## Supplement S1: Country-wise description of input data and assumptions made to develop the global inventory of groundwater use in irrigation

AQUASTAT (FAO, 2009) was the major data source reporting area equipped for irrigation (AEI), area actually irrigated (AAI) and the source of irrigation water per country. We used the data recorded in the AQUASTAT main country data base (http://www.fao.org/nr/water/aquastat/data/query/index.html) or the information provided by AQUASTAT country profiles (http://www.fao.org/nr/water/aquastat/countries/index.stm). These data were replaced for many countries if:

- similar information from other sources became available at the sub-national scale
- no data have been available in AQUASTAT.

Data sources different from AQUASTAT (FAO, 2009) used to separate the extent of areas irrigated with groundwater (AEI_GW), areas irrigated with surface water (AEI_SW) and areas irrigated with nonconventional water sources (AEI_NC) are documented below for each country. Water was assumed to represent groundwater if it was extracted from wells, tube-wells, boreholes or springs. Water was assumed to be surface water if it was extracted from rivers, reservoirs, lakes, streams, dams, canals, wetlands, ponds or tanks. Waste water and water produced by desalinization plants represented water from non-conventional sources. Spate irrigation areas and equipped wetlands and inland valley bottoms were assumed to be irrigated with surface water. Furthermore it was assumed that water supplied by public networks and water extracted from "other sources" represents a mixture of water from different sources with the same fraction of groundwater, surface water and non-conventional water as computed before by using water from known sources. Percentage of AEI irrigated with groundwater (PCT_AEI_GW) was computed as follows:

$$PCT\_AEI\_GW = 100 * AEI\_GW / (AEI\_GW + AEI\_SW + AEI\_NC) \quad (1)$$

where AEI_GW was the area equipped for irrigation irrigated with groundwater (ha), AEI_SW was the area equipped for irrigation irrigated with surface water (ha) and AEI_NC was the area equipped for irrigation irrigated with water from non-conventional sources (ha). For countries not listed below the separation of AEI into AEI_GW, AEI_SW and AEI_NC was completely based on AQUASTAT statistics at the country level. Sources used to define AEI per subnational unit are only reported if AEI and the related reference for it differed from the statistics used to develop version 4 of the global map of irrigation areas GMIA (Siebert et al., 2005; updated by Siebert et al., 2006).

# AFRICA

### Algeria:

Irrigated area from groundwater for each of the five hydro geographic regions of Algeria was computed based on the reported percentages of groundwater use in full/partial control irrigation areas in these regions (FAO, 2008a). 3000 ha irrigation area using non-conventional water sources was assigned to each of the four northern regions (Oranie – Chott Chergui, Cheliff – Zahrez, Algérois – Hodna – Soummam, Constantinois – Seybouse – Mellegue).

### Angola:

Information on the actual extent of irrigation is Angola is very scarce. The last information on AEI used by FAO AQUASTAT and in the GMIA refers to year 1975 (about 80 000 ha). In contrast, AEI was 340 478 ha in year 2005 according to a recently published report (SWECO Grøner, 2005). Another study reported an AEI of 85 829 ha but considered only 7 of the 16

provinces (MINADER, 2005). In any case it is sure that large parts of this area are currently not in operation and area actually used for irrigation was estimated at 35 000 ha (FAO, 2009). The information on water sources for irrigation is also very week. In year 1974 all irrigation was from surface water (FAO, 2009). However, according to the SWECO Grøner assessment use of groundwater for irrigation is important in the coastal area and in the southwestern provinces, especially in the basins of Dande, Bengo, Cuanza, Longa, Queve, Cunene and Cubango were water taken from the alluvium after rivers have dried up (SWECO Grøner, 2005). Based on this qualitative information AEI irrigated with groundwater was estimated at 20% while extent of AEI was set to 80 000 ha.

**Burkina Faso:**
Based on the classification of full/partial control schemes and equipped wetlands in the AQUASTAT country profile (FAO, 2009) irrigated area from groundwater was estimated being 3000 ha while area irrigated with surface water was estimated at 22 000 ha.

**Burundi:**
Since wells are only used for drinking water (FAO, 2009) irrigated area from groundwater was set to 0.

**Comoros:**
Groundwater extracted by boreholes is the only water source on Grand Comoros while water use on the other two islands is from surface water (rivers). Irrigated area on Grand Comoros was 5 ha and thus about 4% of the total irrigated area (FAO, 2005). Therefore percentage of irrigated area from groundwater sources was estimated at 4%.

**Egypt:**
In year 2000 about 11% of the irrigated area of the country (361 176 ha) was irrigated from groundwater and 217 527 ha from mixed water while the remaining 2 843 475 ha were irrigated from surface water (FAO, 2009). Groundwater extraction is concentrated in desert oases, on the Sinai peninsula and the New Valley (FAO, 2009) and therefore in the related provinces of Matruh, Al Wadi al Jadid, Al Jizah, Janub Sina and Shamal Sina. Total irrigated area in these provinces was 331 927 ha. The province Al Jizah was split in a western part representing oases agriculture and an eastern part representing irrigation using water from the Nile River. It was assumed that irrigation in the provinces mentioned before (except the eastern part of Al Jizah) was from groundwater. The remaining groundwater irrigation area, the area irrigated from mixed water and the irrigation area from surface water was assigned to the remaining part of the country representing mainly the use of River Nile water, reused drainage water and treated waste water.

