0	3,192	-8%	-29%	24%	Italy

Introduction to Appendix Table B2.

Column	Description	Data input or Calculation	Unit
C1	Net irrigated area in 1990	C8 in table 1	1,000 ha
C2	Irrigation withdrawals in 1990	C9 in table 1	km^3
C3	Depth of irrigation withdrawals on net irrigated area	C2/C1x100	m
C4	Potential crop months	No. of months with ave. temp. >=10 C^0	Months
C5	NET - net evapotranspiration for the first season	Data (see Appendix table B1)	m
C6	Assumed irrigation effectiveness	Data	%
C7	Irrigation requirement for the first season	C5/C6	m
C8	Surplus or deficit after first season	C3 - C7	m
C9	Irrigation intensity in the first season	Min (1,C7/C3)	%
C10	Surplus loss between seasons	Data	%
C11	Carry over to second season	Max (0,C8 x C10)	m
C12	NET - net evapotranspiration for the second season	Data (see Appendix table B1)	m
C13	Irrigation requirement for the second season	C12/C6	m
C14	Surplus or deficit after first season	C11-C13	m
C15	Annual irrigation intensity	C9+Min(1,C11/C13)	%
C16	NET - total annual net evapotranspiration	C1x(C5xC9+C12x(C15-C9))/100	km^3
C17	Depth of annual NET on gross irrigated area	C16/(C1xC15)/100	m

Country	ID	1990 data				First Season							Second season			Annual summary		
		Net irrigated area (NIA)	Irr. WITH on NIA	Estimated depth months	Potential crop	NET	Effec. effi. assu. Base = 70%	Irr. req.	Surplus or deficit	Irr. intensity	% surplus loss between season 50%	Carry over to remaining season	NET	Irr. req.	Surplus or deficit	Ann irr intensity	Annual NET on gross irr. area Total	Depth
		(1,000 ha)	km³	m	Months	m	%	m	m	%	m	m	m	m	m	%	km³	m
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
World		245,067	2353															
Countries		220,376	2086	1.37	10.6	0.2	69%	0.28	1.08	97%	50%	0.55	0.38	0.55	0.26	146%	892	0.28
% of total		90%	89%															
Group	1	37,507	371	2.09	11.1	0.36	69%	0.52	1.53	99%	48%	0.79	0.65	0.94	0.40	138%	202	0.39
% of total		17%	18%														23%	
Group	2	3,101	23	1.14	12	0.18	70%	0.26	0.88	95%	50%	0.45	0.41	0.58	0.19	148%	14	0.30
% of total		1%	1%														2%	
Group	3	23,301	149	1.45	11	0.17	69%	0.24	1.21	97%	50%	0.62	0.43	0.62	0.25	156%	65	0.18
% of total		11%	7%														7%	
Group	4	38,735	384	1.21	9	0.15	68%	0.22	0.99	98%	50%	0.50	0.22	0.32	0.25	144%	173	0.31
% of total		18%	18%														19%	
Group	4	24,623	211	1.10	9	0.16	69%	0.23	0.87	95%	50%	0.44	0.17	0.26	0.30	130%	65	0.20
% of total		11%	10%														7%	
