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The Digital Global Map of Irrigation Areas – Development and Validation of Map Version 4

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Abstract

A new version of a digital global map of irrigation areas was developed by combining irrigation statistics for 26 909 sub-national statistical units and geo-spatial information on the location and extent of irrigation schemes. The difference to map version 3 (available at: http://www.fao.org/ag/agl/aglw/aquastat/irrigationmap/index.stm) is the incorporation of a map update for Africa, Europe and parts of Latin America. The map shows the percentage of each 5 arc minute by 5 arc minute grid cell (about 86 km² along the equator) that was equipped for irrigation around the year 2000. It is thus an important data set for global studies related to land and water, but also for assessments on food security or to quantify possible impacts of climate change on agriculture. The data set and the mapping methodology are described and an estimate of map quality is given at the scale of countries, world regions and the globe. Two indicators of map quality were developed for this purpose, and the map was compared to irrigated areas as derived from remote sensing based global land cover inventories. The main result of the study is that 278.8 million ha were equipped for irrigation at the global scale, of which about 68 % is located in Asia, 17 % in America, 9 % in Europe, 5 % in Africa and 1 % in Oceania. The largest contiguous areas of high irrigation density are found in North India and Pakistan along the rivers Ganges and Indus, in the Hai He, Huang He and Yangtze basins in China, along the Nile river in Egypt and Sudan, in the Mississippi-Missouri river basin and in parts of California. Smaller irrigation areas are spread across almost all populated parts of the world. At the global scale, the overall map quality is good, but there are large regional differences of map quality. It was found that remote sensing based land cover inventories report higher values for the global extent of irrigated land and that there is a need for a systematic comparison of the different data sets.

2 Introduction

Agriculture is by far the largest water-use sector, accounting for about 70 percent of all water withdrawn worldwide from rivers and aquifers for agricultural, domestic and industrial purposes (SHIKLOMANOV, 2000; FAO, 2006). To model irrigation water requirements at the global scale (DÖLL AND SIEBERT, 2002), to assess irrigated food production in general (WOOD ET AL., 2000; FAURES ET AL., 2002) or to quantify the impact of irrigated agriculture on climate (OKI ET AL., 2001; DE ROSNAY ET AL., 2003; BOUCHER ET AL., 2004; GORDON ET AL., 2005) or on river discharge (HADDELAND ET AL., 2006) it is therefore important to know distribution and extent of irrigated areas in the world. The first digital global map (or rather data set) of irrigated areas was

published in 1999 (Döll and Siebert, 2000). Since then, the map has been updated several times and a new mapping methodology was developed (SIEBERT AND DÖLL, 2001) Here we present the most recent version 4.0 of the Global Map of Irrigation Areas, which shows the fraction of 5 arc minutes by 5 arc minutes cells that was equipped for irrigation around the year 2000. To our knowledge, this is the only global data set of irrigated areas that is not primarily based on remote sensing information. We describe the mapping methodology (section 3) and the mapping results (section 4). Two indicators of map quality were developed and the map was compared to another global irrigation map, that is based on remote sensing (section 5).

3 Data and methods

The global map of irrigation areas was developed by combining sub-national irrigation statistics with geospatial information on the position and extent of irrigation schemes to compute the fraction of 5 arc minute cells that was equipped for irrigation, which is called irrigation density (Fig. 1). Irrigation statistics for 26 909 sub-national units (e.g. districts, counties, provinces, governorates, river basins), from national census surveys and from reports available at FAO (through its AQUASTAT global water and agriculture information system), World Bank and other international organizations, were used to develop the most recent map version 4 (Fig. 2).

