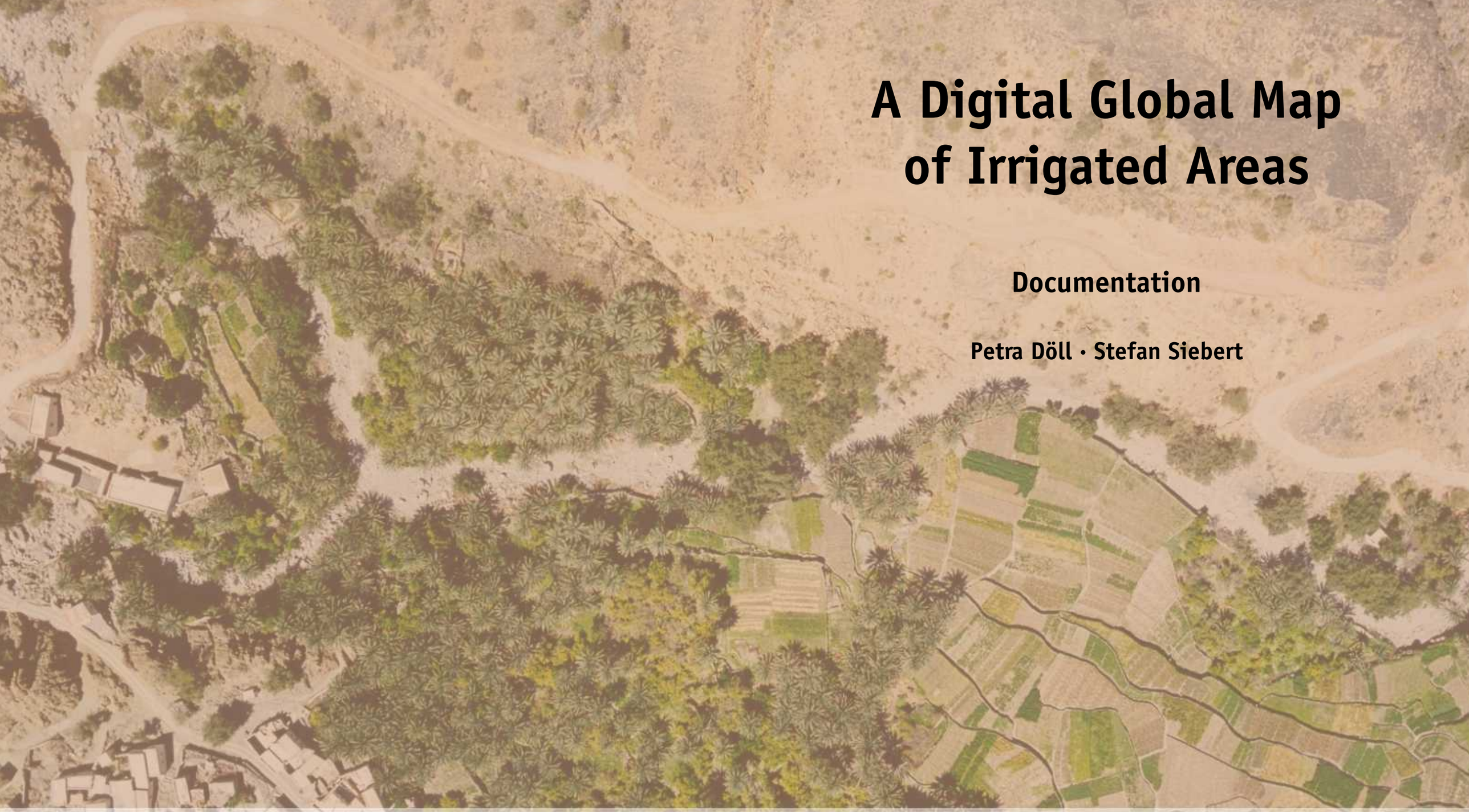


A Digital Global Map of Irrigated Areas

Documentation

Petra Döll · Stefan Siebert

University of Kassel
Center for Environmental Systems Research
Kurt-Wolters-Straße 3 · 34125 Kassel · Germany
Phone +49.561.804.3266 · Fax +49.561.804.3176
cesr@usf.uni-kassel.de · http://www.usf.uni-kassel.de

Cover photograph reproduced with kind permission of Prof. Buerkert,
Institute of Crop Science, University of Kassel

University of Kassel
Center for Environmental Systems Research

KASSEL WORLD WATER SERIES · REPORT No 1

A Digital Global Map of Irrigated Areas

Documentation

Petra Döll and Stefan Siebert

Center for Environmental Systems Research
University of Kassel

June 1999

The Kassel World Water Series:

Report No 1 – A Digital Global Map of Irrigated Areas
Report No 2 – World Water in 2025
Report No 3 – Water Use in Semi-Arid and Northeastern Brazil

A Digital Global Map of Irrigated Areas

Kassel World Water Series. Report Number 1

Report A9901, June 1999

Center for Environmental Systems Research,
University of Kassel, 34109 Kassel, Germany
Tel. 0561 804 3266, Fax. 0561 804 3176
Internet: http://www.usf.uni-kassel.de

Please cite as:
"Döll, P., Siebert, S. (1999): A Digital Global Map of Irrgated Areas. Report A9901, Center for Environmental Systems Research, University of Kassel, Kurt Wolters Strasse 3, 34109 Kassel, Germany."

Abstract

For the purpose of global modeling of water use and crop production, a digital global map of irrigated areas was developed. The map depicts the percentage of each 0.5° by 0.5° cell that was equipped for irrigation in 1995. It was derived by combining information from large-scale maps with outlines of irrigated areas (one or more countries per map), FAO data on total irrigated area per country in 1995 and national data on total irrigated area per county, drainage basin or federal state. This documentation describes the dataset, the data and map sources as well as the map generation, and it discusses the data uncertainty.

We plan to improve this map in the future. Therefore, comments, information and data that might contribute to this effort are highly welcome.

Table of Contents

1 Introduction

In many parts of the world, water and food scarcity are expected to restrict human development during the next century. Approximately 70% of the global water withdrawal and 85% of the consumptive water use is for irrigation, while, according to FAO, irrigated agriculture produces 40% of the world's food. Therefore, information on irrigation water use and irrigated crop production is highly relevant for assessing the possible impact of climate, demographic and socioeconomic change on the global water and food situation. The basis for such an assessment is to know the location and the extent of currently irrigated areas.

According to FAO, there is irrigation in 174 out of the 225 countries. FAO only provides data on the total irrigated area within each country (in their databases AQUASTAT and FAOSTAT), but does not give information on the location of the irrigated areas within each country. Large-scale irrigation maps (e.g. in Achtnich, 1980) show the outlines of areas in which irrigation in wide-spread. But only part of the area within such each "irrigated area" is actually equipped for irrigation (compare the "irrigated area" along the Po River in Italy in Fig. 2), such that for modeling purposes, it is necessary to determine what fraction of the "irrigated area" can be considered to be irrigated. Therefore, it is necessary to combine information on the (approximate) location of irrigated areas with information on the total irrigated area within a spatial unit, e.g. a country or a drainage basin.

To our knowledge, we have generated the first digital global map of irrigated areas that shows the spatial distribution of irrigated areas within each country. This required us to combine heterogeneous information from national and international sources. The resulting raster map indicates the fraction of each spatial mapping unit (0.5° by 0.5° cell) that was equipped for irrigation in 1995.

Using our water availability and use model WaterGAP, the map of irrigated areas will be applied to simulate irrigation water use on the global scale. In particular, we want to assess how irrigation water requirements will be affected by climate change. Besides, based on the 1995 map, scenarios of the future extension of irrigated areas and the corresponding change in irrigation water use will be computed. Besides, the map will serve as a basis for modeling irrigated crop production.

This documentation presents a concise description of the data set, which includes information on the data sources of the map (Chapter 2). It informs on the map generation (Chapter 3) and discusses the uncertainties of the data set (Chapter 4) as well as the need for improved information on irrigated areas (Chapter 5). In Appendix A, the global map of irrigated areas

map is shown in various sections, together with a map representation of its data sources. In Appendix B, detailed information on the data sources as well the applied total values of irrigated area per country, federal state or drainage basin is provided.

2 Description of Data Set

The digital global map of irrigated areas is a raster map with a resolution of 0.5° by 0.5°. For the whole land area of the globe (except Antarctica), the data set provides the percentage of each 0.5 ° by 0.5 ° cell area that was equipped for irrigation in 1995, the so-called irrigation density. The map is shown in Appendix A1. The area actually irrigated in 1995 was smaller, but is unknown for most countries. In the following, the areas equipped for irrigation will be called "irrigated areas". The global irrigated area on the map is 2,571,753 km^2. Of the irrigated areas, 67.8% are in Asia, 16.4% in America, 10.1% in Europe, 4.7% in Africa and 1.0% in Australia. Flood recession cropping areas and cultivated wetlands are not included in the map.

2.1 Data Format

The data set is available in ASCII format with 720 columns and 360 rows of real numbers. We provide two files:

1. In file irr_frac_05.asc, each number represents the irrigated area within each cell in percent of the total cell area.
2. In file irr_area_05.asc, each number represents the irrigated area within each cell expressed in km^2.

At the beginning of each file, there is a header appropriate for displaying the file with ARC/INFO or ArcView. The first data value in each file corresponds to the cell with the coordinates 179.5°-180° W and 89.5°-90° N. The no-data value of -9 is assigned to cells without land (and Antarctica). There are 66896 land cells. These land cells are based on the 5' by 5' land cells of the FAO Soil Map of the World (IMAGE 2.2 land mask: whenever there is a 5' land cell with a 0.5° cell, this 0.5° cell is a land cell).

2.2 Data Sources

The global map of irrigated areas is mainly based on maps showing the outline of the main irrigation areas within a country as well as FAO data on the total irrigated area in a country. Both types of information had to be combined as maps do not provide information on the irrigation density within the areas that are assigned to be irrigated. For most countries, the maps provided in Achtnich (1980) were used (comp. Appendix B1 for detailed information on the map source for each country). If available, data on total irrigated area per country were taken from the FAO database AQUASTAT (FAO, 1995, 1997a, 1997b), otherwise those of the FAO database FAOSTAT (http://www.fao.org) were used.

For the countries with the globally largest irrigated areas, more detailed information was taken into account (Table 1). India, China and the USA, are the three most important irrigating countries, having 47% of the global irrigated area. For India, a national map of irrigated areas and values of the irrigated areas in each federal state could be obtained, while for China and the USA, values of the irrigated area in each county were available. Out of the ten countries with the largest irrigated areas (66% of the global irrigated area), more detailed information was accessible for six (India, China, USA, Pakistan, Mexico and Thailand). Besides, for five additional countries, information on the irrigated area in each federal state or drainage basin could be taken into account (last five countries in Table 1). Chapter 3 describes how this information was used for map generation. Details on the data sources for each country can be found in Appendix B1.

Table 1: Countries, their irrigated areas and the type of data used to derive the distribution of irrigated areas within the countries.

Rank	Country	irrigated area [km^2]	type of data source
1	India	501,020	national irrigation map of 1989, and irrigated area per federal state
2	China	460,030	county data
3	USA	234,938	county data
4	Pakistan	172,000	national irrigation map of 1994, and irrigated area per country
5	Iran	72,640	irrigation map from Achtnich, and irrigated area per country
6	Mexico	61,000	irrigation map from Achtnich, and irrigated area per federal state
7	Russian Federation	53,600	irrigation map from Achtnich, and irrigated area per country
8	Thailand	50,040	irrigation map from Achtnich, and irrigated area per drainage basin
9	Indonesia	45,800	various irrigation maps, and irrigated area per country
10	Turkey	41,860	irrigation map from Achtnich, and irrigated area per country
12	Spain	35,270	irrigation map from Achtnich, and irrigated area per drainage basin
16	Brazil	31,690	irrigation map from Achtnich, and irrigated area per federal state
23	Australia	23,170	various irrigation maps, and irrigated area per federal state
33	South Korea	13,350	irrigation map from Achtnich, and irrigated area per federal state
75	Venezuela	1,850	irrigation map from Achtnich, and irrigated area per federal state
	World	2,571,753	---

Table 2 shows which fraction of the global irrigated area drawn on the map is based on which type of information. 44.4% of the global irrigated area was assigned based on an irrigation map plus the value of the irrigated area of the specific country, while 27.0% was based on county data and 24.6% based on an irrigation map plus the value of the irrigated area in the federal state. Only 0.6 % of the global irrigated area had to be assigned based on other types of maps, and only 0.1% based merely on information on the total irrigated area in the country. Appendix A2 provides a map representation of the type of information that was available for assigning irrigated areas.

Table 2: Irrigated area in global map according to the type of used information.

Type of information	number of countries	percent of global irrigated area
irrigation map plus value of irrigated area per country	136	44.41
irrigation map plus value of irrigated area per federal state	6	24.58
irrigation map plus value of irrigated area per drainage basin	2	3.32
other map (e.g. map of rice fields) plus value of irrigated area per country	9	0.57
value of irrigated area per country	19	0.10
county data	2	27.02

3 Map Generation

The generation of the digital map of irrigated areas included a variety of steps that depended on the type of data that was available for the respective country. First, the location of irrigated areas within each country was determined, mainly by digitizing irrigation maps. Then, the irrigation density was modeled on a 5' raster based on information on the total irrigated area within a spatial unit (e.g. a country), and finally the information was aggregated to a 0.5° raster. Fig. 1 provides an overview of the map generation process. The eight main steps depicted in Fig. 1 are described below (sections 3.1 to 3.8, as indicated in Fig. 1).