China		47,965	463.39	0.97	10	0.18	60%	0.29	0.67	100%	50%	0.34	0.24	0.40	0.00	184%	181.2	0.21
% of total		22%	22%														20%	
India		45,144	484.15	1.07	12	0.21	60%	0.35	0.72	100%	50%	0.36	0.48	0.81	0.00	145%	192.4	0.29
% of total		20%	23%														22%	

Country	ID	1990 data: Net irrigated area (NIA) (1,000 ha)	1990 data: Irr. WITH on NIA km³	1990 data: Estimated depth months m	1990 data: Potential crop Months	First Season: NET m	First Season: Effec. effi. assu. Base = 70% %	First Season: Irr. req. m	First Season: Surplus or deficit m	First Season: Irr. intensity %	First Season: % surplus loss between season 50% m	First Season: Carry over to remaining season m	Second season: NET m	Second season: Irr. req. m	Second season: Surplus or deficit m	Annual summary: Ann irr intensity %	Annual summary: Annual NET on gross irr. area Total km³	Annual summary: Annual NET on gross irr. area Depth m
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Libya	1	470	3.48	0.74	12	0.27	70%	0.39	0.35	100%	50%	0.17	0.72	1.03	0.00	117%	1.9	0.34
Saudi Arabia	2	900	15.02	1.67	12	0.39	70%	0.55	1.12	100%	50%	0.56	0.79	1.13	0.00	150%	7.0	0.52
UAE	3	63	1.24	1.97	12	0.40	70%	0.57	1.40	100%	50%	0.70	0.84	1.20	0.00	158%	0.6	0.56
Kuwait	4	3	0.45	15.16	12	0.25	70%	0.35	14.81	100%	50%	7.40	0.73	1.04	6.37	200%	0.0	0.49
Oman	5	58	1.19	2.04	12	0.48	70%	0.68	1.36	100%	50%	0.68	0.79	1.13	0.00	160%	0.6	0.60
Jordan	6	63	0.79	1.25	9	0.50	70%	0.71	0.54	100%	50%	0.27	0.60	0.85	0.00	132%	0.4	0.52
Yemen	7	348	2.61	0.75	12	0.55	70%	0.78	-0.03	96%	50%	0.00	0.74	1.05	0.00	96%	1.8	0.55
Israel	8	206	1.50	0.73	12	0.21	70%	0.31	0.42	100%	50%	0.21	0.72	1.03	0.00	121%	0.7	0.30
Afghanistan	9	3,000	23.56	0.79	8	0.66	70%	0.94	-0.15	84%	50%	0.00	0.69	0.98	0.00	84%	16.5	0.66
Egypt	10	2,648	43.96	1.66	12	0.29	70%	0.42	1.24	100%	20%	0.99	0.78	1.11	0.00	189%	26.2	0.52
Tunisia	11	300	2.74	0.91	11	0.28	70%	0.40	0.51	100%	50%	0.25	0.58	0.83	0.00	131%	1.4	0.35
Iraq	12	3,525	39.37	1.12	11	0.41	70%	0.59	0.53	100%	50%	0.26	0.63	0.90	0.00	129%	21.0	0.46
Singapore	13	0	0.00	N/S	12	0.00	70%	0.00	NS	NS	50%	NS	0.03	0.04	NS	NS	NS	NS
Iran	14	7,000	59.17	0.85	9	0.51	70%	0.73	0.11	100%	50%	0.06	0.81	1.15	0.00	105%	38.7	0.53
Syria	15	693	11.80	1.70	9	0.41	70%	0.58	1.12	100%	50%	0.56	0.60	0.85	0.00	166%	5.5	0.48
Pakistan	16	16,940	149.48	0.88	12	0.33	60%	0.55	0.34	100%	50%	0.17	0.63	1.06	0.00	116%	72.6	0.37
South Africa	17	1,290	14.97	1.16	11	0.24	70%	0.35	0.81	100%	50%	0.41	0.47	0.67	0.00	160%	6.8	0.33