**Eritrea:**
About 16 800 ha are equipped for full/partial control irrigation and 51 970 ha for spate irrigation (Government of Eritrea, 2008). The percentage of groundwater use in full/partial control schemes was 96.6% in year 1993 (FAO, 2009). It was assumed that this percentage still represents recent day conditions resulting in an area irrigated with groundwater of 16 229 ha.

**Ethiopia:**
The percentage of AEI irrigated with groundwater was computed for each province by using an inventory reporting the water sources of 791 irrigation schemes (Awulachew et al., 2007). Total AEI in this inventory was 107 266 ha. The inventory did not report spate irrigation which may be practised on more than 100 000 ha (Government of Ethiopia, 2008). This may

explain the difference to the total irrigated area reported by the Ministry of Water Resources (289 530 ha) and reported in the AQUASTAT country profile (FAO, 2009). In any case irrigation using groundwater (mainly from springs) is practised only on a small scale in the provinces of Dire Dawa, Harari, Oromia and Amhara. Since no data were available for Addis Ababa it was assumed that the percentage of groundwater use is similar to that one computed for Harari. Total area irrigated with groundwater computed that way was 2611 ha. It was assumed that AAI is similar to AEI (FAO, 2009).

**Gabon:**
Based on the qualitative information contained in the AQUASTAT country report (FAO, 2009) and groundwater use in neighbouring countries (Cameroon, Republic of Congo) it was assumed that all irrigation is from surface water.

**Gambia:**
Irrigated area in year 1999 was 2149 ha. Only 15 ha were irrigated with groundwater from wells and boreholes in the Lamin Horticultural Project and the Bakau Horticultural Project. The other irrigation schemes used surface water provided by pumping from the river or by tidal irrigation (FAO, 2005).

**Ghana:**
By year 2000, AEI in formal irrigation schemes consisted of 8587 ha in public schemes and 10 413 ha in private schemes (FAO, 2009). The extent of informal peri-urban irrigation is not exactly known. Alone in the area around Kumasi about 11 900 ha were reported (FAO, 2009) and the total extent of peri-urban irrigation in Ghana was estimated at 40 000 ha (Drechsel et al., 2006). While the area in formal irrigation schemes is irrigated with surface water (FAO, 2009), farmers in informal irrigation use different water sources like shallow wells, streams, waste water or pipe-born water (Drechsel et al., 2006). Based on the information in Drechsel et al. (2009) we estimated that 3% of the informal irrigation area is irrigated with waste water, 30% with groundwater and 67% with surface water.

**Lesotho:**
By 1999, out of the 2637 ha equipped for irrigation only 67 ha were still under operation (FAO, 2009). While the large scale schemes (mainly sprinkler irrigation) went completely out of operation, small scale irrigation for vegetable production was successful. While rivers are the water source of large scale schemes, water for small scale agriculture and home gardens is extracted from the domestic supply system or from small streams or ponds using pumps. Irrigation potential from groundwater is limited to the area around Maputoe (FAO, 2009). Based on this information AEI and AAI using groundwater was estimated at 50 ha.

**Liberia:**
Based on the qualitative information contained in the AQUASTAT country reports (FAO, 2009) and groundwater use in neighbouring country Guinea, percentage of irrigation area from groundwater was estimated at 0.5%.

**Morocco:**
Irrigated area of private irrigation schemes was available for 16 regions distinguishing wells, springs, reservoirs, treated waste water, mixed sources and water from transfers (FAO, 2008b). The total area of private irrigation schemes in year 2002 was 626 609 ha and more than 90% used groundwater. In contrast, public irrigation schemes mainly used irrigation water extracted from surface water sources (FAO, 2009). The separation of irrigated areas from groundwater and surface water for the public irrigation schemes was based on Table 3 in

FAO (2008b) and AQUASTAT data reported in Tables 12 and 13 of the country profile Morocco (FAO, 2009). Total groundwater irrigation area computed that way was 677 201 ha (46% of total).

**Mozambique:**
In most irrigation schemes of Mozambique surface water from rivers is being used. Groundwater is used to a very limited extent by the family smallholder sector (FAO, 2009). Based on this qualitative information it was assumed that groundwater is used by 10% of the small scale schemes (<50 ha). This resulted in a total of 639 ha (about 0.5% of the total irrigation area).

**Namibia:**
Location and extent of schemes irrigating with groundwater was derived from an inventory related to year 1999 (Christelis and Struckmeier, 2001). Total AEI irrigated with groundwater according to this inventory was 1632 ha or 22% of total AEI. The sum of AEI irrigated with groundwater was then computed for each of the 23 basins contained in version 4 of the GMIA as subnational units of Namibia. It was assumed that AAI was similar to AEI.

**Niger:**
Percentage area irrigated from groundwater was set to the related percentage of irrigation water use from groundwater (1.86%).