3.1 Digitization of Maps with Outlines of Irrigated Areas

For 144 countries, maps with outlines of irrigated areas were available. For 28 countries with irrigation, however, there were no irrigation maps. For 9 of these countries, the following type of maps was used to locate irrigated areas (compare also Appendix B1):

1. maps of rice production areas
2. maps of horticultural areas
3. maps of agricultural areas (in the case of Scandinavia)

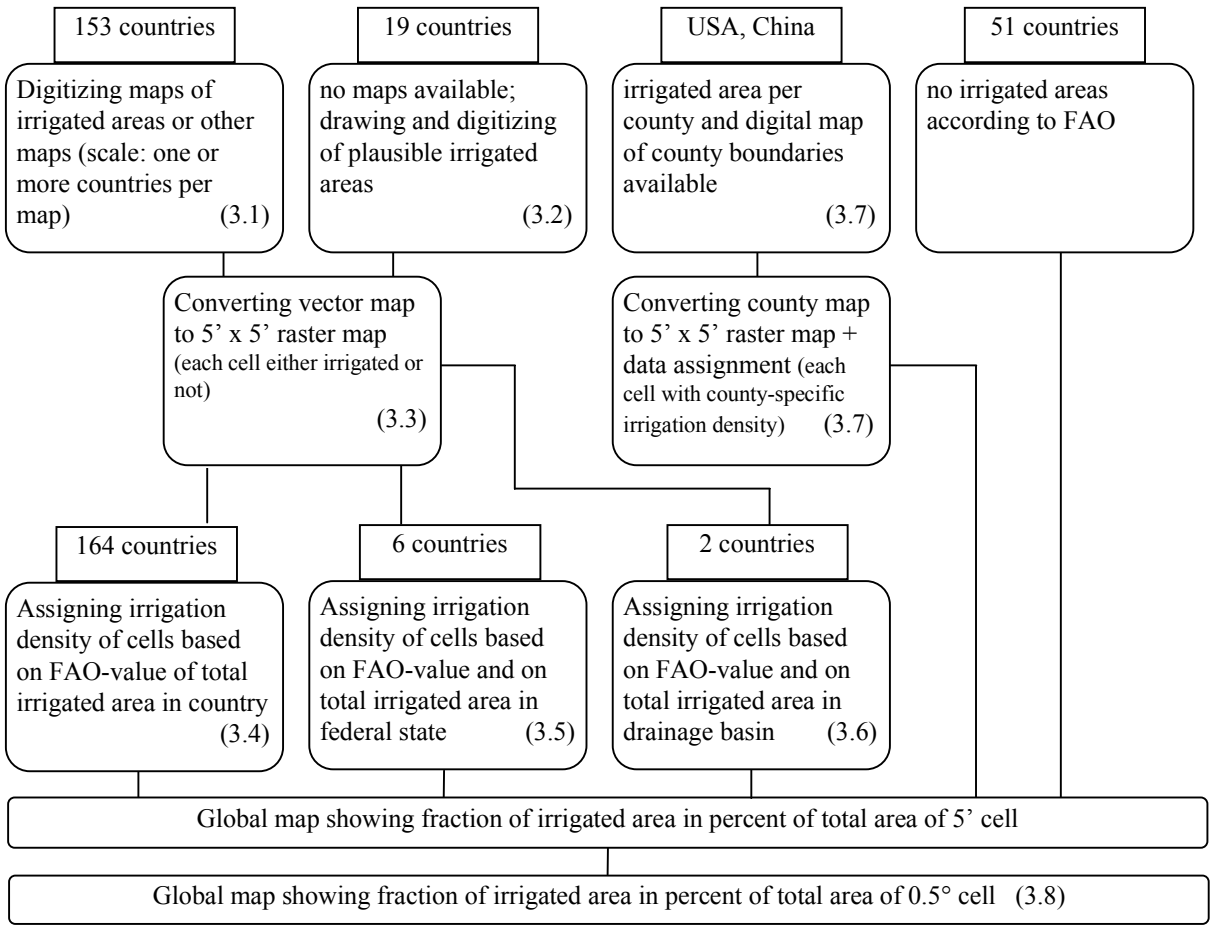


Fig. 1: Flow diagram describing the production of the digital global map of irrigated areas.

The irrigation maps as well as the other maps were digitized using the GIS software IDRISI 2. First, the maps were scanned and georeferenced. This was followed by a manual digitization of the irrigated areas on the screen.

3.1.1 Scanning

The available paper maps with outlines of irrigated areas (Appendix B1) were scanned. Depending on the map scale, resolutions between 150 and 600 dpi were chosen, such that the obtained pixel images had a resolution well above 5' (minute geographical longitude or latitude).

3.1.2 Georeferencing

Fig. 2 shows the scanned map of Italy from Achtnich (1980) together with the location of towns that were added for georeferencing. In the Achtnich maps, irrigated areas are shown in gray, and important towns are drawn as points; however, the names of the towns are not given in Achtnich. The scanned maps were georeferenced by using the geographic coordinates of

these towns, or, if provided, the points of intersection of meridians and parallels. Sometimes, additional towns had to be added to the maps if the given towns were not close enough to the irrigated areas. The geographic coordinates of towns were obtained from the data base of the GEOnet Names Server of the US NIMA (National Imagery and Mapping Agency, http://164.214.2.59/gns/html/index.html). Thus, each pixel was defined by a geographic coordinate.

Fig. 2: Scanned map of irrigated areas in Italy (Achtnich, 1980) together with towns used for georeferencing.

3.1.3 Manual digitization of outlines of irrigated areas

The outlines of the irrigated areas on the georeferenced scanned maps were manually redrawn on the screen using the mouse cursor. Thus, polygons of irrigated areas were produced. With the GIS software ARC/INFO, the polygons were combined to one global map.

3.2 Assignment of Plausible Locations for Irrigated Areas

For 19 countries with irrigated areas according to FAO, no further information on the location of irrigated areas within the country was available. It was either assumed that irrigation is equally spread over the country, or that the irrigated areas occur close to large rivers (Appendix B1).

3.3 Conversion to 5' by 5' Raster Maps

Using ARC/INFO, a raster of 5' geographical longitude and 5' geographical latitude was positioned over the polygon map derived from steps 3.1 and 3.2. For each of the 4320 x 2160 cells, it was determined whether it is assumed to be irrigated or not. If more than half of the cell area is covered, the 5' cell is assumed to be irrigated. As a result of the rasterizing process, some small irrigated areas disappeared.

3.4 Assignment of Irrigation Density Based on FAO-Values of Irrigated Area per Country

In reality, only very few 5' by 5' cells (corresponding to areas of 9.25 km by 9.25 km at the equator) are 100% irrigated. Therefore, if we assumed that the total area of each irrigated cell was irrigated, we would overestimate the actual irrigated area. For 164 countries, the irrigation density *d*, i.e. the fraction of a 5' cell area that is irrigated, was determined by comparing the sum of the areas of all irrigated cells $area_{irr\_cells}$ within a country (from step 3.3) to the total irrigated area $area_{irr\_total}$ of the country (FAO data). Thus, with an exception discussed below, the same irrigation density is assigned to all cells within a country. The irrigation density *d* is computed as

$$d(country) = 100 \frac{area_{irr\_total}(country)}{\sum area_{irr\_cells}(country)} \quad (1)$$

The cells were related to countries by converting the global "Administrative Unit Boundaries" map of ESRI to a raster map of 5' resolution.

When adding up the areas of all the irrigated 5' cells within a country, the sum was mostly much larger than the total irrigated area of the country $area_{irr\_total}$, as provided by FAO, and thus the irrigation density is less than 100%. After assigning an irrigation density according to Eq. 1, the total irrigated area within a country is equal to the FAO-value. In 13 countries, however, the FAO values were higher than the sum of the areas of the irrigated cells (Albania, Armenia, Bangladesh, El Salvador, France, North Korea, Kyrgyzstan, Moldova, Nepal, Romania, Russia, Slovakia, Tajikistan). In small countries like Albania, this could be due to the rasterizing process, while in the case of large countries, the irrigation maps must be assumed to be outdated. In the 13 countries, the irrigation density of all irrigated 5' cells was set to 100%, and the neighboring cells were assigned to be irrigated, too, with the appropriate irrigation density, such that Eq. 1 was fulfilled. Fig. 3 shows the result of step 3.5 for Southeast Europe. The irrigation densities within each country are identical (on the 5' by 5' raster), except in the case of Albania, where the irrigated area from the Achtnich map had to be extended; the Achtnich area is assigned an irrigation density of 100%, and the neighboring cells a lower irrigation density of 1.7%.

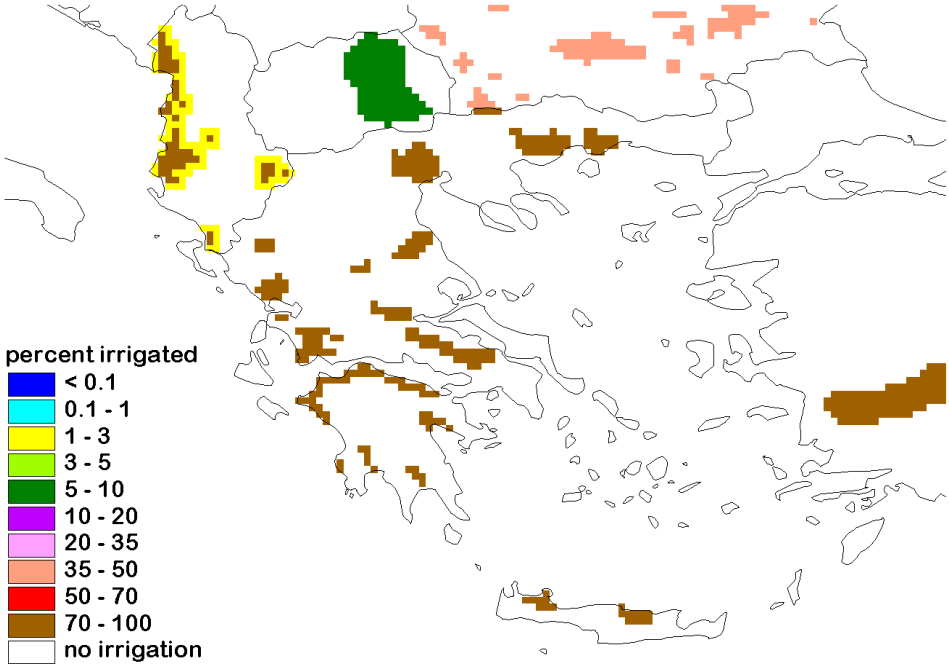


Fig. 3: Irrigation density of 5' by 5' cells in Southeast Europe, part of global 5' by 5' irrigation map.

3.5 Assignment of Irrigation Density Based on FAO-Values of Irrigated Area per Country and Irrigated Area per Federal State

In the case of six countries (India, Mexico, Brazil, Australia, South Korea and Venezuela), data on total irrigated area in each federal state of the country were available. In these countries, irrigation densities for each federal state were computed such that the sum of the irrigated area of all the cells within the federal state was equal to the total irrigated area within the federal state. The cells were related to the federal states by using the "Administrative Unit Boundaries" map of ESRI. Furthermore, the irrigation areas and thus the irrigation densities within each of the federal states were adjusted such that the total irrigated area within each of the six countries was equal to the FAO country value for 1995 as given in Appendix B1 ("adjusted state values"). Table 3 provides an overview of the methods that were used to harmonize the irrigation map information and the data on irrigated area in each federal state. Eq. 2 shows how the irrigation density within each federal state was computed in case 1 of Table 3.

$$d(fed.state, country) = 100 \frac{area_{irr\_total}(fed.state)}{\sum area_{irr\_cells}(fed.state)} \frac{area_{irr\_total}(country)}{\sum area_{irr\_total}(fed.state)} \quad (2)$$

Table 3: Methodology for assigning irrigation densities based on data of total irrigated area within a federal state (on 5' raster map).

case	condition	method
1	sum of the cell area of all irrigated cells is larger than the adjusted state value	irrigation density of all irrigated cells is computed according to Eq. 2
2	sum of the cell area of all irrigated cells is larger than 0 but smaller than the adjusted state value	irrigation density of all irrigated cells is set equal to 100%. Irrigation is extended to neighboring cells, which obtain adjusted irrigation densities such that the sum of all irrigated areas is equal to the state value
3	no irrigated cells (based on irrigation maps) but state value larger than 0	homogeneous distribution of the total irrigated area of the state to all cells within the state

3.5.1 India

Data of the total irrigated area in the 31 federal states of India 1992-93 were provided by the Central Board for Irrigation and Power of India (A.R.G. Rao, personal communication, 1998; Appendix B2). The sum of all irrigated areas in the federal states differs from the FAO country value for 1995 by less then 0.01%. Different from other countries, a map of irrigated areas was available from the same institution that showed existing and planned irrigated area in India 1989. Both the existing and planned irrigated areas were digitized and rasterized. Therefore, methods different from those given in Table 3 were used to generate the irrigation density of the 5' cells belonging to India. These methods are listed in
Table 4.

3.5.2 Mexico

Data of the total irrigated area in the 32 federal states of Mexico 1994 were provided by the FIRCO of Mexico (Julio Lorda, personal communication, 1998; Appendix B3). The FAO-value for the irrigated area in Mexico 1995 is 2.2% higher than the sum of the irrigated areas in all federal states. In 15 federal states, the Achtnich map did not indicate any irrigation, although according to FIRCO, 15.2% of the total irrigated area of Mexico was located in these states 1994. In these 15 states, the irrigated areas were distributed equally over all 5' cells within the respective state (Appendix B3).

3.5.3 Brazil

Data of the total irrigated area in the 27 federal states of Brazil 1996 were provided by the Ministry of Environment, Water Resources and Amazon (F. A. Rodriguez, personal communication, 1998; Appendix B4). The FAO-value for the irrigated area in Brazil 1995 is 20.5% higher than the sum of the irrigated areas in all federal states. This is due to the fact that the state values refer to the areas actually irrigated in 1995, while the FAO-value refers to

the areas equipped for irrigation. In 10 federal states, the Achtnich map did not indicate any irrigation. In 6 of the states, the irrigated areas were distributed equally over all 5' cells within

Table 4: Methodology of assigning irrigation densities in India (on 5' raster map). The total irrigated area within a federal state is always equal to the state values provided by the Central Board of Irrigation and Power (Appendix B2).

condition	**method**	**federal states**
state without irrigation	all cells get an irrigation density of 0	Andaman and Nicobar Islands
total area of cells with existing irrigation is larger than state value	irrigation density of cells with existing irrigation is adjusted according to Eq. 2 (to values lower than 100%)	Delhi, Haryana, Karnataka, Pondicherry, Punjab
total area of cells with existing irrigation is smaller than state value, total area of cells with existing and planned irrigation larger than state value	irrigation density of cells with existing irrigation is set to 100%, while the irrigation density of cells with planned irrigation is adjusted	Andhra Pradesh, Bihar, Dadra and Nagar Haveli, Goa, Kerala, Maharashtra, Madhya Pradesh, Orissa, Tamil Nadu, West Bengal
no clear distinction of existing and planned irrigated areas in the map	the irrigation density of cells with existing and planned irrigation is adjusted to the same value	Uttar Pradesh
the sum of the areas of cells with existing and planned irrigation is smaller than the state value	irrigation density of cells with existing or planned irrigation is set to 100%. The other irrigated area are distributed equally over all the other cells in the federal state. In the case of the arid Rajahstan, the other irrigated areas are distributed only in neighboring cells.	Arunachal Pradesh, Assam, Chandigarh, Daman & Diu, Gujarat, Himachal Pradesh, Jammu & Kashmir, Meghalaya, Manipur, Mizoram, Nagaland, Sikkim, Tripura; Rajasthan

the respective state. For the states of Acre, Amazonas, Rondonia and Roraima, however, which have very small irrigated areas, 1-2 cells in each state were arbitrarily chosen to be irrigated.