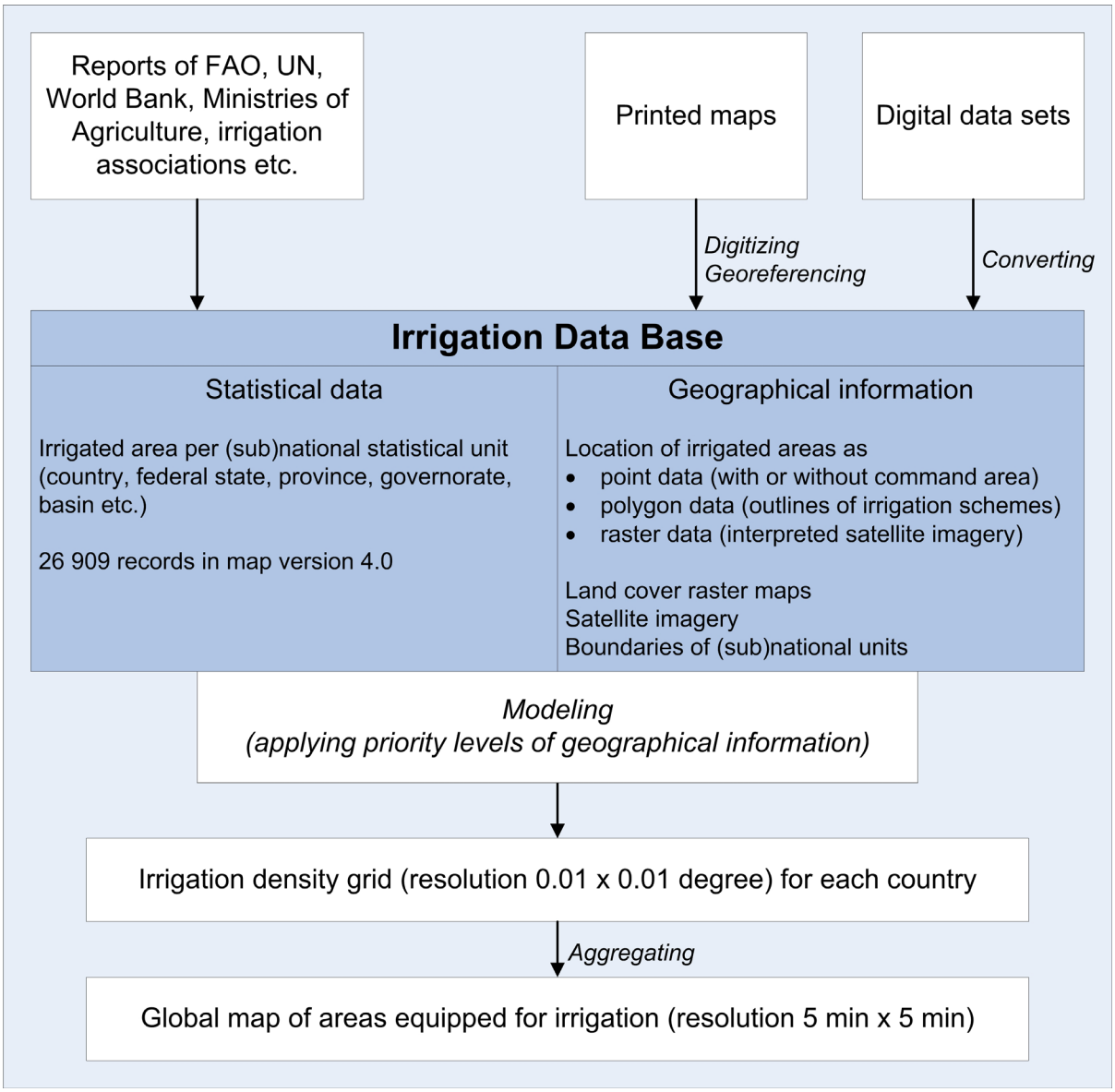

Figure 1. Scheme of mapping methodology used to develop the Global Map of Irrigation Areas.