Country	ID	1990 data: Net irrigated area (NIA) (1,000 ha)	1990 data: Irr. WITH on NIA km³	1990 data: Estimated depth months m	1990 data: Potential crop Months	First Season: NET m	First Season: Effec. effi. assu. Base = 70% %	First Season: Irr. req. m	First Season: Surplus or deficit m	First Season: Irr. intensity %	First Season: % surplus loss between season 50% m	First Season: Carry over to remaining season m	Second season: NET m	Second season: Irr. req. m	Second season: Surplus or deficit m	Annual summary: Ann irr intensity %	Annual summary: Annual NET on gross irr. area Total km³	Annual summary: Annual NET on gross irr. area Depth m
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
GROUP	**2**																	
Congo	18	1	0.00	0.49	12	0.04	70%	0.06	0.43	100%	50%	0.22	0.14	0.20	0.02	200%	0.0	0.09
Zaire	19	9	0.08	0.88	12	0.03	70%	0.05	0.83	100%	50%	0.42	0.19	0.27	0.14	200%	0.0	0.11
Gabon	20	4	0.00	0.09	12	0.02	70%	0.03	0.06	100%	50%	0.03	0.12	0.17	0.00	117%	0.0	0.04
Niger	21	66	0.44	0.66	12	0.47	70%	0.67	0.00	100%	50%	0.00	0.66	0.95	0.00	100%	0.3	0.47
Cameroon	22	21	0.13	0.60	12	0.01	70%	0.02	0.58	100%	50%	0.29	0.14	0.20	0.09	200%	0.0	0.08
Cote d'Ivorie	23	66	0.51	0.78	12	0.08	70%	0.12	0.66	100%	50%	0.33	0.36	0.52	0.00	164%	0.2	0.19
Botswana	24	2	0.05	2.20	12	0.41	70%	0.59	1.62	100%	50%	0.81	0.46	0.66	0.15	200%	0.0	0.44
Lesotho	25	3	0.03	1.04	9	0.35	70%	0.50	0.54	100%	50%	0.27	0.54	0.78	0.00	135%	0.0	0.40
Burundi	26	14	0.07	0.50	12	0.13	70%	0.18	0.32	100%	50%	0.16	0.33	0.47	0.00	134%	0.0	0.18
Guinea-Bissau	27	17	0.01	0.03	12	0.00	70%	0.00	0.03	100%	50%	0.02	0.57	0.82	0.00	102%	0.0	0.01
Uganda	28	9	0.22	2.37	12	0.07	70%	0.10	2.27	100%	50%	1.13	0.19	0.27	0.86	200%	0.0	0.13
Nigeria	29	230	1.92	0.84	12	0.09	70%	0.12	0.71	100%	50%	0.36	0.52	0.75	0.00	148%	0.8	0.23
Ghana	30	6	0.27	4.56	12	0.35	70%	0.50	4.05	100%	50%	2.03	0.43	0.61	1.42	200%	0.0	0.39
Benin	31	6	0.09	1.36	12	0.10	70%	0.14	1.22	100%	50%	0.61	0.49	0.70	0.00	187%	0.0	0.28
Angola	32	75	0.43	0.57	12	0.14	70%	0.21	0.37	100%	50%	0.18	0.38	0.55	0.00	134%	0.2	0.20
Haiti	33	75	0.03	0.04	12	0.23	70%	0.32	-0.28	13%	50%	0.00	0.37	0.53	0.00	13%	0.0	0.23
Mozambique	34	105	0.43	0.41	12	0.17	70%	0.24	0.16	100%	50%	0.08	0.39	0.56	0.00	114%	0.2	0.20
Liberia	35	2	0.08	4.25	12	0.00	70%	0.00	4.25	100%	50%	2.12	0.13	0.19	1.93	200%	0.0	0.07
Somalia	36	180	0.83	0.46	12	0.57	70%	0.81	-0.35	57%	50%	0.00	0.65	0.93	0.00	57%	0.6	0.57