**Nigeria:**
Irrigation in the public irrigation schemes is predominantly from surface water sources (rivers, lakes, reservoirs). An inventory of 62 public irrigation schemes covering 82 205 ha listed 60 irrigation schemes having surface water supply and two schemes (in total 240 ha) having supply from groundwater (ENPLAN Group, 2004). In contrast, water supply in the private sector was reported to be mainly from shallow wells or small streams (FAO, 2009). It was assumed, that the percentage of irrigation area supplied from groundwater for public and state farms was similar to the percentage reported by ENPLAN Group (2004) while for the private irrigation schemes 50% groundwater supply was assumed. Irrigation in the traditional fadama-system was assigned to surface water supply because this system represents wetland cultivation using flood recession water. Although it was reported that farmers in the fadama-system also use wells to extract the water (FAO, 2009), most of these structures are not permanent and move from year to year. This procedure resulted in 66 800 ha AEI irrigated with groundwater (about 23% of total AEI).

**Réunion:**
See French over-sea departments in section Europe.

**Rwanda:**
Based on the qualitative information contained in the AQUASTAT country report (FAO, 2009) and groundwater use in neighbouring countries (Cameroon, Republic of Congo) it was assumed that only 1% of the irrigation area has groundwater supply.

**Sao Tome and Principe:**
All irrigation is reported to be from surface water sources (FAO, 2005).

**Sierra Leone:**

Based on the qualitative information contained in the AQUASTAT country reports (FAO, 2009) and groundwater use in neighbouring country Guinea, percentage of irrigation area from groundwater was set to 0.5%.

**Somalia:**
Before the outbreak of the civil war in 1991 area equipped for irrigation was 200 000 ha of which 50 000 ha AEI was full/partial control surface irrigation and 150 000 ha spate irrigation (FAO, 2009). Full/partial control irrigation was mainly practised along the Juba and Shabelle rivers in the southern part of the country while in the dryer northern part of Somalia irrigation is practised as small-scale irrigation in dry riverbeds or adjacent areas, using water pumped from shallow wells and as spate irrigation. The war has affected most of the full/partial control schemes in the south so that today hardly any scheme is fully operational (SWALIM, 2007a). In contrast most of the small-scale irrigation in the northern part is operational. To assign groundwater and surface water supplied irrigation areas, the country was split into a northern part and a southern part. Water supply is the southern part is from surface water (SWALIM, 2007a). To the northern part we assigned 10 000 ha of groundwater irrigation representing extraction of irrigation water from springs and by wells (SWALIM, 2007b) and the remaining irrigation was assumed to be from surface water (representing spate irrigation areas).

**Swaziland:**
In 2000, total AEI was 49 843 ha (FAO, 2009). Public and private large scale schemes usually extract the irrigation water from reservoirs, while in small scale private schemes irrigation water is normally abstracted directly from the rivers using electric pumps (Riddell and Manyatsi, 2003). Based on this information AEI using groundwater was estimated at 1000 ha.

**Tunisia:**
Total irrigated area per region in year 2006 was derived from the National Investment Brief Tunisia released on occasion of the conference "Water for Agriculture and Energy in Africa" (Government of Tunisia, 2008). The separation into surface water and groundwater supply and irrigation areas from non-conventional sources was available for each of the regions (AGRIDEV, 2009) while the spate irrigation area per governorate was based on AQUASTAT data. The computed country totals agree well with statistics reported in the AQUASTAT country profile (FAO, 2009).

**Uganda:**
Based on the qualitative information contained in the AQUASTAT country report (FAO, 2009) and groundwater use in neighbouring countries (Cameroon, Republic of Congo) it was assumed that only 1% of the irrigation area has groundwater supply.

**United Republic of Tanzania:**
According to the report of the agricultural census 2003 irrigated area in season 2002/2003 was 166 710 ha in small-scale farms (National Bureau of Statistics, 2007) and 27 054 ha in large-scale farms (National Bureau of Statistics, 2006), which is summing up to 193 764 ha. In contrast, an inventory of irrigation schemes prepared for the National Irrigation Master Plan (NIMP) reported an AEI of 184 330 ha (Ministry of Agriculture and Food Security, 2002). Both inventories disagreed significantly in reported irrigated areas, in particular at the district level but also at the regions-level. Reasons for the disagreement maybe that the census was a sample census considering less than 30% of all villages and the use of different definitions for irrigated land (e.g. related to rainwater harvesting). AEI was therefore computed in this study as the average of the irrigated areas reported by the census reports and the NIMP. AEI

irrigated with groundwater was computed based on the number of farms using the water sources river, lake, canal, dam, well, and borehole reported for each district in the census reports, resulting in an AEI irrigated with groundwater of 17 465 ha or 9.2% of total AEI. It was assumed that AAI was similar to AEI.

**Zambia:**
Area irrigated with groundwater was 6646 ha or 12% of the full/partial equipped irrigated area in year 2002 (FAO, 2009), most of it located on dolomite or limestone aquifers in the copperbelt region (Jacob Burke, FAO, pers. communication). Based on this information and a geological map of the Kafue basin (Burke, 1994), 3000 ha AEI irrigated with groundwater were assigned to each of the provinces of Copperbelt and Lusaka and the remaining part to the rest of the country.