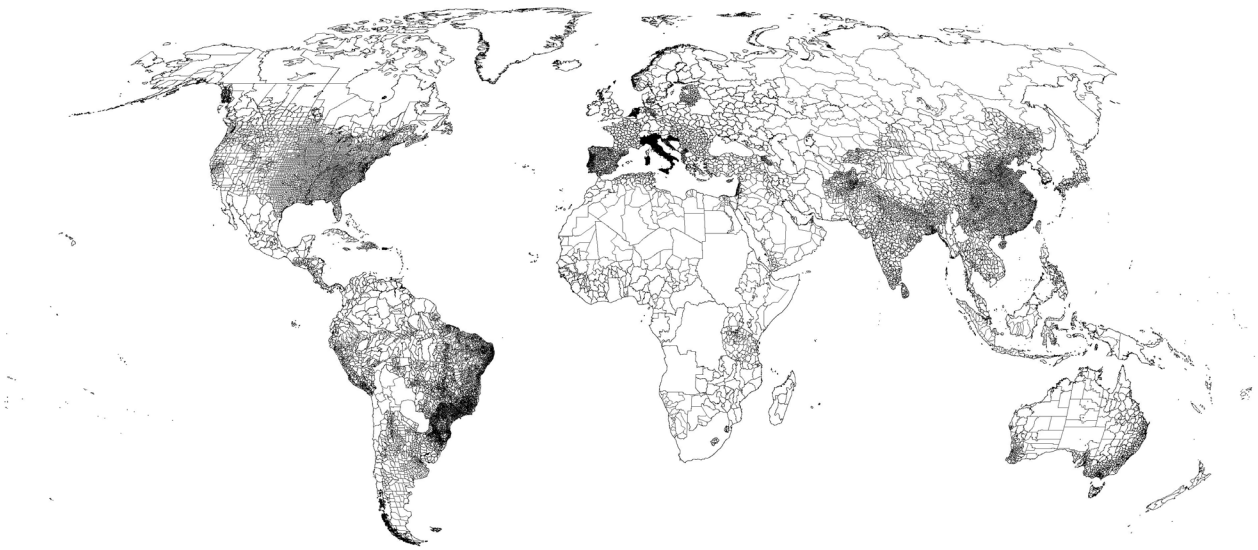

Figure 2. Location and extent of the 26 909 sub-national units with information on area equipped for irrigation used to develop the Global Map of Irrigation Areas Version 4 (Robinson projection).

In order to distribute the areas equipped for irrigation within the sub-national units, geospatial information on position and extent of irrigated areas was derived by digitizing hundreds of irrigation maps available in reports of FAO, World Bank, irrigation associations or national ministries of agriculture. Additionally, information from several atlases or inventories based on remote sensing available in digital format was utilized. For most of the countries, more than one data source was used. As the relevance and reliability of the maps varies, it was necessary to decide which geospatial record should be used in a specific sub-national unit. This was realized by applying a priority level to each record. Only if the extent of all digitized irrigated areas with the highest priority level was smaller than the total irrigated area reported for the specific sub-national unit, also records with the second highest priority were considered. This distribution process was repeated down to the next lower priority level until the sum of irrigated area in the map was equal to the irrigated area in the sub-national statistics. In many sub-national units, lack of geospatial information on irrigation made is necessary to use indirect information to infer areas within the sub-national unit where irrigation is probable. Such information includes areas where the main irrigated crops are grown, or cultivated areas in very arid regions. For arid regions, remote sensing data were additionally used to verify the available maps.

4 Results

The total area equipped for irrigation in map version 3 of the Global Map of Irrigation Areas is 278.8 Mha. About 68 % is located in Asia, 17 % in America, 9 % in Europe, 5 % in Africa and 1 % in Oceania. The largest values of irrigated area on the country level are those for India (57.3 Mha), China (53.8 Mha), the United States (27.9 Mha) and Pakistan (14.4 Mha). The largest contiguous areas of high irrigation density are found in North India and Pakistan along the rivers Ganges and Indus, in the Hai He, Huang He and Yangtze basins in China, along the Nile river in Egypt and Sudan, in the Mississippi-Missouri river basin and in parts of California. Other areas of high irrigation density with regional importance are located along the Snake and Columbia rivers in the northwestern United States, along the western coasts of Mexico and Peru, in central Chile, in the rice growing areas along the border between Brazil and Uruguay, along the Danube and Po rivers in Europe, in the Euphrates-Tigris basin in Iraq and Turkey, the Aral sea basin, the Amu Darya and Syr Darya river basins, the Brahmaputra basin in China and Bangladesh, the Mekong delta in Vietnam, the plain around Bangkok in Thailand, the island of Java (Indonesia)

and the Murray-Darling basin in Australia. Smaller irrigation areas are spread across almost all populated parts of the world (Fig. 3).