Sudan	37	1,946	14.69	0.75	12	0.48	70%	0.68	0.07	100%	50%	0.04	0.69	0.98	0.00	104%	9.8	0.48
Paraguay	38	67	0.37	0.55	12	0.18	70%	0.26	0.29	100%	50%	0.15	0.37	0.52	0.00	128%	0.2	0.22
Ethiopia	39	162	2.08	1.28	12	0.13	70%	0.18	1.10	100%	50%	0.55	0.44	0.62	0.00	189%	0.8	0.27
Chad	40	14	0.15	1.11	12	0.22	70%	0.31	0.79	100%	50%	0.40	0.61	0.86	0.00	146%	0.1	0.34
Burkina Faso	41	20	0.29	1.45	12	0.06	70%	0.08	1.37	100%	50%	0.68	0.60	0.86	0.00	180%	0.1	0.30

		1990 data				First Season							Second season			Annual summary		
Country	ID	Net irrigated area (NIA)	Irr. WITH on NIA	Estimated depth months	Potential crop	NET	Effec. effi. assu. Base = 70%	Irr. req.	Surplus or deficit	Irr. intensity	% surplus loss between season 50%	Carry over to remaining season	NET	Irr. req.	Surplus or deficit	Ann irr intensity	Annual NET on gross irr. area Total	Annual NET on gross irr. area Depth
		(1,000 ha)	km³	m	Months	m	%	m	m	%	m	m	m	m	m	%	km³	m
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
GROUP	**3**																	
Nicaragua	42	85	0.73	0.86	12	0.16	70%	0.22	0.64	100%	50%	0.32	0.41	0.58	0.00	155%	0.3	0.24
Cen. Afr. Rep.	431	0.06	8.87	12	0.13	70%	0.19	8.68	100%	50%	4.34	0.40	0.57	3.77	200%	0.0	0.26	
Tanzania	44	144	0.91	0.63	12	0.12	70%	0.17	0.46	100%	50%	0.23	0.43	0.61	0.00	138%	0.4	0.20
Guinea	45	90	0.70	0.77	12	0.09	70%	0.13	0.64	100%	50%	0.32	0.42	0.61	0.00	153%	0.3	0.21
Nepal	46	900	2.74	0.30	9	0.14	70%	0.20	0.10	100%	50%	0.05	0.43	0.62	0.00	109%	1.6	0.16
Peru	47	1,450	4.66	0.32	12	0.28	70%	0.40	-0.08	80%	50%	0.00	0.45	0.64	0.00	80%	3.3	0.28
Kenya	48	54	1.57	2.91	12	0.32	70%	0.46	2.45	100%	50%	1.22	0.46	0.65	0.57	200%	0.4	0.39
Guatemala	49	117	0.95	0.81	12	0.08	70%	0.12	0.69	100%	50%	0.34	0.30	0.42	0.00	182%	0.4	0.18
Senegal	50	94	1.35	1.44	12	0.30	70%	0.42	1.02	100%	50%	0.51	0.58	0.83	0.00	161%	0.6	0.40
Mali	51	78	1.44	1.84	12	0.25	70%	0.36	1.48	100%	50%	0.74	0.57	0.81	0.00	191%	0.6	0.40
Bolivia	52	110	1.12	1.02	12	0.27	70%	0.39	0.63	100%	50%	0.31	0.43	0.62	0.00	151%	0.5	0.33
Turkey	53	3,800	22.15	0.58	9	0.38	70%	0.54	0.04	100%	50%	0.02	0.49	0.70	0.00	103%	14.9	0.38
Zimbabwe	54	100	1.06	1.06	12	0.21	70%	0.30	0.75	100%	50%	0.38	0.32	0.46	0.00	182%	0.5	0.26
Namibia	55	4	0.16	3.94	12	0.40	70%	0.58	3.36	100%	50%	1.68	0.60	0.85	0.83	200%	0.0	0.50
Colombia	56	680	2.42	0.36	12	0.10	70%	0.15	0.21	100%	50%	0.10	0.21	0.29	0.00	136%	1.2	0.13
Zambia	57	30	1.17	3.90	12	0.07	70%	0.11	3.80	100%	50%	1.90	0.45	0.64	1.26	200%	0.2	0.26