**Zimbabwe:**
Total AEI was estimated at 173 513 ha in year 1999 and most formal irrigation schemes in the country depend on water stored in small- and medium-sized dams (FAO, 2009). It was estimated that more than 17 000 ha of agricultural land are irrigated commercially using groundwater (Masiyandima and Giordano, 2007). It is however not reported whether these statistics refer to the area actually irrigated or to the area equipped for irrigation. Based on this information AEI using groundwater was estimated at 20 000 ha.

## AMERICA

**Central America (Belize, El Salvador, Guatemala, Honduras, Panama):**
Sub-national statistics on areas irrigated with surface- and groundwater were extracted from Ballestero et al. (2007) and references cited therein. AAI was computed based on the AEI reported in Ballestero et al. (2007) and the ratio between AAI and AEI reported in FAO, 2000.

**Antigua and Barbuda:**
Surface supplies were reported to be the main source of irrigation water with occasional use of groundwater when municipal demand allows (FAO, 2000). Based on this qualitative information AEI irrigated with groundwater was estimated at 15%.

**Argentina:**
AEI irrigated with groundwater was estimated for each district based on the total number of farms irrigating by using different sources of water as reported by the agricultural census 2002 (INDEC, 2006). Percentage of AEI irrigated with groundwater was computed as 100 * NR_FARMS_GW / (NR_FARMS_GW + NR_FARMS_SW) where NR_FARMS_GW was the number of farms irrigating using groundwater and NR_FARMS_SW was the number of farms irrigating using surface water. The total area irrigated with groundwater computed this way was 323 415 ha or 24% of the total irrigated area reported by the census data base. This is close to the estimates reported by AQUASTAT for year 1999 (26%).

**Barbados:**
Irrigation water use is mainly based on the use of 120 private hand-dug wells while use of dams and streams is very limited (FAO, 2000). Based on this qualitative information amount of irrigation area supplied by groundwater was estimated to be 90%.

**Brazil:**

Sub-national irrigation statistics available for Brazil do not distinguish the source of water supply for irrigation (ANA, 2005a). To estimate the percentage of irrigation areas supplied by groundwater we used therefore an inventory of wells used for irrigation (Serviço Geológico do Brasil, 2009) and reports showing the extent and describing the characteristics of the major aquifers of Brazil (Ministério do Meio Ambiente, 2006; ANA, 2005b). The extent of the aquifers was digitized from the maps contained in these reports. The aquifers were classified into 5 groups depending on the reported mean capacity of wells fed by the aquifers (Table S1). Using version 4 of the GMIA (Siebert et al., 2006) we computed for each county the sum of AEI covering these aquifers and considering the weights shown in Tab. S1 the potential sum of AEI irrigated with groundwater. Next we estimated for each county a sum of potential groundwater irrigation area defined by existing wells. We considered 6841 registered wells that were reported to be used for irrigation and assigned to each well an irrigation area depending on the aquifer in which the well was located (Table S1). The total potential groundwater irrigation area computed based on the coverage by major aquifers was 562 628 ha and the area computed based on the number and location of tube wells was 83 956 ha. Finally, we computed for each county the sum of both potential groundwater irrigation areas and limited this sum to be not larger than the total AEI reported in the agricultural census 1996 (IBGE, 2002). Total AEI from groundwater computed that way was 591 439 ha and thus close to the area reported by AQUASTAT for year 1998 (545 000 ha).

**Table S1.**
Parameters used to estimate area irrigated with groundwater per municipal unit in Brazil.

| Aquifer productivity class | Mean capacity of wells ($m^3$ $h^{-1}$) | Weights assigned to compute irrigated area from groundwater (-) | Irrigated area assigned to each registered tube well (ha) |
|---|---|---|---|
| Very high | 30 | 1.00 | 30 |
| High | 15 | 0.50 | 15 |
| Medium | 10 | 0.25 | 10 |
| Low | 5 | 0.10 | 5 |
| Very low | 2 | 0.00 | 2 |

**Canada:**
Sources of irrigation water were available for the provinces of Alberta (per basin), British Columbia (per water region) and Ontario (Alberta Environment, 2007; Ministry of Agriculture and Food, 2000; National ad-hoc Committee on Groundwater, 2003). More than 80% of the total irrigated area of the country is located in these three provinces. For the other provinces area irrigated from ground- and surface water was estimated based on statistics and information provided by several other reports (CBCL Limited, 2003; Kulshreshtha, 2006; Saskatchewan Environment, 2005). Total AEI_GW was 81 395 ha. Irrigated area in year 2005 (1 123 873 ha) was derived from the agricultural census report (Statistics Canada, 2007).