3.5.4 Australia

In addition to the Achtnich map, a map of the Australian Government on irrigated areas in the southern Murray-Darling Basin from 1998 was used to locate irrigated areas. Data of the total irrigated area in the 8 federal states of Australia 1983/84 were taken from Stein (1986) (Appendix B5). The FAO-value for the irrigated area in Australia 1995 is 42.5% higher than the sum of the irrigated areas in all federal states. According to the Australian Department of Primary Industries and Energy (http://www.dpie.gov.au), 70% of the area irrigated in Australia in 1994 is located in the Murray-Darling Basin. The projection of the irrigated areas per federal state to 1995 was made such that this information was taken into account.

3.5.5 South Korea

Data of the total irrigated area in the 14 federal states of South Korea 1994 were taken from the Yearbook on Land and Water Development Statistics 1995 (provided by Yung-Duk Lim, personal communication, 1998; Appendix B6). The FAO-value for the irrigated area in South Korea 1995 is 60.5% higher than the sum of the irrigated areas in all federal states. The reason for this discrepancy is unknown. Like in Brazil, the national data might relate to the areas that were actually irrigated, while the FAO value refers to the areas equipped for irrigation. In 3 federal states, the Achtnich map did not indicate any irrigation although in 1994 6.4% of the total irrigated area of South Korea was located in these states. In these 3 states, the irrigated areas were distributed equally over all 5' cells within the respective state (Appendix B6).

3.5.6 Venezuela

Data of the total irrigated area in the 24 federal states of Venezuela 1984 were provided by Gonzalo Freites of the Hydraulic Department of the UCV, Caracas (personal communication, 1998; Appendix B7). However, the provided values might underestimate the actual irrigation as small private irrigation was not taken into account. The FAO-value for the irrigated area in Venezuela 1995 is 14.0% higher than the sum of the irrigated areas in all federal states. In 3 federal states, the Achtnich map did not indicate any irrigation (only 2.6% of the total irrigated area of Venezuela according to Freites). In the state of Portuguesa, the mapped irrigated areas had to be extended (Appendix B7).

3.6 Assignment of Irrigation Density Based on FAO-Values of Irrigated Area per Country and Irrigated Area per Drainage Basin

The methodology for assigning irrigation densities in Thailand and Spain, the two countries for which total irrigated areas in drainage basins were available, is rather similar to step 3.5 (Table 3 and Eq. 2, with "federal state" replaced by "drainage basin"). The cells were related to the drainage basins by first digitizing the maps with the drainage basin boundaries that were provided by the institutions that also provided the data on irrigated area per drainage basin, and then converting them to 5' raster maps.

3.6.1 Thailand

Data of the total irrigated area in 25 drainage basins were provided by the Royal Irrigation Department of Thailand (Charoon Kamoiratana, personal communication, 1998), and were first published in 1993 (Appendix B8). The FAO-value for the irrigated area in Thailand 1995 is 3.5% higher than the sum of the irrigated areas in all drainage basins. In 4 drainage basins, the Achtnich map did not indicate any irrigation. In these basins, the irrigated area (as given by the Royal Irrigation Department) was distributed equally over all 5' cells within the basin (Appendix B8).

3.6.2 Spain

Data of the total irrigated area in 11 drainage basins were provided by the Spanish National Committee of the International Commission on Irrigation and Drainage (José Hernandez Urrutia, personal communication, 1998; Appendix B9). The FAO-value for the irrigated area in Spain 1995 is 5.5% higher than the sum of the irrigated areas in all drainage basins. Based on information in Popp and Rother (1993), the irrigated areas in the Guadalquivir basin as indicated by Achtnich were extended manually. In 2 drainage basins (the Balearic and Canary Islands), the Achtnich map did not indicate any irrigation. In these basins, the irrigated area was distributed equally over all 5' cells within the basin (Appendix B9).

3.7 Assignment of Irrigation Density using County Values of Irrigated Area

For both China and the USA, lists of irrigated area per county as well as digital maps of the county boundaries were available. This information was used to determine the irrigation densities on the 5' raster map. First, the digital county maps (polygon maps) were converted to 5' raster maps, such that each cell belonged to a county. The irrigated area of the county was then equally distributed among all cells belonging to the county. No corrections with respect to the FAO country values were made.

3.7.1 China

Data on the irrigated area in 2410 out of the 2435 counties in China were available for the year 1990 from the Statistics Publishing House (1991); the digital county map was provided by CIESIN (1996). For the 25 counties without data, we assume that there is no irrigation. In 7 mostly small counties (10 5' cells), irrigation densities of more than 100% percent had to be assigned due to the rasterizing which had lead to too small county areas. However, with the aggregation to 0.5° cells, these errors are assumed to vanish. On the map, there are 460030 km^2 of irrigated area in China, while the FAO gives a value of 498579 km^2 for 1995. Fig. 4 shows the irrigation density of the 5' by 5' cells in China.

3.7.2 USA

Data on the irrigated area in the 3146 counties of the USA were available for the year 1995 from the USGS (1995). The digital county map was provided by USGS (1998). For the Hawaiian Islands, county boundaries were not available; therefore, the irrigated areas given in Achtnich (1980) were used, and a constant irrigation density was assigned to all irrigated cells based on the total irrigated area on the Hawaiian Islands (Appendix B1). The very small irrigated areas in Alaska were neglected. On the map, there are 234938 km^2 of irrigated area in the USA, while the FAO gives a value of only 212000 km^2 for 1995. Fig. 5 shows the irrigation density of the 5' by 5' cells in the USA.

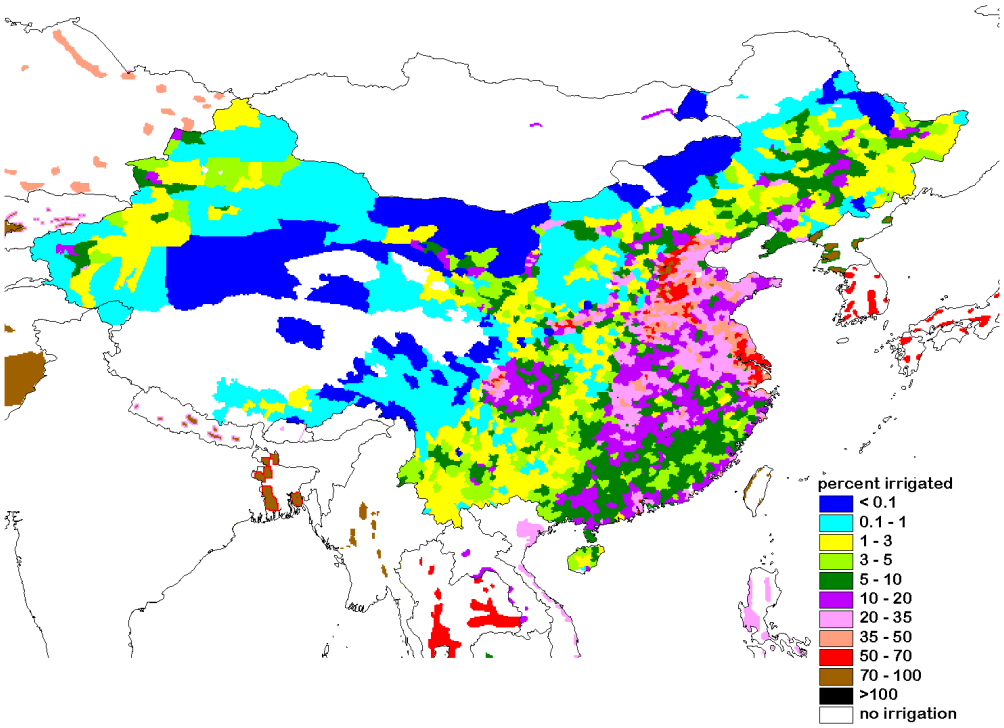


Fig. 4: Irrigation density of 5' by 5' cells in China, based on data on irrigated area in each county in China; part of global 5' by 5' irrigation map.

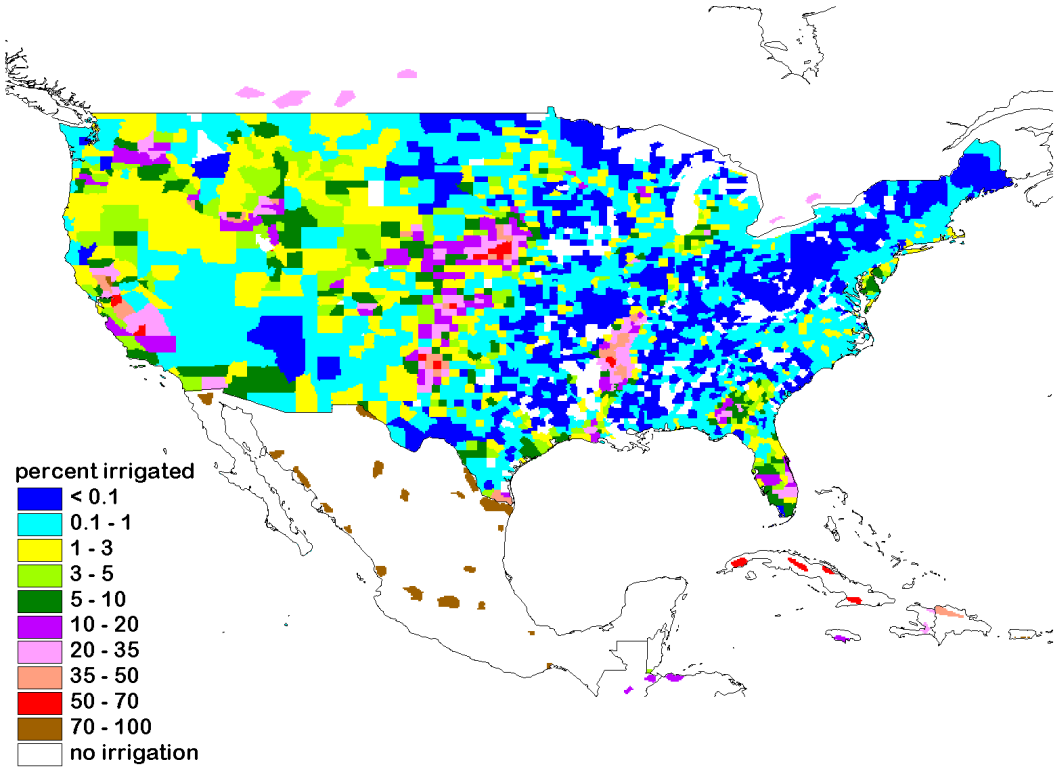


Fig. 5: Irrigation density of 5' by 5' cells in the USA, based on data on irrigated area in each county in the USA; part of global 5' by 5' irrigation map.

3.8 Conversion of the 5' by 5' Raster Map to the 0.5° by 0.5° Digital Global Map of Irrigated Areas

The 5' by 5' raster map was aggregated to a 0.5° by 0.5° grid. The aggregation was done by summing up all the irrigated areas within the 36 5' cells within each 0.5° cell. A comparison of

Fig. 6 and Fig. 7 gives an impression of the impact of the different raster sizes.

4 Discussion

The global map of irrigated areas shows all the areas that, in 1995, were equipped for irrigation. In general, these areas are larger than those that were actually irrigated in 1995. In Africa, about 18% of the area equipped for irrigation is not irrigated (FAO, 1995), and in the Near East, it is 16% (FAO, 1997a). Of course, these numbers will vary from year to year, but no pertinent information is available. For individual countries, the values range from 0% (e.g. Egypt and Kenya) to 90% (Benin). For example, in Brazil, 19% of the area equipped for irrigation was not irrigated in 1995 (Griesinger, Ministry of Environment, Water Resources and Amazon, Brazil, personal communication, 1998).

The quality of the generated global map of irrigated areas depends on the quality of used base data and the errors that occurred during the map generation. The latter are mainly caused by

- the rasterizing process (e.g. irrigated areas which covered less than 50% of a 5' cell disappeared)
- the positioning of irrigated areas in countries without irrigation maps
- the assumption that the irrigation density within a spatial unit (e.g. a country) is constant

The uncertainty resulting from errors in the map generation process is considered to be lower than that resulting from the (low) quality of the used input data, in particular

- the total area equipped for irrigation per country as provided by FAO
- for China and USA, the national compilations of irrigated areas per county.
- the maps of Achtnich (1980) and others

The quality of these data is discussed below.

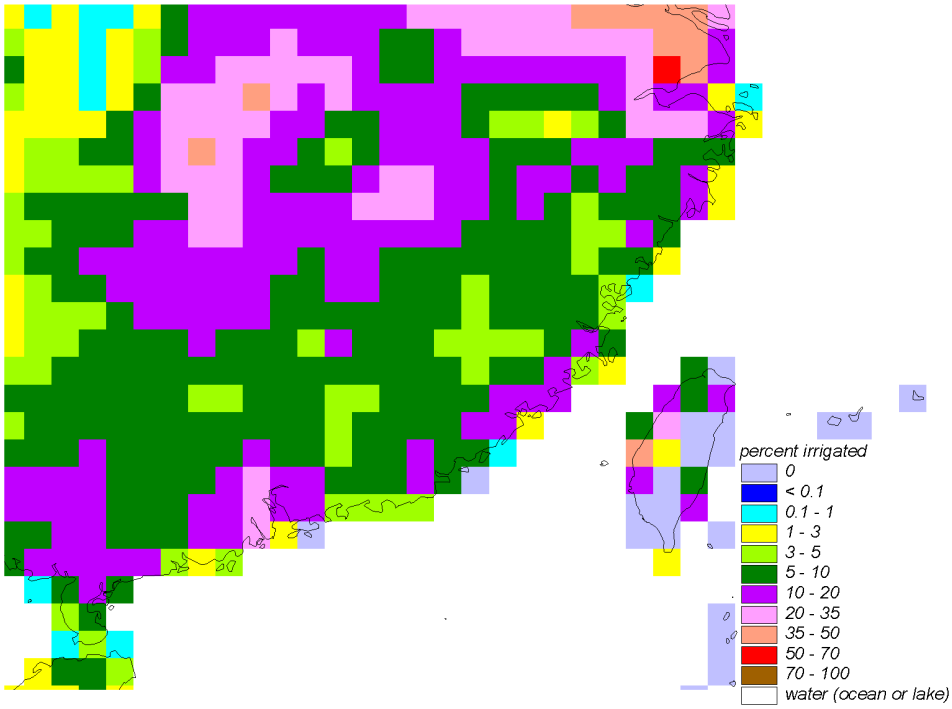


Fig. 6: Irrigation map with a resolution of 5' by 5' (Southeast China and Taiwan).