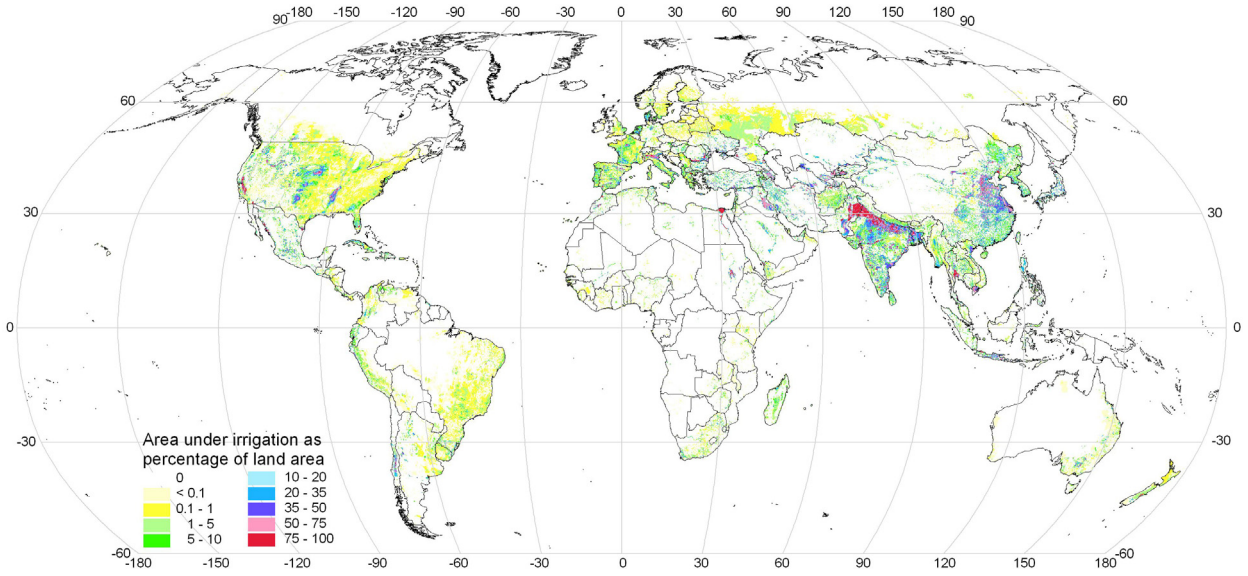

Figure 3. Global Map of Irrigation Areas Version 4: Percentage of 5-minute grid cell area that was equipped for irrigation around the year 2000 (Robinson projection).

5 Assessment of map quality

A common method to assess the quality of a macro-scale data set is to compare it with independent smaller-scale information at selected locations and then to draw conclusions with respect to the quality at these locations and in general. Here, however, a comparison to information collected at the ground would require to measure irrigated area of 5 arc minute by 5 arc minute grid cells, which is practically not feasible. Besides, any generalization would not be possible, as the map quality is different in each individual sub-national unit depending on the data sources used in the specific case. Instead, to assess the quality of the Global Map of Irrigation Areas, two indicators were computed that take into account the geospatial information density (section 5.1), and the map was compared to the irrigated areas of two global land cover inventories that are based on remote sensing (section 5.2).

5.1 Indicators of map quality

Because of the mapping methodology (see section 3), the quality of the mapping product is strongly influenced by the density and reliability of the used information. Thus the map quality differs from country to country and even within countries.

Two country-specific indicators were developed to quantify the density of information used as input data sources: indicator A (*IND_A*) represents the density of the used sub-national irrigation statistics while indicator B (*IND_B*) represents the density of the available geospatial records on position and extent of irrigated areas. Marks derived from the two indicators were combined to obtain a mark for the overall map quality for each country. The overall map quality mark was downgraded for a country when it was found that sub-national statistics coming from different sources disagreed, when statistics were found to be incomplete or when geo-spatial information was found to be out of date. Marks for the overall mapping quality in world regions or at global scale were computed as average of the marks for the overall quality at country level weighted by the irrigated area in the corresponding countries. A detailed description of the calculation of the two indicators is given in SIEBERT ET AL. (2005).