**Chile:**
Area irrigated from groundwater was 58 900 ha (3.2% of total AEI) in year 1999 (AQUASTAT database). An inventory of registered irrigation schemes indicating the source of irrigation water was available (Dirección de Obras Hidráulicas, 2009) but covered only 1 010 113 ha and listed only 3800 ha of irrigation areas supplied by groundwater. Therefore an inventory of registered wells (Comisión Nacional de Riego, 2008) showing the location of about 5000 wells used for irrigation was used to define irrigated area from groundwater for each district by assigning a constant irrigated area to each well so that the total irrigated area from groundwater was equal to the 58 900 ha reported by FAO AQUASTAT. AAI was derived from statistics collected by the agricultural census 2007 (INE, 2009). AEI was

computed by scaling the difference between AAI and total cultivated land (INE, 2009) for each district so that AEI per region was similar to AEI per region reported in the AQUASTAT country report (FAO, 2009). In regions where AAI reported for year 2007 was larger than AEI reported by AQUASTAT for year 1999, AEI was set to AAI reported for year 2007. This resulted in a total AEI of 1 936 402 ha.

**Colombia:**
Very little information has been available regarding the source of water used for irrigation. The available data indicate that surface water from rivers, reservoirs and lakes is by far the major source of irrigation water. An inventory of wells per hydro-geological zone shows that only in the major irrigation areas along the Magdalena and Cauca Rivers and in the surrounding of Bogota there is a significant number of wells used for irrigation (Leyva, 2001).Based on this indicative information and also considering the situation in neighbouring countries, percentage of AEI irrigated with groundwater was estimated at 5%.

**Cuba:**
AEI was 870 317 ha in year 1997. AAI declined from 822 225 ha in 1997 (FAO, 2000) to 180 900 ha in year 2007 (ONE, 2008). In year 1997 about half of the AEI was irrigated with groundwater (FAO, 2000). It was assumed that the percentage of AEI irrigated with groundwater in year 2007 was similar to the percentage reported for year 1997. AEI was assumed to be similar to AEI reported for year 1997.

**Dominican Republic:**
AEI in 2009 was 306 485 ha (INDRHI, 2009a) of which 257 747 ha were actually irrigated in season 2003/2004 (INDRHI, 2009b). About 22% of the AEI were irrigated with groundwater in year 1999 (FAO, 2000) and we assumed that this also represents current day conditions.

**Ecuador:**
AEI and the source of irrigation water per province were derived from the database of the agricultural census 2000 (INEC, 2008). Total AEI was 853 332 ha, of which 105 120 ha were irrigated with groundwater extracted by wells.

**French Guiana:**
See French over-sea departments in section Europe.

**Grenada:**
All irrigation in Grenada is assumed to be based on surface water, 1% from river diversion, 6.5% from reservoirs and the remainder from direct pumping from rivers (FAO, 2000).

**Guadeloupe:**
See French over-sea departments in section Europe.

**Guyana:**
Irrigation water supply in Guyana is from reservoirs (so called conservancies) using a network of main and secondary canals or from rivers through pumping. In contrast, domestic water supply in the coastal area is mainly depending on groundwater (FAO, 2000). Based on this information it was assumed that all irrigation is from surface water.

**Haiti:**
Very little information has been available related to sources of irrigation water in Haiti. The largest irrigation scheme in the country (35 411 ha area equipped for irrigation, 39% of total

irrigation area in Haiti) is located in the Artibonite valley and uses water from the Artibonite River (FAO, 2000). Also, it was reported, that total groundwater resources of the country account for 17% of the total water resources. Based on this information percentage of irrigated area from groundwater sources was estimated at 15%.

**Jamaica:**
It was estimated that 92% of the total water withdrawal in year 1993 was from groundwater and that agriculture accounted for 75% of the withdrawals (FAO, 2000). This gives evidence for the importance of groundwater use in irrigation. Based on this information percentage of irrigated areas supplied by groundwater was estimated at 90%.

**Martinique:**
See French over-sea departments in section Europe.

**Mexico:**
Ground- and surface water use for irrigation by county was extracted from a database provided by CONAGUA (Comisión Nacional del Agua, 2008a). The data are consistent to statistics published per province in the annual water report (Comisión Nacional del Agua, 2008b). It was assumed that the percentage of AEI irrigated with groundwater was similar to the percentage of water use for irrigation that was from groundwater. Total AEI irrigated with groundwater computed that way was 2 489 785 ha (39%) while total AEI irrigated with surface water was 3 929 018 ha (61%).

**Nicaragua:**
According to the agricultural census 2001 AEI was 133 673 ha (INIDE, 2002). No statistics on AAI or on the source of water for irrigation were available from the census. Therefore AAI was computed using the ratio between AAI and AEI reported for year 1998 (FAO, 2000). The percentage of AEI irrigated using groundwater was derived from the same source. These statistics referred to year 1997.

**Paraguay:**
Water extracted from small streams and rivers is the major source of irrigation water in Paraguay (FAO, 2000; Espínola, 2005) while artesian wells are used at some places. Based on this indicative information percentage of irrigated area from groundwater sources was estimated at 10%.

**Peru:**
Irrigated area from wells, rivers, lakes, springs, reservoirs and combinations of these water sources were derived for each district from the agricultural census database (INEI, 2009). The statistics refer to year 1994. Irrigated area from groundwater was computed as the sum of irrigated area from wells, springs and half of the irrigated area of locations irrigated from both, wells and rivers. Total AEI irrigated with groundwater computed this way was 489 948 ha while AEI irrigated with surface water was 1 239 118 ha. AAI was computed by multiplying the ratio between AAI and AEI available at the department level for year 1992 (DGAS, 1992).