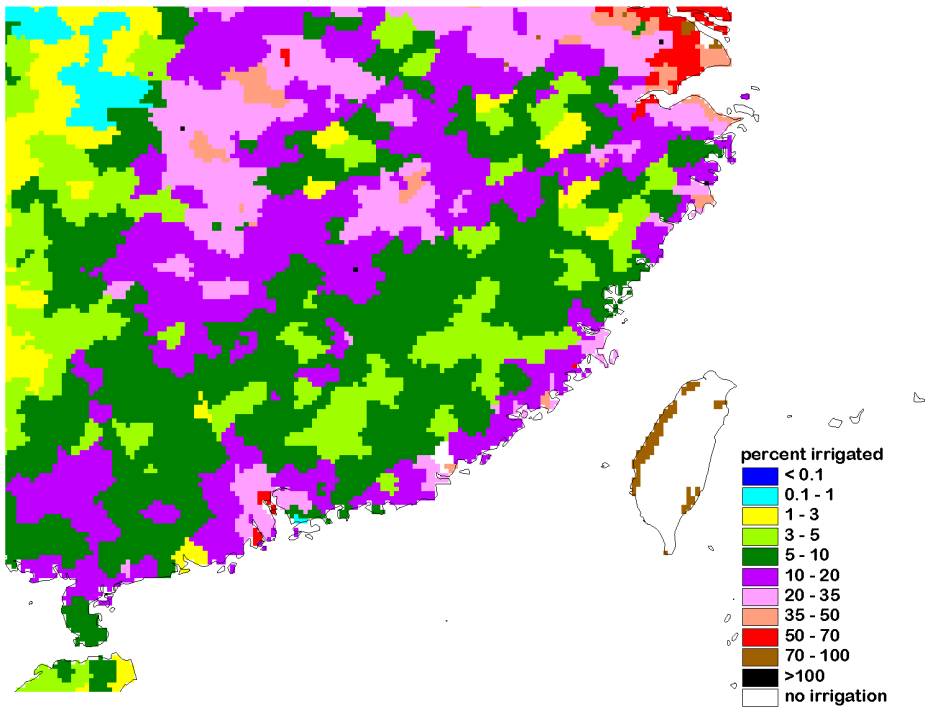


Fig. 7: Irrigation map with a resolution of 0.5° by 0.5° (Southeast China and Taiwan), generated by aggregating the 5' map (Fig.6).

The reliability of the FAO data on total irrigated area per country varies greatly (comp. e.g. FAO, 1995). Most countries who report to the FAO do not have a register of irrigated areas or good national statistics. It seems that often little knowledge about the location of small-scale private irrigation exists, and that sometimes these irrigated areas are not taken into account by the national statistics. Besides, there exist discrepancies between country values provided by FAOSTAT and AQUASTAT, respectively. According to Marc Faures from FAO (personal communication, 1998), AQUASTAT values should be taken if the long time series provided in FAOSTAT are not required. Therefore, values from AQUASTAT were selected if available. As an example, for Azerbaijan, FAOSTAT gives a value of 10000 km^2 for 1995, while AQUASTAT lists 14531 km^2 for the same year. Although the data are listed as representative for 1995 (in the case of FAOSTAT data) or close to 1995 (in the case of AQUASTAT), some values are only estimates that are derived from much older data (e.g. Angola from 1974).

One should assume that the best available data are the data on irrigated area per county, for China and the USA. However, the International Water Management Institute considers the quality of the Chinese county data to be only mediocre (Ian Makin, IWMI, personal communication).

A large part of the used irrigation maps are from Achtnich (1980), who mostly modified other authors' maps from the years 1963 to 1970. According to FAO, in 1970, the global irrigated areas only amounted to 65%, and in 1980, to 81% of the area irrigated in 1995. Therefore, more recently implemented irrigation locations are not represented by maps, and the mapped irrigation in 1995 is therefore probably too dense and localized. In addition, when the polygon map of irrigated areas is rasterized with a resolution of 5' by 5', irrigated areas with less approx. 50 km^2 disappear as they are smaller than half a 5' cell.

In order to obtain a coarse estimate of the applicability of Achtnich's maps for today's irrigation, the Achtnich (1980) maps for USA, China and India were compared to the newer information that was used to derive the global map of irrigated areas (USA: county data of 1995, China: county data of 1990, India: map of 1989 + federal state data of 1992/93). Besides, a comparison to the county data for the USA and China gives an idea of the concentration of irrigated areas which occurs when outlines of irrigated areas are drawn at a rather large scale. The correspondence between the Achtnich maps and the digital map is rather good. All the areas that are shown as irrigated by Achtnich are areas with a high irrigation density in the digital map, and most of the areas with an irrigation density greater than 10% in the digital map are represented in the Achtnich maps. As an example, please

compare Fig. 8 , which shows the irrigated areas in North America according to Achtnich (1980), to Fig. 9 , which, for the USA, represents detailed information on the irrigated area in

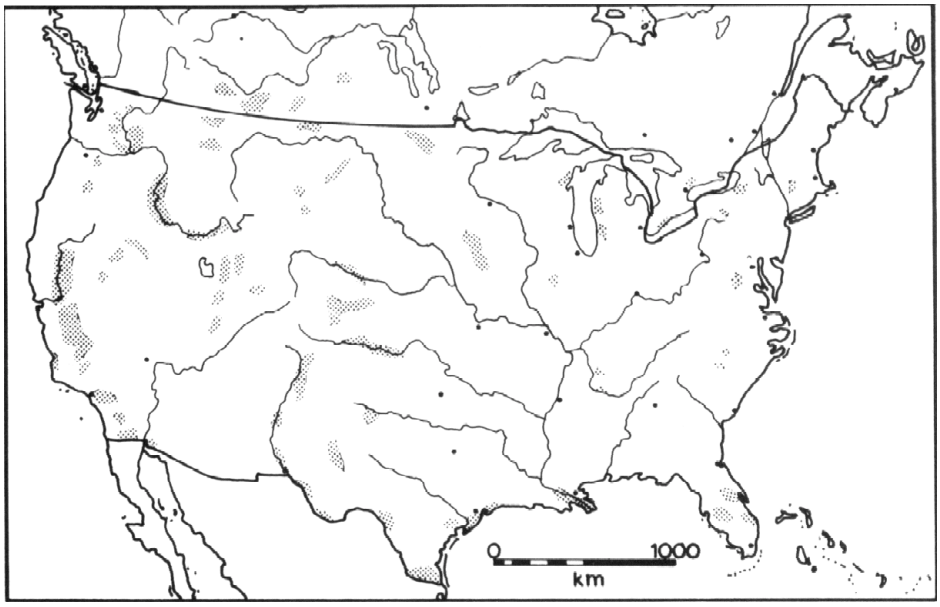


Fig. 8: Irrigated areas in North America, scanned from Achtnich (1980).

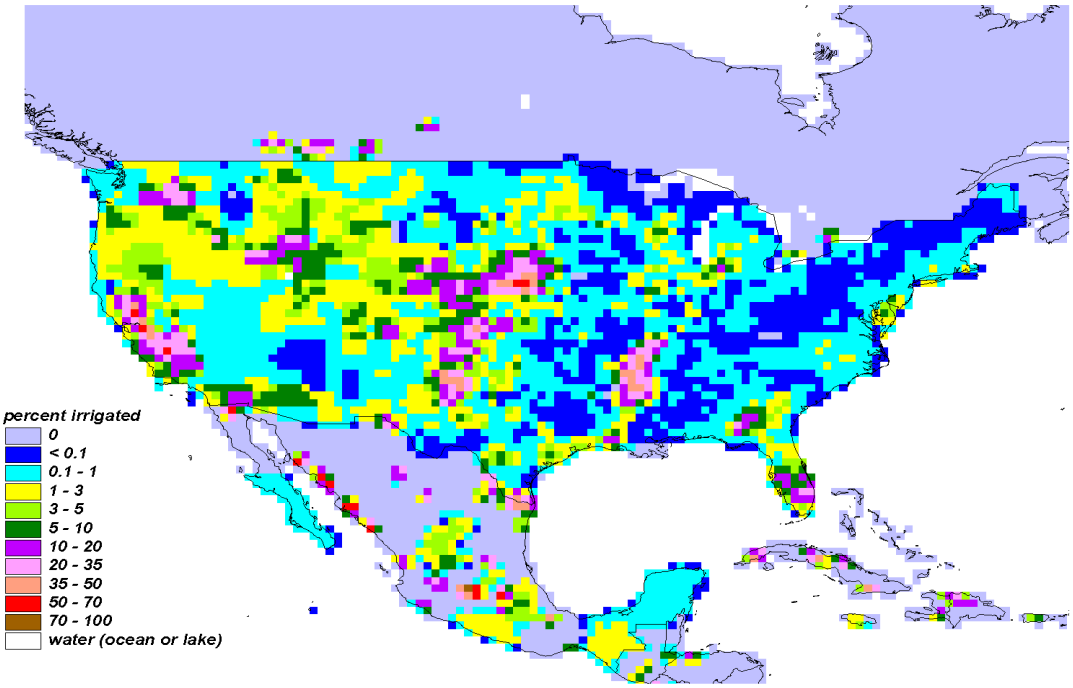


Fig. 9: Irrigation in North America according to digital global map of irrigated areas, with irrigation in USA based on detailed county data.

each U.S. county. Notwithstanding the general good correspondence, the large irrigated area in the Southeast of the USA (Arkansas and Missouri) would be completely missing if we had to rely on the Achtnich map. One reason for that might be that in 1970, the USA had only 75% of the irrigated area in 1995. What is obvious from the comparison of the USA maps is the strong concentration of irrigated areas that occurs when a map with outlines of the (main) irrigated areas is used to derive the spatial distribution of irrigated areas within a country. In reality, irrigation is more scattered.

Due to the described uncertainties of the input data and the inaccuracies resulting from the map generation process, it is appropriate to aggregate the 5' map to a map with a resolution of 0.5° by 0.5°. Besides, spatially explicit global modeling is often done on a 0.5° grid.

In summary, the information provided by the global map of irrigated areas is still rather uncertain. This is mainly due to the quality of the data that served as input to the map. However, at the moment, it appears to be the best information available. In our opinion, the presented dataset is appropriate for use in global and continental assessments.

5 Further Improvements

In the future, we intend to improve the global map of irrigated areas by including more information on the distribution of irrigated areas within countries as provided by national agencies or researchers. For example, for Brazil, data on irrigated area in each county is available from the agricultural census 1995/96. For Turkey, a printed list of irrigated areas that are connected to reservoirs is available, but the location of the reservoirs is provided only on a very coarse map. In addition, we have obtained more information on the distribution of irrigation in Germany and Canada.

We would be very thankful for receiving information on the distribution of irrigated areas within the countries for which we have obtained such information. We also appreciate comments on the quality of the presented map as well as suggestions for improvement.

For most countries, improved national data on the location and extent of irrigated areas are highly desirable. These could be acquired by implementing an irrigation register and by locating irrigated areas with the help of remote sensing. In view of the increasing global problem of water scarcity, international efforts to achieve a better knowledge about current irrigation appear to be worthwhile.

6 References

Achtnich, W. (1980): Bewässerungslandbau, Verlag Eugen Ulmer, Stuttgart.

Central Board of Irrigation and Power (1994): Irrigation Map of India 1994, New Delhi.

Central Board of Irrigation and Power (1989): Irrigation Atlas of India, Vol. II, New Delhi.

Consortium for International Earth Science Information Network (CIESIN) (1996): China Administrative Regions GIS Data 1:1M, County Level, 1990.

Environmental Systems Research Institute (ESRI) (1996): CD-Rom ESRI - Data and Maps, Vol. I.

FAO (1997a): Irrigation in the Near East region in figures. Water Report 9, FAO/AGL, Rome, 281 pp.

FAO (1997b): Irrigation in the countries of the former Soviet Union in figures. Water Report 15, FAO/AGL, Rome, 226 pp.

FAO (1995): Irrigation in Africa in figures. Water Report 7, FAO/AGL, Rome, 336 pp.

FAO (1987): Irrigated areas in Africa, FAO, Rome.

Framji, K. K., Garg, B. C., Luthra, S. D. L.(1981-83): Irrigation and Drainage in the World, Vol. 1-3, International Commission on Irrigation and Drainage, New Delhi.

Government of Pakistan, Ministry of Water & Power (1994): Irrigation System of Pakistan.

International Institute for Land Reclamation and Improvement (ILRI) (1996): Annual Report 1996, Wageningen.

Popp, H., Rother K. (Hrsg.) (1993): Die Bewässerungsgebiete im Mittelmeerraum, Passavia Universitätsverlag Passau.

Schneider, M. B. (1990): Bewässerungslandwirtschaft in Namibia und ihre Grundlagen in der Kolonialzeit, Namibia Wissenschaftliche Gesellschaft (Hrsg.), Windhoek.

Statistics Publishing House (1991): China County-Level Data on Population (Census) and Agriculture 1990.

Statistisches Bundesamt: Länderbericht Hong Kong 1995, Länderbericht Slowenien 1995, Länderbericht Katar 1994, Länderbericht Schweden 1994, Länderbericht Taiwan 1994, Länderbericht Weißrußland 1994, Länderbericht Belgien 1993, Länderbericht Dänemark 1993, Länderbericht Finnland 1993, Länderbericht Indonesien 1993, Länderbericht Niederlande, Länderbericht Brunei 1992, Länderbericht Bahrein 1991, Länderbericht Norwegen 1991.

Stein, T. M. (1986): Verbreitung der Beregnung in den Bundesstaaten Australiens, Gesamthochschule Kassel, Witzenhausen.

USGS (1995): National water-use data 1995.