At the global scale, the overall map quality was good, but there were large regional differences of map quality (Tab. 1). At the level of world regions, map quality in North America (overall mark 1.03), Southern Europe (1.35), Oceania (1.44), Northern Africa (1.46), Southern Africa (1.50) and Central Asia (1.63) was best. Western Africa (2.90) and the Russian Federation (4.00) have the worst map quality.

Table 1. Sum of area equipped for irrigation in countries with very good, good, fair and poor map quality and resulting final mark for map quality for the entire world and 19 world regions.

	Sum of area equipped for irrigation (ha)				
Region	Very good	Good	Fair	Poor	Final mark
North America	27,913,872	785,046	0	0	1.03
Central America	65,608	6,975,342	1,146,204	3,000	2.13
South America	0	8,696,204	2,681,422	118,180	2.25
Northern Africa	3,422,178	2,891,641	0	0	1.46
Western Africa	27,216	138,354	911,040	75,763	2.90
Eastern Africa	1,894,774	330,623	1,575,821	21,430	1.93
Southern Africa	1,616,120	60,071	387,254	80,000	1.50
Western Europe	476,315	728,774	933,420	140,070	2.32
Eastern Europe	361,433	3,822,190	2,580,140	115,000	2.36
Southern Europe	8,261,998	4,450,761	0	0	1.35
Russian Federation	0	0	0	4,899,900	4.00
Near East	403,645	14,834,051	3,601,912	0	2.17
Central Asia	7,708,097	4,991,658	2,155,200	0	1.63
East Asia	525,528	57,832,365	1,517,300	0	2.02
South Asia	4,958,127	72,278,871	0	0	1.94
South-East Asia	5,565,415	7,821,600	3,406,320	0	1.87
Oceania	2,056,580	372	580,882	0	1.44
World	**65,256,907**	**186,637,922**	**21,476,915**	**5,453,343**	**1.88**

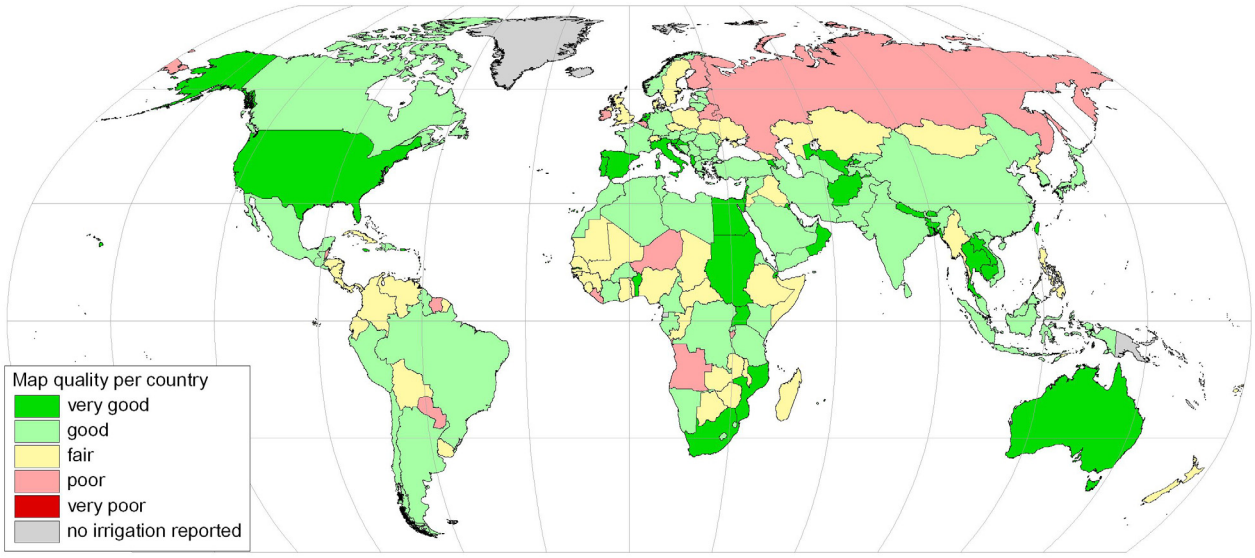

Figure 4. Global Map of Irrigation Areas Version 4: map quality by country (Robinson projection).