**Puerto Rico (USA):**
AEI per county was derived from the Global Map of Irrigation Areas (Siebert et al., 2005). Fraction of AEI from groundwater assumed to be equal to the average fraction of groundwater irrigation water use reported in the water censuses 1995 and 2000 of USGS (USGS, 2005; USGS, 1998). AAI was derived from the agricultural census report of the USDA for year

2002 (NASS, 2004c) or, if there was no data for this year, it was set to values reported in the same publication for year 1997.

**Saint Kitts and Nevis:**
In Nevis approximately 10 ha of land are irrigated half from groundwater and half from surface water. On Saint Kitts 8 ha land are irrigated mainly from the domestic water supply which is from six surface water intakes (small streams) and five wells (FAO, 2000). Based on this information AEI irrigated with groundwater was estimated to be 50% of total AEI.

**Saint Lucia:**
It was assumed that the whole AEI is irrigated with surface water because even for domestic purposes water from groundwater is exceptional (FAO, 2000). This estimate is supported by a description of two main irrigation projects extracting water from the Cul-de-Sac and Roseau rivers (Ministry of Agriculture, Forestry and Fisheries, 2002).

**Trinidad and Tobago:**
Data related to the source of irrigation water were not available for Trinidad and Tobago. However, surface water resources were reported to be much larger than groundwater resources and the largest irrigation scheme of the country uses water diverted from the Caroni River (FAO, 2000). It was furthermore reported that small scale private developments use water extracted from small streams. Based on this information the percentage of irrigated area that is using groundwater was estimated at 10%.

**United States of America (mainland + Hawaii + Alaska):**
AEI per county was derived from the Global Map of Irrigation Areas (Siebert et al., 2005). The percentage of area irrigated with groundwater was derived for each federal state from the Farm and Range Irrigation Surveys (FRIS) of the US Department of Agriculture (NASS, 2004a; NASS 1999). These statistics reported the extent of irrigated areas using wells, on-farm surface water and off-farm surface water. We further downscaled these statistics by using county-level data on irrigation water extraction from ground- and surface water (USGS, 2005; USGS, 1998) by assuming that the ratio between irrigated areas from ground- and surface water was similar to the ratio between groundwater use and surface water use for irrigation. AAI was derived from statistics reported for each county by the agricultural census for year 2002 (NASS, 2004b) or, if there was no data for this year, to values reported in the same inventory for year 1997.

**United States Virgin Islands (USA):**
In year 2002, 23 farms used public utilities as water supplier for irrigation, 77 farms used wells or cisterns and 12 farms used water extracted from lakes or ponds (NASS, 2005). Percentage area irrigated with groundwater was computed based on the number of farms reporting the different water sources and by assuming that the share of groundwater in the public supply system is 80%. AAI was derived from the agricultural census report of the USDA for year 2002 (NASS, 2005).

**Uruguay:**
In year 2000 the number of farms with irrigation equipment was 5608 and 2645 farms (47.1%) used groundwater sources for irrigation. AAI in year 2000 was 217 593 ha. The most important irrigated crop was rice with an irrigated area of 174 728 ha or about 80% of the total AAI (Ministerio de Ganadería, Agricultura y Pesca, 2001). Unfortunately the area irrigated with groundwater was not reported in the agricultural census statistics. However, in year 1998 only 4% of the rice area was irrigated with groundwater while about 50% of the

horticultural area was irrigated with groundwater (FAO, 1999). The number of horticulture farms using irrigation was 3793 in year 2000 while the irrigated horticulture area was 10 846 ha (Ministerio de Ganadería, Agricultura y Pesca, 2001) which could explain the large total number of farms irrigating with groundwater but relative small areas involved. Based on these statistics we estimated that 6989 ha rice, 5423 ha horticulture and 4800 ha other crops were irrigated with groundwater. Furthermore we estimated AEI at 243 419 ha because 595 farms that reported irrigation infrastructure, did not irrigate in year 2000.

## ASIA (EXCL. RUSSIAN FEDERATION)

### Afghanistan:

An inventory available from the FAO-AQUASTAT library related to year 1967 listed areas irrigated from streams, canals, springs, kharezes and wells for each province. The total area irrigated with groundwater according to this inventory was 367 240 ha (15.4%) while area irrigated with surface water was 2 018 050 ha. The numbers found in this inventory agree very well with statistics reported in a more recent publication (Qureshi, 2002). Therefore we used this inventory to compute the percentage of area irrigated with groundwater for each province. AEI was similar to the Global Map of Irrigation Areas (Siebert et al., 2005), in total 3 199 070 ha. AAI was computed by scaling AEI so that total AAI per region was similar to the statistics reported for season 2001/2002 (Maletta and Favre, 2003), in total 1 731 784 ha. AEI_GW computed that way was 575 211 ha (18% of total AEI), AAI_GW was 282 337 ha (16% of total AAI).