USGS (1998): Counties and county equivalents in the conterminous United States 1: 2,000,000, Version 2.1 (http://water.usgs.gov)

Appendix A1: Digital global map of irrigated areas 1995

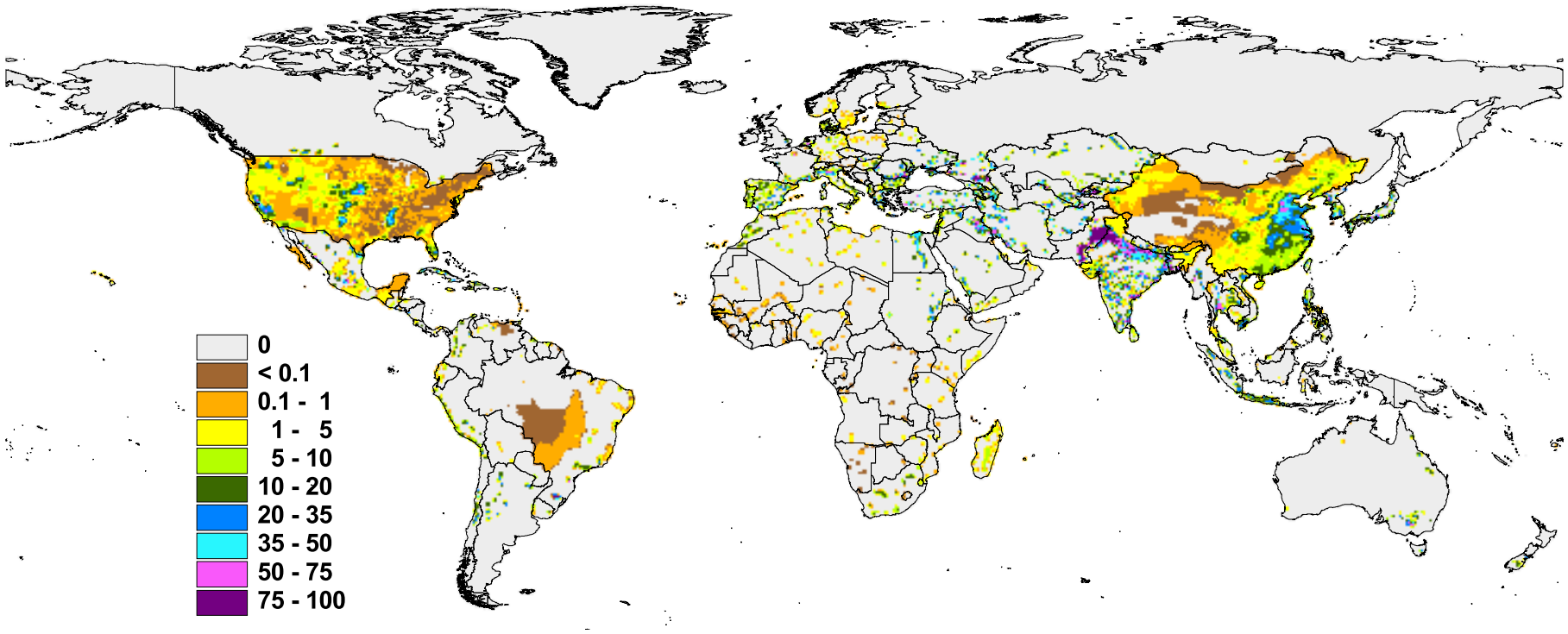


Fig. A1.1: Digital global map of irrigated areas. Map shows the fraction of the area of each 0.5° by 0.5° cell that was equipped for irrigation in 1995.

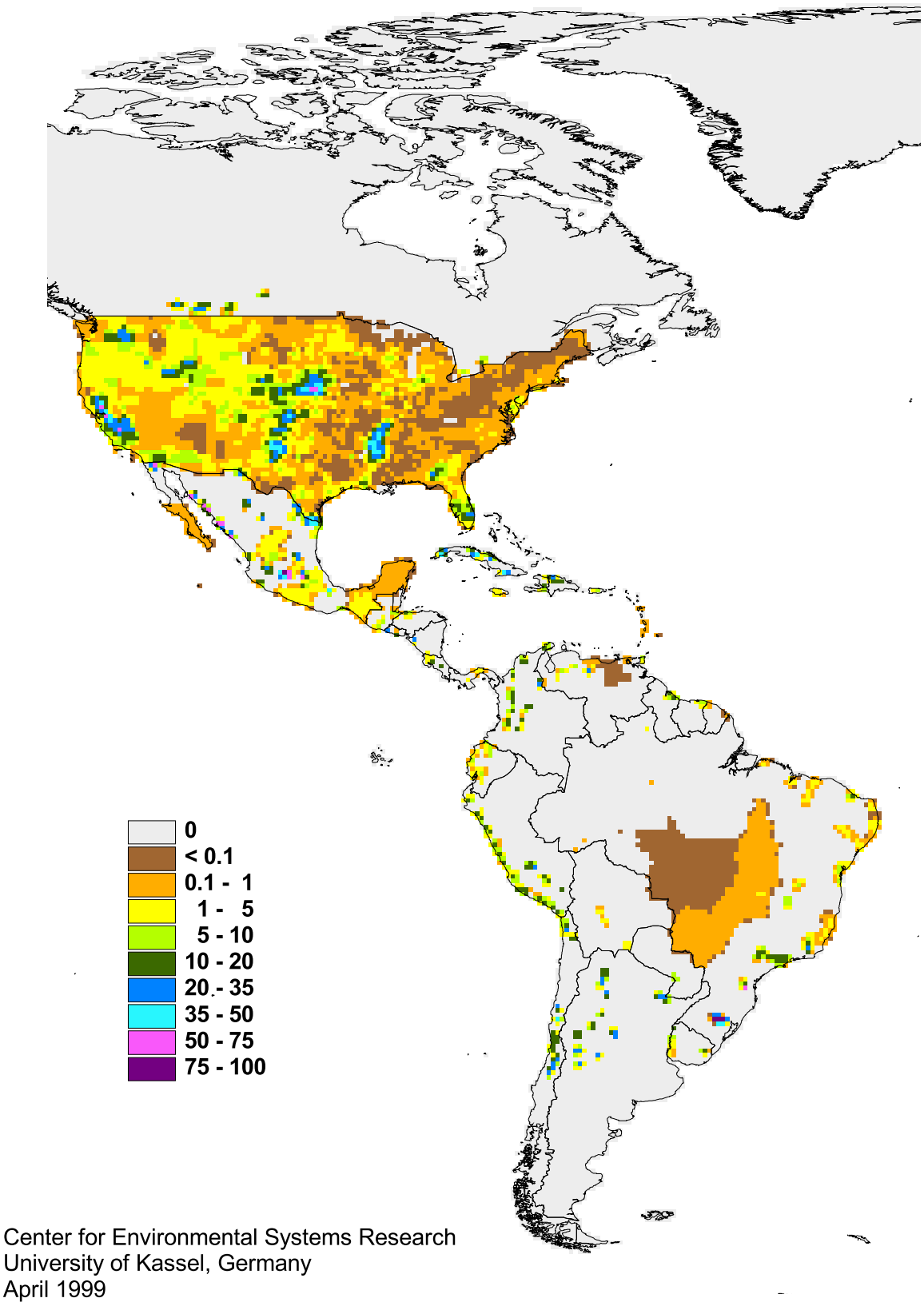


Fig. A1.2: Irrigated areas in America; section of the global map of irrigated areas. Map shows the fraction of the area of each 0.5° by 0.5° cell that was equipped for irrigation in 1995.

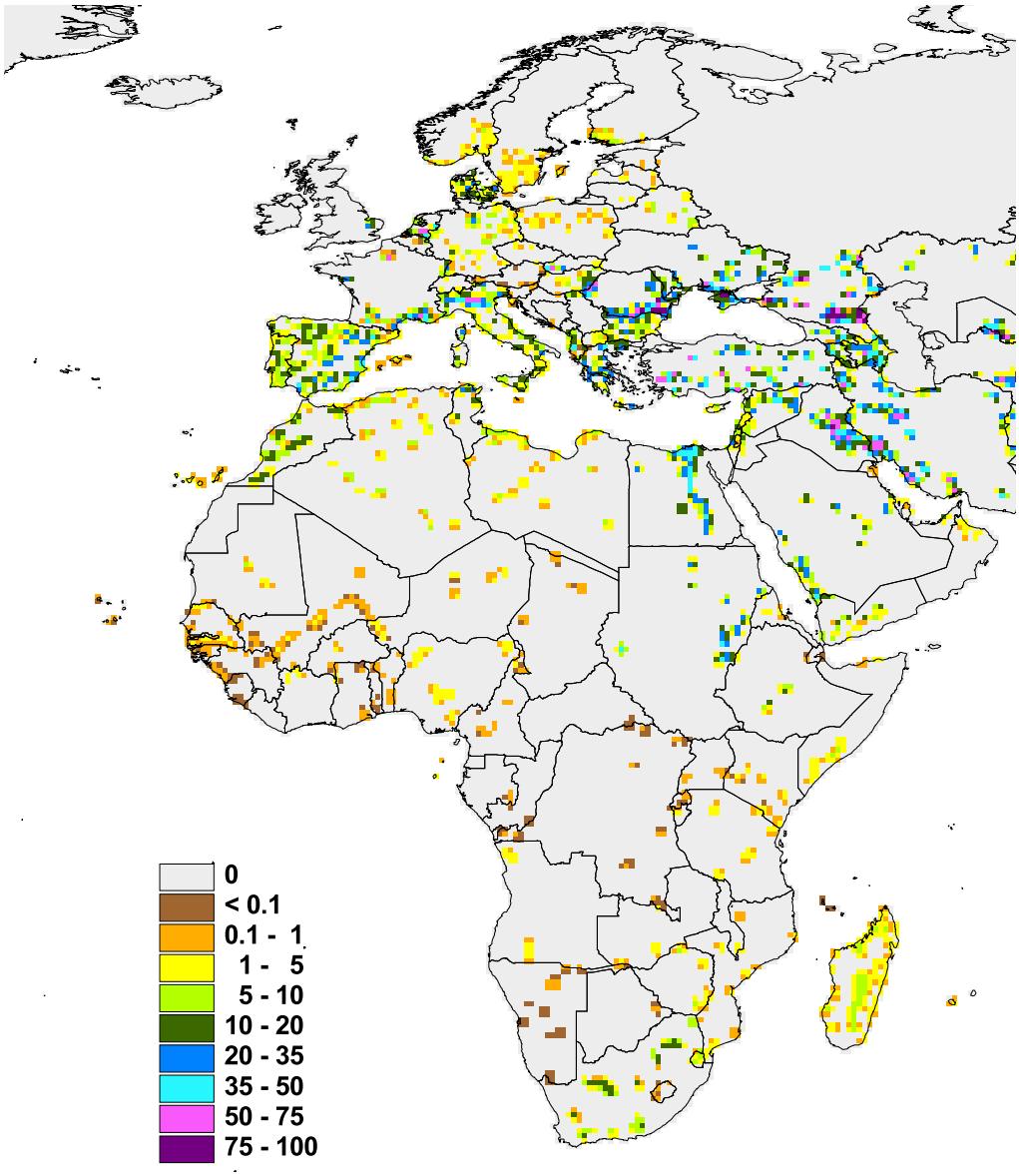


Fig. A1.3: Irrigated areas in Africa and Europe; section of the global map of irrigated areas. Map shows the fraction of the area of each 0.5° by 0.5° cell that was equipped for irrigation in 1995.

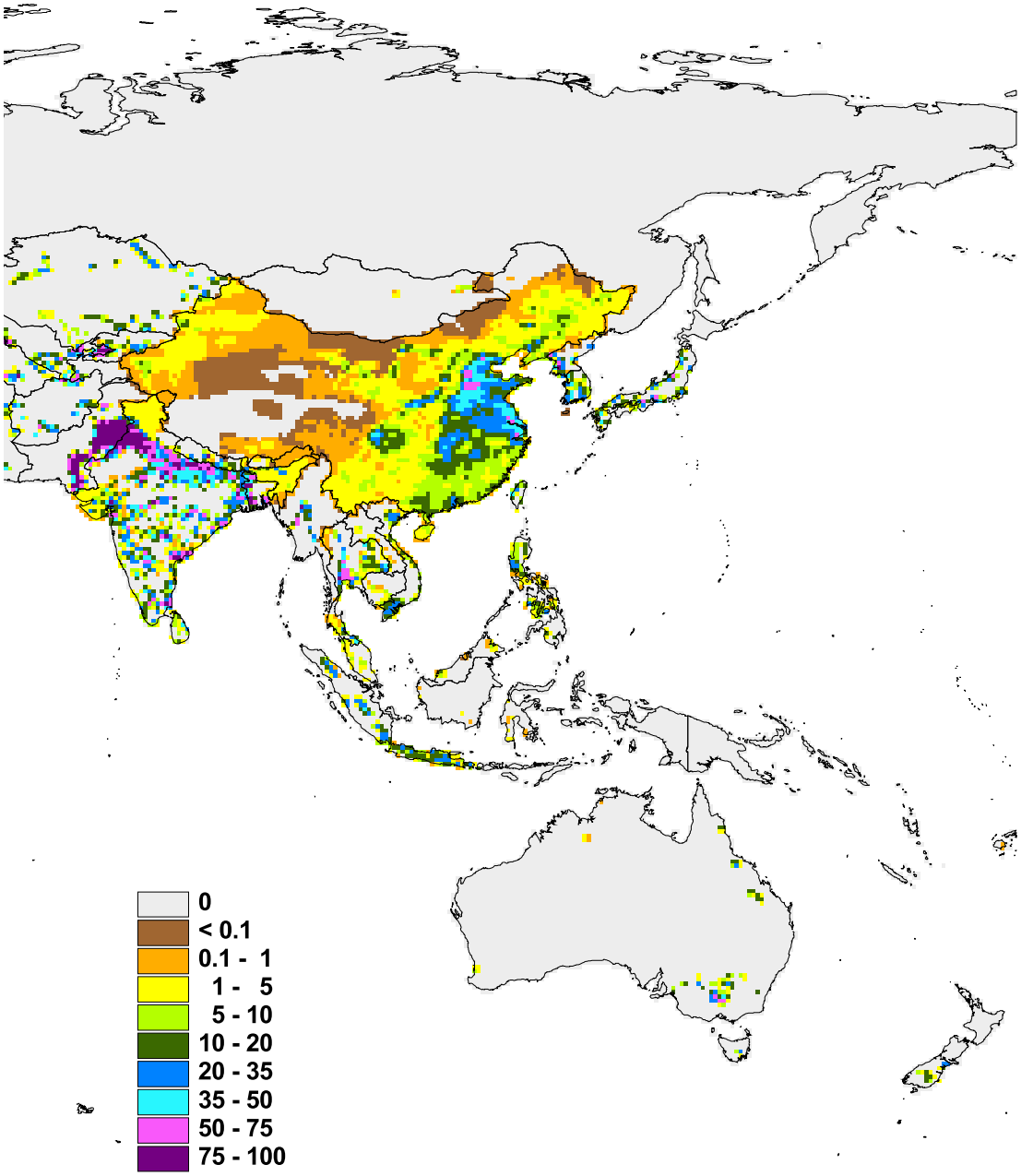
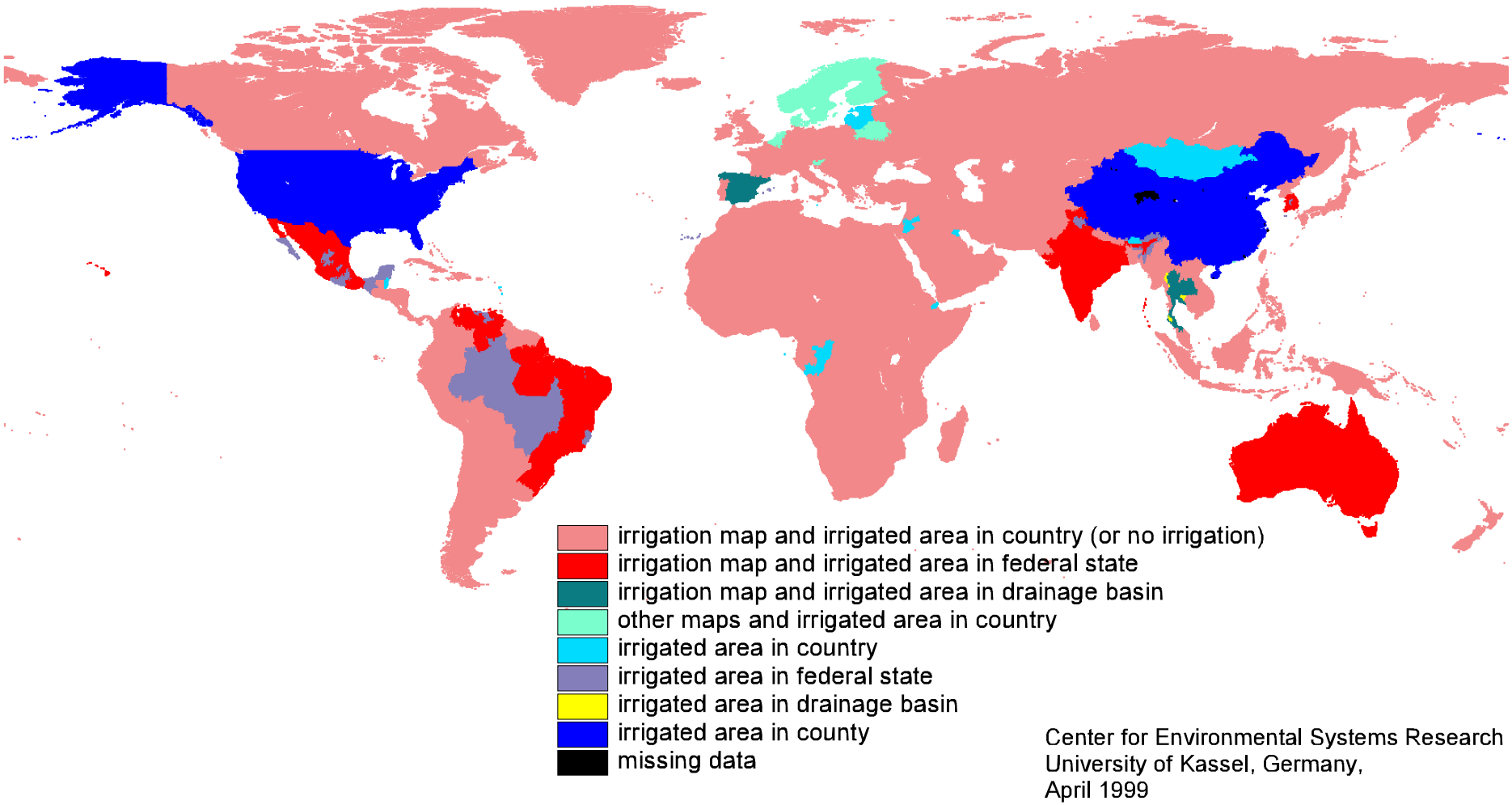