About 65 Mha of areas equipped for irrigation were located in countries where map quality was estimated to be very good, 187 Mha in countries with good map quality, 21 Mha in countries with fair map quality and 5 Mha in countries with poor map quality. Map regions of excellent or very poor map quality did not exist at the country scale (Fig. 4). Consequently about 90 % of the total irrigated area of the world was located in countries where the map quality was assessed to be very good or good.

5.2 Comparison to remote sensing based global land cover inventories

As result of a comparison of the previous map version 3 to the remote sensing based land cover inventories GLCC (Global Land Cover Characterization, USGS, 2000) and GLC2000 (Global Land Cover 2000 database, European Commission, Joint Research Centre, 2003) it was recommended not to use these inventories to extract irrigated areas (SIEBERT ET AL., 2005). A comparison to version 2 of the Global Irrigated Area Map GIAM10 km (THENKABAIL ET AL., 2006) showed that the corresponding Total Area Available for Irrigation (*TAAI*) is much larger in this data set (411.7 Mha). Furthermore it was found that the two global irrigation maps also differed at the country scale. Differences of the irrigated areas by country between these maps of less than 30 % were exceptional, even if only countries with more than 2 Mha irrigated area were considered (Tab. 2). This highlights that there is a need for a systematic comparison of the two data sets to reduce the uncertainty in global and regional estimates of the extent of irrigated areas.

Table 2. Total area equipped for irrigation (TAEI) in the Global Map of Irrigation Areas 4.0 and Total Area Available for Irrigation (TAAI) in the Global Irrigated Area Map 2.0 for countries with more than 2 Mha irrigated area reported by the statistics.

Country	*TAEI* in GMIA (FAO/UF) v. 4 (ha)	*TAAI* in GIAM10 km (IWMI) v. 2 (ha)
India	57,291,407	99,758,291
China	53,823,000	108,464,668
USA	27,913,872	27,593,858
Pakistan	14,417,464	13,169,652
Iran	6,913,800	2,449,769
Mexico	6,435,800	3,672,395
Thailand	4,985,708	6,457,890
Russia	4,899,900	21,724,537
Indonesia	4,459,000	3,042,001
Uzbekistan	4,223,000	3,478,349
Turkey	4,185,910	5,974,186
Italy	3,892,202	2,738,565
Bangladesh	3,751,045	5,125,146
Spain	3,575,488	3,297,105
Iraq	3,525,000	2,069,099
Egypt	3,422,178	2,086,783
Afghanistan	3,199,070	947,542
Brazil	3,149,217	4,045,823
Japan	3,129,000	2,421,219
Vietnam	3,000,000	4,263,540
France	2,906,081	2,392,733
Ukraine	2,395,500	2,897,304
Romania	2,149,903	2,284,667
Australia	2,056,580	12,491,207
World	**278,825,086**	**411,733,720**

6 Conclusions

The quality of the Global Map of Irrigation Areas, which was compiled by combining sub-national irrigation statistics for 26 909 statistical units with geo-spatial information on the location and extent of irrigation schemes, differs strong between countries and world regions, depending on the density and reliability of the used data sources. The overall map quality of version 4 of the global irrigation map is estimated as good. Improvements of the irrigation map are in particular necessary for Russia.

Large differences were found when comparing our Global Map of Irrigation Areas with the Global Irrigated Area Map, which was developed by IWMI and is mainly based on the application of remote sensing techniques. A systematic comparison to this map is necessary to identify (and if possible to reduce) sources of uncertainties in both data sets to get more consistent mapping results.

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