### Bangladesh:

The percentage of AAI from groundwater was computed by using statistics on the source of irrigation water per greater district (Ministry of Agriculture, 2007) that referred to the season 2004/05. Since these statistics (and other statistics provided for example by the Bangladesh Bureau of Statistics) refer to gross irrigated areas, AAI per greater district was computed as the sum of growing areas of the irrigated crops boro rice, wheat, potato, sugar cane, cotton, vegetables and others published in the same handbook. Total AAI computed that way was 4 695 520 ha, of which 3 458 592 ha (74%) were from groundwater and 1 236 928 ha (26%) from surface water. It was assumed that AEI is similar to AAI.

### China:

#### *Mainland:*

Province data on AEI, AAI and AEI irrigated with ground- and surface water was extracted from Ministry of Water Resources (2006). It was thereby assumed that the AEI irrigated with groundwater is similar to the area covered by tube wells.

#### *Taiwan Province of China:*

Area irrigated from groundwater and surface water sources was derived for each county and city from the report of the agriculture, forestry, fishery and husbandry census 2005 (Statistical Bureau, 2007). It was assumed that the area supplied by “irrigation associations”, “rivers and ponds” and “other sources” represented area irrigated with surface water while area served with “groundwater” represented area irrigated with groundwater.

### Cyprus:

AEI in the Republic of Cyprus was 45 452 ha in 2003, while AAI was reported to be 35 931 ha (CYSTAT, 2004). It was assumed, that 51.2% of the area is irrigated with groundwater, 48.2% with surface water and 0.5% with water from nonconventional sources (FAO, 1997b). In North Cyprus, 10 006 ha were irrigated in year 2002 (Elkiran and Ergil, 2006) and based on the amount of water consumption from different sources we estimated that 90% of the AEI

in North Cyprus was estimated with groundwater, 7% with surface water and 3% with water from nonconventional sources.

**Guam (USA):**
In year 2002, by far the most of the irrigating farms used water from public utilities for irrigation (136 of 142 farms in total; NASS, 2004d). Based on this information the percentage of area irrigated with groundwater was assumed to be 80%. AAI was derived from the agricultural census report of the USDA for year 2002 (NASS, 2004d) or, if there was no data for this year, it was set to values reported in the same publication for year 1997.

**India:**
Data on the extent of area equipped for irrigation is not collected by statistical surveys in India. Therefore, statistics on the Net Irrigated Area (NIA) provided by the reports and data bases of the Agricultural Census 2000/2001 of the Ministry of Agriculture (Ministry of Agriculture, 2009a), the Input Survey 2001/2002 of the Ministry of Agriculture (Ministry of Agriculture, 2009b), and the Minor Irrigation Census 2000/2001 of the Ministry of Water Resources (Ministry of Water Resources, 2005) were used to estimate AEI. NIA does not account for AEI that were left fallow or were completely rainfed in the year of the statistics. NIA is therefore likely to be lower than the AEI. AEI per district was computed as the maximum of NIA reported by the three inventories aforementioned. The percentage of area irrigated with groundwater was computed by using the agricultural census statistics and the minor irrigation census statistics because these inventories also reported the source of irrigation water. In general, percentage of area irrigated with groundwater (P_AEI_GW) was computed as follows:

$$P\_AEIGW = 100\frac{Max(NIAGW\_AGC, NIAGW\_MIC)}{Max(NIAGW\_AGC, NIAGW\_MIC) + Max(NIASW\_AGC, NIASW\_MIC)} \quad (2)$$

where NIAGW_AGC was the NIA irrigated with groundwater according to the Agricultural Census (ha) , NIAGW_MIC was the NIA irrigated with groundwater according to the Minor Irrigation Census (ha) and NIASW_AGC and NIASW_MIC were the respective net irrigated areas irrigated with surface water as reported by the two census data bases (ha). Exceptions from this general procedure are documented in the following by federal state:

***Andaman and Nicobar Islands:***
Only Minor Irrigation Census data was used.

***Arunachal Pradesh:***
Data from the Minor Irrigation Census was used because in the agricultural census data base most of the NIA was assigned to "other sources", it was assumed that "Major/medium schemes" in MIC represent surface water sources (862 ha of 39 958 ha total NIA).

***Bihar:***
In the agricultural census data base there was no data, therefore another inventory reporting NIA for season 1993/1994 (Government of Bihar, 1996) was used as second data source.

***Daman and Diu:***
Because of missing data in the Minor Irrigation Census, only the Agricultural Census data base was used.

***Jharkhand:***
In the agricultural census data base there was no data, therefore another inventory reporting NIA for season 1993/1994 (Government of Bihar, 1996) was used as second data source.

***Lakshadweep:***
It was assumed that all irrigation is from groundwater.

***Meghalaya:***

In the agricultural census data base there was no data, therefore the Minor Irrigation Census was used as the only data source.

***Uttar Pradesh:***

The percentage of AEI irrigated with groundwater was computed by assuming that all areas reported in category "others" refer to irrigation from surface water to account for the specific relevance of water extractions from rivers and reservoirs in some districts of the state.

Total AEI computed that way for India was 61 907 846 ha, of which 39 425 869 ha (63.7%) were irrigated with groundwater and 22 481 977 ha (36.3%) were irrigated with surface water. AAI was computed for each district as maximum of AEI_AGC and AEI_MIC and neglected therefore the statistics collected by the Input survey in period 2001/02. Total AAI estimated that way for year 2001 was 58 129 630 ha.