Fig. A1.4: Irrigated areas in Asia and Australia; section of the global map of irrigated areas. Map shows the fraction of the area of each 0.5° by 0.5° cell that was equipped for irrigation in 1995.

Appendix A2: Map and data sources of global digital map of irrigated areas 1995



Appendix B1: Map and data sources per country, including comments on the location of irrigated areas (**update from 16 June 1999**)

In the most recent version of the digital global map of irrigated areas of June 1999, the country values of irrigated areas have been changed compared to the April 99 version. This is the case for 16 countries (Russia, Pakistan, Jordan, Benin, Burkina Faso, Ivory Coast, Gabon, Guinea, Guinea Bissau, Liberia, Nigeria, Rwanda, Sierra Leone, Togo, Uganda and Zaire). Now, if AQUASTAT data were used, the irrigated area includes:

- full and partial control irrigation; equipped areas
- spate irrigation area
- equipped wetlands and inland valley bottoms

It does not include "other cultivated wetlands" and "flood recession cropping areas", as there is no control, and thus irrigation water use cannot be computed as the optimal irrigation requirement.

	country	data source for irrigated area in 1995	irrigated area (1000 ha)	map sources and comments
1	AFGHANISTAN	FAOSTAT	2799.996	map in Achtnich, p. 38
2	ALBANIA	FAOSTAT	340	map in Helmut Toepfer, "Bewässerungslandwirtschaft und Nahrungsmittelprd. in Albanien" in Popp, Rother, p.107
3	ALGERIA	AQUASTAT	555.501	map of irrigated areas in Northern Africa in Achtnich p. 63
4	AMERICAN SAMOA		0	no irrigation
5	ANDORRA		0	no irrigation
6	ANGOLA	AQUASTAT	75	map of irrigated areas in Central Africa in Achtnich, p. 68; map of irrigated areas in the South of Africa in Achtnich, p. 70
7	ANTIGUA & BARBUDA		0	no irrigation
8	ARGENTINIA	FAOSTAT	1699.999	map of irrigated areas in Southern America in Achtnich, p. 83
9	ARMENIA	AQUASTAT	285.649	map in Achtnich, p. 36
10	ARUBA		0	no irrigation
11	AUSTRALIA	FAOSTAT	2317	map of the Australian Department of Primary Industries & Energy "Irrigation in the southern Murray-Darling Basin", map in Achtnich, p. 85; to take into account irrigated areas in the states Northern Territory (N.T.) and Australian Capital Territory (A.C.T.), small irrigated areas near Darwin and Canberra were added.
12	AUSTRIA	FAOSTAT	4	map in Achtnich, p. 25
13	AZERBAIJAN	AQUASTAT	1453.32	map in Achtnich, p. 36
14	BAHAMAS		0	no irrigation
15	BAHRAIN	AQUASTAT	3.165	map of oasis areas in: Statistisches Bundesamt, "Länderbericht Bahrain 1991", Wiesbaden 1992, p. 13
16	BANGLADESH		3200.006	map in Achtnich, p. 40
17	BARBADOS	FAOSTAT	1	no irrigation maps available, whole island irrigated with same intensity
18	BELARUS	AQUASTAT	131	map of areas in which fruits and vegetables are grown (Minsk, Witebsk, Mogiljow, Gomel) in Statistisches Bundesamt, "Länderbericht Weißrußland 1994", p. 12

	country	data source for irrigated area in 1995	irrigated area (1000 ha)	map sources and comments
19	BELGIUM & LUXEMBOURG	FAOSTAT	1	map of areas on which vegetables and sugar beets are grown in: Statistisches Bundesamt, "Länderbericht Belgien 1993", p. 12
20	BELIZE	FAOSTAT	3	no irrigation maps available, some areas in the south near the borderline to Guatemala were marked as irrigated
21	BENIN	AQUASTAT	10.236	Africa map of FAO (FAO: "Irrigated areas in Africa", Rome, 1987)
22	BERMUDA		0	no irrigation
23	BHUTAN	FAOSTAT	39	no irrigation maps available, some areas near the capital and in a basin in the east of the country assumed to be irrigated
24	BOLIVIA	FAOSTAT	78	map of irrigated areas in Equador, Peru and Bolivia in Achtnich, p. 81
25	BOSNIA HERZEGOVINA	FAOSTAT	2	in Achtnich worldmap: irrigated area near borderline to Croatia N Dubrovnik
26	BOTSWANA	AQUASTAT	1.381	map of irrigated areas in Southern Africa in Achtnich, p. 70
27	BRAZIL	FAOSTAT	3168.91	map in Achtnich, p. 82; data on irrigated areas in the Brazilian states: personal communication with Dr. F. A. Rodriguez, Ministry of Environment, Water Resources and Amazon, 1998. For the states of Acre, Amazonas, Rondonia and Roraima with very small irrigation areas according to the state values but no areas given in Achtnich, arbitrary locations were chosen (on the 0.5° grid only, on 5' grid equal distribution of irrigated area))
28	BRIT. INDIAN OCEAN TERR.		0	no irrigation
29	BRIT. VIRGIN ISLANDS		0	no irrigation
30	BRUNEI DARUSSALAM	FAOSTAT	1	map of agricultural areas in Statistisches Bundesamt: "Länderbericht Brunei 1992"
31	BULGARIA	FAOSTAT	800.001	map in Achtnich, p.17
32	BURKINA FASO	AQUASTAT	24.33	map of irrigated areas West Africa in Achtnich, p. 67
33	BURUNDI	AQUASTAT	14.4	map of irrigated areas in Central Africa in Achtnich, p. 68
34	CAMBODIA	FAOSTAT	173	map of Indochina in Achtnich, p. 44
35	CAMEROUN	AQUASTAT	20.97	FAO (1987)
36	CANADA	FAOSTAT	709.998	map of irrigated areas in North America in Achtnich, p. 81
37	CANTON & ENDERBURY		0	no irrigation
38	CAPE VERDE	AQUASTAT	2.779	FAO (1987)
39	CAYMAN ISLANDS		0	no irrigation
40	CENTRAL AFRICAN REPUBLIC	AQUASTAT	0.135	map of irrigated areas in Central Africa in Achtnich, p. 68
41	CHAD	AQUASTAT	14.02	map of irrigated areas in Northern Africa in Achtnich, p. 63
42	CHILE	FAOSTAT	1265	map of irrigated areas in South America in Achtnich, p. 83; map of irrigated areas in Ecuador, Peru and Bolivia in Achtnich, p. 81
43	CHINA	county data	46003.992	county data of irrigated area in 1990 by Statistics Publishing House (1991); county map: CIESIN (1996)
44	CHRISTMAS ISLANDS		0	no irrigation
45	COCOS ISLAND		0	no irrigation
46	COLOMBIA	FAOSTAT	1037.001	map of irrigated areas in South America in Achtnich, p. 80
47	COMOROS	AQUASTAT	0.13	FAO (1987)
48	CONGO	AQUASTAT	0.217	no irrigation maps available, irrigated areas assumed near

	country	data source for irrigated area in 1995	irrigated area (1000 ha)	map sources and comments
				irrigated areas of neighbour countries and near Brazzaville
49	COOK ISLANDS		0	no irrigation
50	COSTA RICA	FAOSTAT	126	map of irrigated areas in Central America in Achtnich, p. 77
51	COTE D'IVOIRE	AQUASTAT	72.75	map of irrigated areas in the West Africa in Achtnich, p. 67
52	CROATIA	FAOSTAT	3	in Achtnich world map irrigated areas W of Rijeka and N of Dubrovnik
53	CUBA	FAOSTAT	910	map of irrigated areas in Central America in Achtnich, p. 77
54	CYPRUS	AQUASTAT	39.938	map in Achtnich, p. 60
55	CZECH REPUBLIC	FAOSTAT	24	map of irrigated areas in the former CSSR in Achtnich, p. 31
56	DENMARK	FAOSTAT	481	small irrigated areas, distributed within the whole country, map of agricultural areas with high yields in Statistisches Bundesamt: Länderbericht Dänemark 1993 p. 12
57	DJIBOUTI	AQUASTAT	0.674	no irrigation maps available, irrigated areas assumed near irrigated areas of neighbour countries and near Djibouti
58	DOMINICA		0	no irrigation
59	DOMINICAN REPUBLIC	FAOSTAT	259	map of irrigated areas in Central America in Achtnich, p. 77
60	EAST TIMOR		0	no irrigation
61	ECUADOR	FAOSTAT	240	map of irrigated areas in Equador, Peru and Bolivia in Achtnich, p. 81
62	EGYPT	AQUASTAT	3245.998	map of irrigated areas in the Northern Africa in Achtnich, p. 63
63	EL SALVADOR	FAOSTAT	120	map of irrigated areas in Central America in Achtnich, p. 77
64	EQUATORIAL GUINEA		0	no irrigation
65	ERITREA	AQUASTAT	28.124	map of irrigated areas in East Africa in Achtnich, p. 69
66	ESTONIA	AQUASTAT	3.68	no irrigation maps available, irrigation assumened S' Lake Wirz und S' Lake Pelpus
67	ETHIOPIA	AQUASTAT	189.556	map of irrigated areas in East Africa in Achtnich, p. 69
68	FAERÖE ISLANDS		0	no irrigation
69	FALKLAND ISLANDS		0	no irrigation
70	FIJI	FAOSTAT	3	map in Achtnich, p.87
71	FINLAND	FAOSTAT	64	map of agricultural areas with suitable climatic conditions in Statist. Bundesamt: Länderbericht Finnland 1993, p. 12
72	FRANCE	FAOSTAT	1630	N France: Achtnich world map, S France: map in Achtnich p. 20 + Andre de Reparaz: Irrigation et agriculture irriguee dans les regions mediterraneennes francaises; map in Popp, Rother p. 80, Korsika: map in Achtnich, p. 20
73	FRENCH GUIANA	FAOSTAT	2	map of irrigated areas in South America in Achtnich, p. 80
74	FRENCH POLYNESIA		0	no irrigation
75	GABON	AQUASTAT	4.45	FAO (1987)
76	GAMBIA	AQUASTAT	1.67	map of irrigated areas in West Africa in Achtnich, p. 67
77	GAZA STRIP	FAOSTAT	12	no irrigation maps available, whole area marked as irrigated
78	GEORGIA	AQUASTAT	469	map in Achtnich, p. 36
79	GERMANY	FAOSTAT	475	map of irrig. areas in former FRG in Achtnich, p. 18; map of irrig. areas in former GDR in Framji p. 395
80	GHANA	AQUASTAT	6.374	map of irrigated areas in West Africa in Achtnich, p. 67
81	GIBRALTAR		0	no irrigation
82	GREECE	FAOSTAT	1328	map in Achtnich, p. 21
83	GREENLAND		0	no irrigation