Brazil	58	2,700	21.55	0.80	12	0.07	70%	0.10	0.70	100%	50%	0.35	0.34	0.49	0.00	171%	8.5	0.18
Venezuela	59	180	3.43	1.90	12	0.27	70%	0.38	1.52	100%	50%	0.76	0.40	0.57	0.19	200%	1.2	0.33
Algeria	60	384	2.69	0.70	10	0.19	70%	0.27	0.43	100%	50%	0.21	0.50	0.71	0.00	130%	1.3	0.26

		1990 data				First Season							Second season			Annual summary		
Country	ID	Net irrigated area (NIA)	Irr. WITH on NIA	Estimated depth months	Potential crop	NET	Effec. effi. assu. Base = 70%	Irr. req.	Surplus or deficit	Irr. intensity	% surplus loss between season 50%	Carry over to remaining season	NET	Irr. req.	Surplus or deficit	Ann irr intensity	Annual NET on gross irr. area Total	Depth
		(1,000 ha)	km³	m	Months	m	%	m	m	%	m	m	m	m	m	%	km³	m
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Australia	61	1,832	5.20	0.28	11	0.19	70%	0.27	0.02	100%	50%	0.01	0.43	0.62	0.00	101%	3.5	0.19
Cambodia	62	160	0.53	0.33	12	0.04	70%	0.05	0.28	100%	50%	0.14	0.45	0.64	0.00	122%	0.2	0.11
Gambia	63	1	0.02	2.44	12	0.10	70%	0.14	2.29	100%	50%	1.15	0.54	0.78	0.37	200%	0.0	0.32
Madagascar	64	1,000	20.39	2.04	12	0.09	60%	0.15	1.89	100%	40%	1.14	0.39	0.65	0.48	200%	4.8	0.24
Indonesia	65	4,410	13.34	0.30	12	0.03	60%	0.05	0.26	100%	50%	0.13	0.21	0.35	0.00	137%	4.6	0.08
Malaysia	66	335	6.46	1.93	12	0.04	60%	0.06	1.87	100%	50%	0.93	0.12	0.20	0.74	200%	0.5	0.08
Belize	67	2	0.02	0.81	12	0.00	70%	0.00	0.81	100%	50%	0.41	0.30	0.42	0.00	196%	0.0	0.15
Albania	68	423	0.27	0.06	8	0.20	70%	0.29	-0.22	22%	50%	0.00	0.35	0.49	0.00	22%	0.2	0.20
Morocco	69	1,258	9.78	0.78	11	0.21	70%	0.30	0.48	100%	50%	0.24	0.54	0.77	0.00	131%	4.7	0.29
Honduras	70	74	1.31	1.77	12	0.06	70%	0.08	1.69	100%	50%	0.85	0.35	0.49	0.35	200%	0.3	0.20
New Zealand	71	280	0.87	0.31	8	0.11	70%	0.16	0.15	100%	50%	0.07	0.24	0.34	0.00	122%	0.5	0.14
Myanmar	72	1,005	3.80	0.38	12	0.07	60%	0.11	0.26	100%	50%	0.13	0.44	0.73	0.00	118%	1.5	0.12
Mauritania	73	49	1.70	3.47	12	0.51	70%	0.72	2.75	100%	50%	1.37	0.77	1.09	0.28	200%	0.6	0.64
El Salvador	74	120	1.13	0.94	12	0.00	70%	0.00	0.94	100%	50%	0.47	0.39	0.55	0.00	185%	0.4	0.18
Lebanon	75	86	0.77	0.90	12	0.04	70%	0.06	0.84	100%	50%	0.42	0.70	1.00	0.00	142%	0.3	0.23
Chile	76	1,265	12.62	1.00	10	0.30	70%	0.42	0.57	100%	50%	0.29	0.54	0.77	0.00	137%	6.3	0.36