	country	data source for irrigated area in 1995	irrigated area (1000 ha)	map sources and comments
84	GRENADA		0	no irrigation
85	GUADELOUPE	FAOSTAT	2	no irrigation maps available, whole island marked as irrigated
86	GUAM		0	no irrigation
87	GUATEMALA	FAOSTAT	125	map of irrigated areas in Central America in Achtnich, p. 77
88	GUINEA	AQUASTAT	92.88	map of irrigated areas in West Africa in Achtnich, p. 67
89	GUINEA BISSAU	AQUASTAT	17.115	map of irrigated areas in West Africa in Achtnich, p. 67
90	GUYANA	FAOSTAT	130	map of irrigated areas in South America in Achtnich, p. 80
91	HAITI	FAOSTAT	90	map of irrigated areas in Central America in Achtnich, p. 77
92	HONDURAS	FAOSTAT	74	map of irrigated areas in Central America in Achtnich, p. 77
93	HONG KONG	FAOSTAT	2	map of paddy rice areas in Statistisches Bundesamt: Länderbericht Hongkong 1995 p. 12
94	HUNGARY	FAOSTAT	210	map in Achtnich, p. 32
95	ICELAND		0	no irrigation
96	INDIA		50101.996	map: Central Board of Irrigation and Power (1994): Irrigation Atlas of India. New Dehli. data: A.R.G. Rao, Central Board of Irrigation and Power (pers. communication 1998), net irrigated area 1992/93 per federal state
97	INDONESIA	FAOSTAT	4579.977	map of irrig. areas in Java in Achtnich, p. 45; irrig. areas in Sumatra in Achtnich worldmap; map of rice growing areas of the other islands published by Statistisches Bundesamt: Länderbericht Indonesien 1993, p. 12-14
98	IRAN	AQUASTAT	7264.24	map in Achtnich, p. 47
99	IRAQ	AQUASTAT	3524.998	map in Achtnich, p. 46
100	IRELAND		0	no irrigation
101	ISRAEL	FAOSTAT	195	map in H. Eichenauer: Die Bewässerungsgebiete Israels. Anmerkungen zu einer Karte 1:1 Million in Popp, Rother p. 136
102	ITALIA	FAOSTAT	2709.998	map in Achtnich, p. 23 + map in Wagner, H. and H.-G.: Die Bewässerungslandwirtschaft in den italienischen Regionen Latium, Abruzzen, Molise und Kampanien in Popp, Rother p. 88,89 + map in Klaus Rother: Die Bewässerungsgebiete des fernsten Italiens in Popp, Rother p. 102
103	JAMAICA	FAOSTAT	33	map of irrigated areas in Central America in Achtnich, p. 77
104	JAPAN	FAOSTAT	2700.004	map in Achtnich, p. 49
105	JORDAN	AQUASTAT	64.3	main part of irrigated areas in Jordan valley (Framji)
	KASAKHSTAN	AQUASTAT	3556.403	maps: Achtnich, p. 36 (S-Kasakhstan) + H.W. Denecke: Towards the integration of irrigation and drainage management in the Aral sea basin. In ILRI - Annual Report 1996, p. 26
107	KENIA	AQUASTAT	66.61	map of irrigated areas in East Africa in Achtnich, p. 69
108	KIRIBATI		0	no irrigation
109	KOREA DPR.	FAOSTAT	1460.001	map of Korea in Achtnich, p. 51
110	KOREA REP.	FAOSTAT	1334.998	map of Korea in Achtnich, p. 51; data of irrigated area per federal state: personal communication with Yung-Duk Lim 1998 (source of data: Yearbook Land and Water Developement Statistics 1995)
111	KUWAIT	AQUASTAT	4.77	no irrigation maps available, small area near Kuwait City marked as irrigated
112	KYRGYZSTAN	AQUASTAT	1077.100	map in: H.W. Denecke. In ILRI - Annual Report 1996, p. 26
113	LAOS	FAOSTAT	177	map of irrigated area in Indochina in Achtnich, p. 44
114	LATVIA	AQUASTAT	20	no irrigation maps available, irrigated areas marked near Riga and along the rivers Aluksne, Daugava and Venta

	country	data source for irrigated area in 1995	irrigated area (1000 ha)	map sources and comments
115	LEBANON	AQUASTAT	87.5	map in Achtnich, p. 52
116	LESOTHO	AQUASTAT	2.722	FAO (1987)
117	LIBERIA	AQUASTAT	2.1	map of irrigated areas in West Africa in Achtnich, p. 67
118	LIBYA	AQUASTAT	470	map of irrigated areas in Northern Africa in Achtnich, p. 63
119	LIECHTENSTEIN		0	no irrigation
120	LITHUANIA	AQUASTAT	9.247	no irrigation maps available, irrigated areas marked near Kaunas (along Nemunas river) and near Vilnius (along Neris river)
121	MACAU		0	no irrigation
122	MACEDONIA	FAOSTAT	61	in Achtnich worldmap irrigated areas in the east along Wadar river
123	MADAGASCAR	AQUASTAT	1087	FAO (1987)
124	MALAWI	AQUASTAT	28	map of irrigated areas in Southern Africa in Achtnich, p. 70
125	MALAYSIA	FAOSTAT	340	map in Achtnich, p. 52
126	MALEDIVES		0	no irrigation
127	MALI	AQUASTAT	78.62	map of irrigated areas in Northern Africa in Achtnich, p. 63; map of irrigated areas in West Africa in Achtnich, p. 67
128	MALTA	AQUASTAT	0.763	no irrigation maps available, whole island marked as irrigated area
129	MARTINIQUE	FAOSTAT	3	no irrigation maps available, whole island marked as irrigated area
130	MAURETANIA	AQUASTAT	49.2	map of irrigated areas in Northern Africa in Achtnich, p. 63
131	MAURITIUS	AQUASTAT	17.5	map in Achtnich, p. 72
132	MEXICO	FAOSTAT	6099.96	map in Achtnich, p. 76, data of irrigated area statewise: communication with Julio Lorda, FIRCO, Mexico City 1998
133	MOLDOVA REP.	AQUASTAT	312	map in Achtnich, p. 34
134	MONGOLIA	FAOSTAT	80	no irrigation maps available, irrigated areas marked near Ulan Bator and in the east (along Cherlen river)
135	MONTSERRAT		0	no irrigation
136	MOROCCO	AQUASTAT	1258.198	map of irrigated areas in Northern Africa in Achtnich, p. 63
137	MOZAMBIQUE	AQUASTAT	106.71	map of irrigated areas in Southern Africa in Achtnich, p. 70
138	MYANMAR	FAOSTAT	1555	map in Achtnich, p. 41
139	NAMIBIA	AQUASTAT	6.142	map in M. B. Schneider, "Bewässerungslandwirtschaft in Namibia", p. 55
140	NAURU		0	no irrigation
141	NEPAL	FAOSTAT	885	map in Achtnich, p. 53
142	NETH. ANTILLES		0	no irrigation
143	NETHERLANDS	FAOSTAT	565	main part of irrigated areas in the east and the south (Achtnich, Framji), map of vegetable growing areas in Statistisches Bundesamt: Länderbericht Niederlande
144	NEW CALEDONIA		0	no irrigation
145	NEW ZEALAND	FAOSTAT	285	map in Achtnich, p. 86
146	NICARAGUA	FAOSTAT	88	map of irrigated areas in Central America in Achtnich, p. 77
147	NIGER	AQUASTAT	66.48	map of irrigated areas in Northern Africa in Achtnich, p. 63; map of irrigated areas in West Africa in Achtnich, p. 67
148	NIGERIA	AQUASTAT	232.821	map of irrigated areas in West Africa in Achtnich, p. 67
149	NIUE		0	no irrigation
150	NORFOLK ISLANDS		0	no irrigation
151	NORWAY	FAOSTAT	100	map of agricultural areas in Länderbericht Norwegen 1991, p. 12
152	OMAN	AQUASTAT	61.55	map of irrigated areas in Arabia in Achtnich, p. 39
153	PACIFIC		0	no irrigation

	country	data source for irrigated area in 1995	irrigated area (1000 ha)	map sources and comments
	ISLANDS			
154	PAKISTAN	AQUASTAT	15729.4	map: government of Pakistan. "Irrigation System of Pakistan", 1994
155	PANAMA	FAOSTAT	32	map of irrigated areas in Central America in Achtnich, p. 77
156	PAPUA NEW GUINEA		0	no irrigation
157	PARAGUAY	FAOSTAT	67	map of irrigated areas in South America in Achtnich, p. 80
158	PERU	FAOSTAT	1752.997	map of irrigated areas in Equador, Peru , Bolivia in Achtnich, p. 81
159	PHILIPPINES	FAOSTAT	1580.003	map in Achtnich, p. 54
160	POLAND	FAOSTAT	100	map in Achtnich, p. 26
161	PORTUGAL	FAOSTAT	632	map in Achtnich, p. 27; location of irrigation projects Mondego, Silves und Alvor in map: Bodo Freund: Entwicklung und Perspektiven der Bewässerungswirtschaft in Portugal. In Popp, Rother p. 9
162	PUERTO RICO	FAOSTAT	40	map in Framji p. 156
163	QATAR	AQUASTAT	12.52	map of oasis areas in: Statistisches Bundesamt (Hrsg.) "Länderbericht Katar 1994", p. 12
164	REUNION	FAOSTAT	12	map in Achtnich, p. 72
165	ROMANIA	FAOSTAT	3110.01	map in Achtnich, p. 28
166	RUSSIAN FED.	AQUASTAT	5158	map of irrigated areas in S Russia in Achtnich, p. 35
167	RWANDA	AQUASTAT	4	FAO (1987)
168	SAMOA		0	no irrigation
169	SAN MARINO		0	no irrigation
170	SAO TOME & PRINCIPE	AQUASTAT	9.7	no irrigation maps available, whole area marked as irrigated
171	SAUDI ARABIA	AQUASTAT	1607.997	map of irrigated areas in Arabia in Achtnich, p. 39
172	SENEGAL	AQUASTAT	71.4	map of irrigated areas in West Africa in Achtnich, p. 67
173	SEYCHELLES		0	no irrigation
174	SIERRA LEONE	AQUASTAT	29.36	map of irrigated areas in West Africa in Achtnich, p. 67
175	SINGAPORE		0	no irrigation
176	SLOVAK. REP.	FAOSTAT	299	map of irrigated areas of the former CSSR in Achtnich, p. 31
177	SLOVENIA	FAOSTAT	2	map of wine, fruits and vegetables growing areas in Statistisches Bundesamt: "Länderbericht Slowenien 1995" p. 12
178	SOLOMON ISLANDS		0	no irrigation
179	SOMALIA	AQUASTAT	200	map of irrigated areas in East Africa in Achtnich, p. 69
180	SOUTH AFRICA	AQUASTAT	1270.002	map of irrigated areas in Southern Africa in Achtnich, p. 70
181	SPAIN	FAOSTAT	3526.999	map in Achtnich, p. 30; map of main basins and data of irrigated areas in these basins: communication with the span. National Committee of the ICID ; some areas along the Guadalquivir river were marked as irrigated too, Baleares und Canary Islands were marked as completely irrigated
182	SRI LANKA	FAOSTAT	550	map in Achtnich, p. 55
183	ST. HELENA		0	no irrigation
184	ST. KITTS & NEVIS		0	no irrigation
185	ST. LUCIA	FAOSTAT	3	no irrigation maps available, whole island marked as irrigated
186	ST. PIERRE MIQUELON		0	no irrigation
187	ST. VINCENT	FAOSTAT	1	no irrigation maps available, whole island marked as

	country	data source for irrigated area in 1995	irrigated area (1000 ha)	map sources and comments
				irrigated
188	SUDAN	AQUASTAT	1946.207	map of irrigated areas in Central Africa in Achtnich, p. 68; map of irrigated areas in East Africa in Achtnich, p. 69
189	SURINAME	FAOSTAT	60	map of irrigated areas in Northern South America in Achtnich, p. 80
190	SWAZILAND	AQUASTAT	67.4	map of irrigated areas in Southern Africa in Achtnich, p. 70
191	SWEDEN	FAOSTAT	115	map of most important agricultural areas in Statistisches Bundesamt: "Länderbericht Schweden 1994", p. 13
192	SWITZERLAND	FAOSTAT	25	map in Achtnich, p. 29
193	SYRIA	AQUASTAT	1013.274	map in Achtnich, p. 56
194	TAJIKISTAN	AQUASTAT	719.2	map in: H.W. Denecke in ILRI - Annual Report 1996, p. 26
195	TANZANIA	AQUASTAT	150	map of irrigated areas in East Africa in Achtnich, p. 69; map of irrigated areas in Southern Africa in Achtnich, p. 70
196	THAILAND	FAOSTAT	5004.012	map in Achtnich, p. 58; data of irrigated areas in 25 main water basins of Thailand and map of these basins: personal communication with Charoon Kamoiratana from the Royal Irrigation Department of Thailand, 1998.
197	TOGO	AQUASTAT	7.008	FAO (1987)
198	TOKELEAU ISLANDS		0	no irrigation
199	TONGA		0	no irrigation
200	TRINIDAD & TOBAGO	FAOSTAT	22	map of irrigated areas in Northern South America in Achtnich, p. 80
201	TUNISIA	AQUASTAT	385	map of irrigated areas in Northern Africa in Achtnich, p. 63
202	TURKEY	AQUASTAT	4185.91	map in Achtnich, p. 59
203	TURKMENISTAN	AQUASTAT	1744.103	map in: H.W. Denecke in ILRI - Annual Report 1996, p. 26
204	TURKS CAICOS ISL.		0	no irrigation
205	TUVALU		0	no irrigation
206	USA	county data	23548.466	county-data: National water-use data files of the U.S. Geological Survey in 1995; county map: USGS (1998); irrigated areas of the Hawaii Islands: map in Achtnich, p. 88
207	UGANDA	AQUASTAT	9.12	map of irrigated areas in East Africa in Achtnich, p. 69
208	UNITED KINGDOM	FAOSTAT	108	in Achtnich worldmap irrigated area in the south-east of UK
209	UKRAINE	AQUASTAT	2605.004	map in Achtnich, p. 34
210	UNITED ARAB EMIRATES	AQUASTAT	66.682	map of irrigated areas in Arabia in Achtnich, p. 39
211	URUGUAY	FAOSTAT	140	map of irrigated areas in Southern South America in Achtnich, p. 83
212	US VIRGIN ISLANDS		0	no irrigation
213	UZBEKISTAN	AQUASTAT	4280.605	map in: H.W. Denecke in ILRI - Annual Report 1996, p. 26
214	VANUATU		0	no irrigation
215	VENEZUELA	FAOSTAT	185	map of irrigated areas in Northern South America in Achtnich, p. 80; data of irrigated areas per federal state: personal communication with Prof. Gonzalo Freites (Hydraulic Department, UCV)
216	VIET NAM	FAOSTAT	1999.996	map of irrigated areas in Indochina in Achtnich, p. 44
217	WALLIS FUTUNA ISLANDS		0	no irrigation
218	WEST BANK	FAOSTAT	9	no irrigation maps available, some areas in the Jordan river valley were marked as irrigated
219	WEST SAHARA		0	no irrigation
220	YEMEN	AQUASTAT	481.52	map of irrigated areas in Arabia in Achtnich, p. 39

	country	data source for irrigated area in 1995	irrigated area (1000 ha)	map sources and comments
221	YUGOSLAWIA FED REP.	FAOSTAT	65	in Achtnich worldmap irrigated areas in the N between Donau river and Theiß river
222	ZAIRE	AQUASTAT	10.5	map of irrigated areas in Central Africa in Achtnich, p. 68; map of irrigated areas in East Africa in Achtnich, p. 69
223	ZAMBIA	AQUASTAT	46.4	map of irrigated areas in Southern Africa in Achtnich, p. 70
224	ZIMBABWE	AQUASTAT	116.577	map of irrigated areas in Southern Africa in Achtnich, p. 70
225	TAIWAN	Länderbericht-Taiwan 1994	465	map in Achtnich, p. 57; source of irrigated area in 1992: Statistisches Bundesamt: Länderbericht Taiwan 1994

The irrigated areas given here are correct for the 5-min map (ESRI land mask). Due to the lower spatial resolution and thus the errors in assigning 0.5° cells to countries, the country values of 0.5° digital global map of irrigated areas can be different.

Appendix B2: Irrigated areas in the federal states of India

federal state	net irrigated area as listed for each federal state in 1992/93 (ha) *	existing irrigated area according to map (in 1989) (ha)	planned irrigated area according to map (in 1989) (ha)
Andaman and Nicobar Islands	0	0	0
Arunachal Pradesh	36000	0	7646
Andhra Pradesh	4029000	3724787	4956914
Assam	572000	161436	153175
Bihar	3344000	1445201	3067317
Chandigarh	2000	0	0
Daman & Diu	1000	0	0
Dadra and Nagar Haveli	4000	0	24101
Delhi	36000	112861	0
Gujarat	2642000	1593132	301490
Goa	23000	0	24760
Himachal Pradesh	99000	0	0
Haryana	2628000	3225126	0
Jammu & Kashmir	311000	101361	57816
Kerala	335000	210462	345051
Karnataka	2194000	3051059	1141978
Meghalaya	45000	0	0
Maharashtra	2470000	2068063	3006066
Manipur	65000	0	15553
Madhya Pradesh	4775000	2822748	2091652
Mizoram	8000	0	0
Nagaland	60000	0	0
Orissa	2070000	1067377	1251167
Pondicherry	23000	67015	0
Punjab	3861000	4202768	0
Rajasthan	4471000	3543532	600407
Sikkim	16000	0	0
Tamil Nadu	2698000	2408388	403159
Tripura	50000	0	0
Uttar Pradesh	11322000	12866868	2472235
West Bengal	1911000	1170458	1883012

* personal communication: A.R.G. Rao, Central Board of Irrigation and Power, New Delhi, 1998

Appendix B3: Irrigated areas in the federal states of Mexico

federal state	irrigated area as listed for each federal state in 1994 (ha) *	irrigated area in 1995 (corrected for FAO total) (ha)	total irrigated area according to scanned irrigation maps (ha)	percentage of 5' cell area irrigated after modeling
Aguascalientes	65992	67418	0	12.129672
Baja California	264537	270252	486703	0 or 55.527042
Baja California Sur	62627	63980	0	0.881238
Coahuila	125015	127716	45513	0 or 100 or 80.860077
Chihuahua	329276	336389	1029822	0 or 32.664810
Chiapas	89396	91327	0	1.240914
Campeche	37200	38004	0	0.756808
Colima	88926	90847	0	15.821923
Durango	92504	94502	299358	0 or 31.568336
Distrito Federal	2035	2079	0	1.429265
Guanajuato	418193	427227	522170	0 or 81.817604
Guerrero	95383	97444	0	1.522163
Hidalgo	135338	138262	80434	0 or 100 or 47.940830
Jalisco	239768	244948	697048	0 or 35.140739
Michoacan	477444	487758	249363	0 or 100 or 40.014641
Mexico	200702	205038	48294	0 or 100 or 62.073612
Morelos	66991	68438	0	12.792886
Nuevo Leon	173694	177446	805405	0 or 22.031944
Nayarit	100702	102878	405097	0 or 25.395742
Oaxaca	98883	101019	334990	0 or 30.155886
Puebla	150188	153433	0	4.481399
Queretaro	50268	51354	0	4.306903
Quintana Roo	23300	23803	0	0.471389
Sinaloa	705326	720563	465257	0 or 100 or 53.104813
San Luis Potosi	200514	204846	277839	0 or 73.728310
Sonora	694715	709723	923408	0 or 76.8591
Tabasco	20041	20474	0	0.861099
Tlaxcala	30748	31412	0	7.780107
Tamaulipas	579276	591790	1356584	0 or 43.623569
Veracruz	106072	108364	8131	0 or 100 or 37.065922
Yucatan	25506	26057	0	0.683789
Zacatecas	220446	225208	0	3.004041
total	5971006	6100000	8035416	

* personal communication: Julio Lorda, FIRCO, Mexico City 1998

Appendix B4: Irrigated areas in the federal states of Brazil

federal state	irrigated area as listed for each federal state in 1996 (ha) *	irrigated area in 1995 (corrected for FAO total) (ha)	total irrigated area according to scanned irrigation maps (ha)	percentage of 5' cell area irrigated after modeling
Acre	600	723	0	0.004737
Alagoas	7500	9039	1981707	0 or 0.456122
Amapa	100	121	25586	0 or 0.471044
Amazonas	1200	1446	0	0.000924
Bahia	140610	169464	2415124	0 or 7.016745
Ceara	77030	92837	519696	0 or 17.863617
Distrito Federal	9940	11980	0	1.966131
Espirito Santo	39500	47606	0	1.042891
Goias	106500	128355	0	0.374634
Litigated Zone	0	0	0	0
Mato Grosso do Sul	55600	67010	0	0.188553
Minas Gerais	260002	313356	2802166	0 or 11.183347
Mato Grosso	8100	9762	0	0.010798
Maranhao	40000	48208	1893657	0 or 2.545762
Paraiba	760	916	1153991	0 or 0.079373
Parana	55000	66286	401339	0 or 16.516199
Para	6260	7545	615378	0 or 1.226002
Piaui	18190	21923	1773312	0 or 1.236251
Pernambuco	85000	102443	2597293	0 or 3.944183
Rio de Janeiro	72000	86775	23834	100 or 7.716886
Rio Grande do Norte	14490	17463	952392	0 or 1.833630
Rio Grande do Sul	974000	1173872	707100	100 or 0.993080
Rondonia	100	121	0	0.000505
Roraima	5000	6026	0	0.026860
Santa Catarina	118800	143179	69218	0 or 68.747849
Sao Paulo	450000	542344	3631690	0 or 14.933537
Sergipe	18040	21742	546978	0 or 3.974894
Tocantins	65100	78459	0	0.284195

* personal communication: Fernando Antonio Rodriguez, Ministry of Environment, Water Resources and Amazon, Brasilia 1998

Appendix B5: Irrigated areas in the federal states of Australia

federal state	irrigated area as listed for each federal state in 1983/84 (ha) *	irrigated area in 1995 (projection, corrected for FAO total) (ha)	total irrigated area according to scanned irrigation maps (ha)	percentage of 5' cell area irrigated after modeling
Australian Capital Territory	220	474	14018	0 or 3.381
New South Wales	661535	823070	1904794	0 or 43.210
Northern Territory	2536	5462	222135	0 or 2.459
Queensland	254380	547868	2192443	0 or 24.989
South Australia	86953	108185	204803	0 or 52.823
Tasmania	39905	85945	139844	0 or 61.457
Victoria	555100	690645	972552	0 or 71.014
Western Australia	25700	55351	433060	0 or 12.781
total	1626329	2317000	6083649	

* Stein (1986)

Appendix B6: Irrigated areas in the federal states of South Korea

federal state	irrigated area as listed for each federal state in 1994 (ha) *	irrigated area in 1995 (corrected for FAO total) (ha)	total irrigated area according to scanned irrigation areas (ha)	percentage of 5' cell area irrigated after modeling
Ch'ungch'ong-bukto	46845.5	75187	0	10.501027
Cholla-bukto	119727.4	192164	216247	0 or 88.862854
Cheju-do	189.6	304	0	0.169813
Cholla-namdo	140452.8	225428	274056	0 or 82.256050
Ch'ungch'ong-namdo	128287.8	205903	234204	0 or 87.916092
Inch'on-jikhalsi	399.8	642	6812	9.419784
Kyongsang-bukto	137267.2	220315	554986	0 or 39.697437
Kangwon-do	38436	61690	108865	0 or 56.666393
Kyonggi-do	99716.7	160046	292825	0 or 54.655888
Kyongsang-namdo	107126.7	171939	343332	0 or 50.079601
Kwangju-jikhalsi	4449.5	7141	7030	0 or 100 or 0.396786
Pusan-jikhalsi	6676.6	10716	0	30.535477
Seoul-jikhalsi	453.3	728	61301	1.186844
Taegu-jikhalsi	1742.3	2796	41746	0 or 6.698615
total	831771.2	1335000	2141404	

* personal communication: Yung-Duk Lim, Seoul 1998, from Yearbook of Land and Water Development Statistics (1995).

Appendix B7: Irrigated areas in the federal states of Venezuela

federal state	irrigated area as listed for each federal state in 1984 (ha) *	irrigated area in 1995 (corrected for FAO total) (ha)	total irrigated area according to scanned irrigation maps (ha)	percentage of 5' cell area irrigated after modeling
Amazonas	0	0	0	0
Anzoategui	2500	2851	0	0.061931
Apure	0	0	0	0
Aragua	8000	9123	0	1.354097
Bolivar	0	0	0	0
Barinas	6700	7641	211411	0 or 3.614101
Cojedes	12675	14454	33713	0 or 42.875317
Carabobo	0	0	0	0
Delta Amacuro	0	0	0	0
Distrito Federal	0	0	16811	0
Dependencias Federales	0	0	0	0
Falcon	0	0	0	0
Guarico	83000	94652	219495	0 or 43.122913
Lara	0	0	84245	0
Merida	0	0	16907	0
Monagas	0	0	0	0
Miranda	1300	1483	0	0.160137
Nueva Esparta	0	0	0	0
Portuguesa	35500	40484	16868	0 or 100 or 34.991154
Sucre	4550	5189	159735	0 or 3.248374
Tachira	0	0	8470	0
Trujillo	8000	9123	244718	0 or 3.728024
Yaracuy	0	0	58959	0
Zulia	0	0	0	0
total	162225	185000	1071332	

* personal communication: Prof. Gonzalo Freites, UCV, Caracas 1998.

Appendix B8: Irrigated areas in the drainage basins of Thailand

No.	drainage basin	irrigated area as listed for each drainage basin in 1993 (ha) *	irrigated area in 1995 (corrected for FAO total) (ha)	total irrigated area according to scanned irrigation maps (ha)	percentage of 5' cell area irrigated after modeling
1	Mae Nam Salawin	30231.68	31287	0	1.659631
2	Mae Nam Khong (Mekong)	270773.28	280222	342547	0 or 81.805367
3	Mae Nam Kok	91258.08	94443	163138	0 or 57.891247
4	Mae Nam Chi	298101.92	308504	1126204	0 or 27.393299
5	Mae Nam Mun	291165.60	301326	2270327	0 or 13.272355
6	Mae Nam Ping	310868.32	321716	619584	0 or 51.924507
7	Mae Nam Wang	75576.00	78213	48725	0 or 100 or 33.003162
8	Mae Nam Yom	159072.80	164624	269858	0 or 61.003910
9	Mae Nam Nan	284901.92	294844	336294	0 or 87.674461
10	Mae Nam Chao Phraya	917020.00	949020	1309233	0 or 72.486694
11	Mae Nam Sakae Krang	105801.60	109494	41239	0 or 100 or 85.602539
12	Mae Nam Pa Sak	122003.20	126261	41402	0 or 100 or 65.650726
13	Mae Nam Tha Chin	439890.24	455240	828952	0 or 54.917576
14	Mae Nam Mae Klong	359966.72	372528	274343	0 or 100 or 38.152298
15	Mae Nam Prachin Buri	99385.92	102854	0	10.585769
16	Mae Nam Bang Pakong	216522.08	224078	390910	0 or 57.322094
17	Tonle Sap	19795.20	20486	0	8.810024
18	East Coast	68320.00	70704	291779	0 or 24.232035
19	Mae Nam Phetchaburi	64153.44	66392	250081	0 or 26.548267
20	West Coast	69188.00	71602	217539	0 or 32.914715
21	Peninsula - East Coast	276304.16	285946	356682	0 or 80.168327
22	Mae Nam Tapi	39355.20	40729	0	3.212461
23	Thale Sap Songkhla	128144.00	132616	144110	0 or 92.023575
24	Mae Nam Pattani	44960.00	46529	93424	0 or 49.804035
25	Peninsula - West Coast	52512.48	54345	169520	0 or 32.058048
	total	4835271.84	5004000	9585891	

* personal communication: Charoon Kamoiratana, Royal Irrigation Department of Thailand, 1998.

Appendix B9: Irrigated areas in the drainage basins of Spain

No.	drainage basin	irrigated area as listed for each drainage basin (ha) *	irrigated area in 1995 (corrected for FAO total) (ha)	total irrigated area according to scanned irrigation maps (ha)	percentage of 5' cell area irrigated after modeling
1	Galicia Norte	26371	27809	12599	0 or 100 or 24.143745
2	Norte	74032	78069	234196	0 or 33.334667
3	Duero	447576	471980	1808796	0 or 26.093584
4	Tajo	201336	212314	945131	0 or 22.463932
5	Guadiana	335590	353888	679286	0 or 52.096985
6	Guadalquivir	602966	635842	961058	0 or 66.160667
7	Sur	142457	150224	151297	0 or 99.290909
8	Segura	276316	291382	128752	0 or 100 or 55.804104
9	Jucar	384802	405783	471426	0 or 86.075607
10	Ebro	738662	778937	1774007	0 or 43.908329
11	Catalonia Internal Basins	67774	71469	237950	0 or 30.035379
12	Balearic Iles	17376	18323	0	3.897302
13	Canary Iles (La Palma, Tenerife, Lanzarote, Fuerteventura, Gran Canaria)	29379	30981	0	4.889371
14	total	3344637	3527000	7404498	

* personal communication: José A. Ortiz Fdz. Urrutia, ICID Spain, Madrid 1998.