Country	ID	1990 data: Net irrigated area (NIA) (1,000 ha)	1990 data: Irr. WITH on NIA km³	1990 data: Estimated depth months m	1990 data: Potential crop Months	First Season: NET m	First Season: Effec. effi. assu. Base = 70% %	First Season: Irr. req. m	First Season: Surplus or deficit m	First Season: Irr. intensity %	First Season: % surplus loss between season 50% m	First Season: Carry over to remaining season m	Second season: NET m	Second season: Irr. req. m	Second season: Surplus or deficit m	Annual summary: Ann irr intensity %	Annual summary: Annual NET on gross irr. area Total km³	Annual summary: Annual NET on gross irr. area Depth m
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
GROUP	**4**																	
Canada	77	718	5.34	0.74	5	0.19	70%	0.27	0.47	100%	50%	0.24	0.00	0.00	0.24	100%	1.4	0.19
USA	78	20,900	196.29	0.94	9	0.36	70%	0.51	0.43	100%	50%	0.22	0.24	0.34	0.00	163%	105.9	0.31
Philippines	79	1,560	25.43	1.63	12	0.03	60%	0.06	1.57	100%	50%	0.79	0.25	0.42	0.37	200%	4.5	0.14
Jamaica	80	33	0.32	0.98	12	0.20	70%	0.29	0.69	100%	50%	0.35	0.47	0.67	0.00	152%	0.1	0.29
Switzerland	81	25	0.05	0.19	5	0.16	70%	0.22	-0.03	86%	50%	0.00	0.00	0.00	0.00	86%	0.0	0.16
Sweden	82	114	0.26	0.23	5	0.19	70%	0.27	-0.04	84%	50%	0.00	0.00	0.00	0.00	84%	0.2	0.19
Vietnam	83	1,840	21.54	1.17	12	0.05	60%	0.08	1.09	100%	50%	0.54	0.39	0.66	0.00	183%	6.9	0.21
Ecuador	84	290	5.37	1.85	12	0.30	70%	0.43	1.42	100%	50%	0.71	0.43	0.62	0.10	200%	2.1	0.37
Norway	85	97	0.17	0.17	3	0.09	70%	0.13	0.04	100%	50%	0.02	0.00	0.00	0.02	100%	0.1	0.09
Poland	86	100	1.35	1.35	5	0.20	70%	0.29	1.06	100%	50%	0.53	0.00	0.00	0.53	100%	0.2	0.20
Mexico	87	5,600	65.34	1.17	11	0.17	70%	0.24	0.92	100%	50%	0.46	0.48	0.69	0.00	167%	27.6	0.29
France	88	1,300	5.66	0.44	7	0.25	70%	0.36	0.08	100%	50%	0.04	0.00	0.00	0.04	100%	3.3	0.25
Argentina	89	1,680	24.78	1.48	11	0.23	70%	0.33	1.14	100%	50%	0.57	0.39	0.56	0.01	200%	10.5	0.31
Greece	90	1,195	3.37	0.28	12	0.16	70%	0.22	0.06	100%	50%	0.03	0.49	0.70	0.00	104%	2.1	0.17
Austria	91	4	0.21	5.27	5	0.11	70%	0.15	5.12	100%	50%	2.56	0.00	0.00	2.56	100%	0.0	0.11
Bangladesh	92	2,936	22.83	0.78	12	0.00	60%	0.00	0.78	100%	50%	0.39	0.38	0.64	0.00	161%	6.9	0.15
Belgium	93	0	0.37	N/S	6	0.10	70%	0.15	NS	NS	50%	NS	0.00	0.00	NS	NS	NS	NS
Costa Rica	94	118	2.29	1.94	12	0.00	70%	0.00	1.94	100%	50%	0.97	0.30	0.43	0.55	200%	0.4	0.15
Dom. Rep.	95	225	2.82	1.25	12	0.12	70%	0.18	1.08	100%	50%	0.54	0.28	0.40	0.14	200%	0.9	0.20

		1990 data				First Season							Second season			Annual summary		
Country	ID	Net irrigated area (NIA)	Irr. WITH on NIA	Estimated depth months	Potential crop	NET	Effec. effi. assu. Base = 70%	Irr. req.	Surplus or deficit	Irr. intensity	% surplus loss between season 50%	Carry over to remaining season	NET	Irr. req.	Surplus or deficit	Ann irr intensity	Annual NET on gross irr. area Total	Depth
		(1,000 ha)	km³	m	Months	m	%	m	m	%	m	m	m	m	m	%	km³	m
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
GROUP	**5**																	
South Korea	96	1,345	12.46	0.93	7	0.15	70%	0.22	0.71	100%	50%	0.36	0.00	0.00	0.36	100%	2.0	0.15
Denmark	97	430	0.51	0.12	5	0.21	70%	0.30	-0.18	40%	50%	0.00	0.00	0.00	0.00	40%	0.4	0.21
UK	98	164	2.47	1.51	5	0.13	70%	0.19	1.32	100%	50%	0.66	0.00	0.00	0.66	100%	0.2	0.13
North Korea	99	1,420	10.92	0.77	6	0.12	70%	0.17	0.60	100%	50%	0.30	0.00	0.00	0.30	100%	1.7	0.12
Panama	100	31	1.39	4.49	12	0.05	70%	0.07	4.42	100%	50%	2.21	0.27	0.38	1.83	200%	0.1	0.16
Sri Lanka	101	520	8.32	1.60	12	0.20	60%	0.34	1.26	100%	50%	0.63	0.49	0.81	0.00	178%	3.0	0.33
Romania	102	3,109	15.53	0.50	7	0.36	70%	0.51	-0.01	98%	50%	0.00	0.00	0.00	0.00	98%	10.9	0.36
Netherlands	103	555	2.63	0.47	5	0.18	70%	0.26	0.22	100%	50%	0.11	0.00	0.00	0.11	100%	1.0	0.18
Thailand	104	4,238	30.11	0.71	12	0.02	60%	0.03	0.68	100%	50%	0.34	0.48	0.80	0.00	143%	9.5	0.16
Spain	105	3,402	19.02	0.56	10	0.25	70%	0.35	0.20	100%	50%	0.10	0.43	0.62	0.00	117%	10.9	0.27
Cuba	106	900	8.21	0.91	12	0.24	70%	0.35	0.57	100%	50%	0.28	0.47	0.67	0.00	143%	4.0	0.31
Germany	107	482	8.73	1.81	5	0.19	70%	0.27	1.54	100%	50%	0.77	0.00	0.00	0.77	100%	0.9	0.19
Bulgaria	108	1,263	2.92	0.23	7	0.32	70%	0.45	-0.22	51%	50%	0.00	0.00	0.00	0.00	51%	2.0	0.32
Finland	109	64	0.94	1.47	3	0.16	70%	0.22	1.25	100%	50%	0.63	0.00	0.00	0.63	100%	0.1	0.16
Surinam	110	59	0.42	0.72	12	0.02	70%	0.03	0.69	100%	50%	0.34	0.14	0.20	0.14	200%	0.1	0.08
Portugal	111	630	3.50	0.56	12	0.09	70%	0.12	0.43	100%	50%	0.22	0.43	0.62	0.00	135%	1.5	0.18
Uruguay	112	120	0.68	0.57	12	0.04	70%	0.06	0.51	100%	50%	0.25	0.42	0.60	0.00	142%	0.3	0.15
Hungary	113	204	2.47	1.21	7	0.32	70%	0.46	0.75	100%	50%	0.38	0.00	0.00	0.38	100%	0.7	0.32
Japan	114	2,846	45.40	1.60	10	0.03	60%	0.05	1.55	100%	50%	0.77	0.03	0.05	0.73	200%	1.6	0.03
Guyana	115	130	1.43	1.10	12	0.05	70%	0.07	1.03	100%	50%	0.52	0.10	0.15	0.37	200%	0.2	0.07
Italy	116	2,711	33.17	1.22	11	0.20	70%	0.28	0.95	100%	50%	0.47	0.38	0.54	0.00	188%	14.3	0.28

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P O Box 2075, Colombo, Sri Lanka
Tel (94-1) 867404 • Fax (94-1) 866854 • E-mail IIMI@cgnet.com
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