**Indonesia:**

AEI was 4 427 922 ha in year 1995 and irrigation from groundwater covered an area of 44 209 ha or 1% of total AEI (FAO, 2000). Following the categorization used by FAO (only technical and semi-technical systems are included in AEI) AEI increased to 6 039 057 ha in year 2005 (Ministry of Public Works, 2006). We assumed that the percentage of area irrigated with groundwater did not change between 1995 and 2005.

**Iran (Islamic Republic of):**

Percentage of irrigation water use from ground- and surface water reported for 8 water regions and year 1995 (Bybordi, 2002) was combined to the Global Map of Irrigation Areas (Siebert et al., 2005) to compute AEI irrigated with groundwater for each region. It was assumed that the ratio between AEI irrigated with groundwater and total AEI was similar to the ratio between irrigation water use from groundwater and total irrigation water use. AEI from groundwater computed that way for the whole country was 55% and scaled to meet the 62.1% percentage irrigated area with groundwater supply reported in the AQUASTAT data base for year 2003 (FAO, 2009). AEI in year 2003 was 8 297 031 ha while AAI was 6 423 342 ha (Statistical Centre of Iran, 2006).

**Israel:**

49% of the total water use in Israel is from groundwater, 33% from surface water (extraction from the Jordan River) and 13% from treated wastewater and 5% from desalination plants (ARIJ, 2007). About two third of the water use is for irrigation. About 90% of the fresh water resources have been incorporated into a single system that enables implementation of a uniform national policy of water production and regular supply to the different sectors of consumers (Sitton, 2000). This also means that water from different sources is mixed and transported over long distances. Therefore it was assumed that the partitioning of water supply into different water sources also represents the percentages of irrigated area irrigated from the corresponding water sources.

**Japan:**

AEI was 3 128 079 ha in year 1993, comprising of 2 781 411 ha irrigated paddy fields and 346 668 ha irrigated upland fields. The whole irrigated area was irrigated with surface water. Additionally, 500 000 ha were irrigated with groundwater mainly in the dry season (FAO, 2000). The total extent of paddy fields decreased to 2 530 000 ha in year 2007 and the rice growing area reduced from 2 118 000 ha in 1995 to 1 688 000 ha in year 2006 indicating the growing diversification of crops in paddy fields (Statistics Bureau, 2009). Even when assuming that all paddy fields are irrigated and that the irrigated area in upland fields did not decrease, total AEI in year 2006 was 2 876 668 ha at maximum. Based on these data and

additional statistics (Ministry of Agriculture, Forestry and Fisheries, 2009) we estimated AEI at 2 800 000 ha and AAI at 2 600 000 ha. We assumed that 500 000 ha are irrigated from both, groundwater and surface water resulting in a total AEI irrigated with groundwater of 250 000 ha and a total AEI irrigated with surface water of 2 550 000 ha.

**Jordan:**
AEI was 78 860 ha in year 2004 while AAI was 72 009 ha (FAO, 2009). AEI increased to 83 450 ha in year 2006 (Department of Statistics, 2009a). Sources of irrigation water were derived from the database of the agricultural census 2007 for each province (Department of Statistics, 2009b). However, total irrigated area reported in this inventory (125 870 ha) was significantly larger than the area reported in the aforementioned statistics, while total cultivated area was similar. One reason maybe that the limited availability of water resources was not considered in these statistics. Therefore total AEI was scaled to 83 450 ha. The percentage of area irrigated with groundwater was close to the statistics reported by FAO. In contrast, AEI irrigated with treated wastewater was 15.9% according to FAO (2009) but 0 according to the agricultural census database (Department of Statistics, 2009b). The reason for this could be that treated waste water is released into rivers and the mixed water is later extracted downstream by the farmers for irrigation (FAO, 2009). Therefore it is very likely that farmers consider the part of treated waste water extracted from the river or reservoir as surface water.

**Kazakhstan:**
AEI and AAI in year 1993 was 3 556 400 ha of which 2 313 100 ha was full or partial control irrigation, 138 700 ha equipped wetlands and inland valley bottoms and 1 104 600 ha spate irrigation. About 179 000 ha were irrigated with groundwater and the remaining area with surface water (FAO, 1997a). Water consumption for irrigation was 15.3 $km^3$ for full control irrigation and 4.6 $km^3$ for spate irrigation in 1993 (UNDP, 2004a) and declined to 7.0 $km^3$ for full control irrigation and 3.3 $km^3$ for spate irrigation in year 2002 (UNDP, 2004b). AAI in full control irrigation schemes declined to 1 441 300 ha in year 2002 (UNDP, 2004b). The same declining trend was also observed for total groundwater withdrawal which was 2.4 $km^3$ in year 1993 and 1.2 $km^3$ in year 2001 (UNDP, 2004a). Based on this information AEI and the partitioning into AEI into area irrigated with groundwater and surface water was set according to the values reported by FAO (1997a) for year 1993 and AAI was estimated at 1 441 300 ha full control irrigation and 800 000 ha spate irrigation.

**Lao People's Democratic Republic:**
Total AEI is 310 000 ha (Pheddara, 2007), of which between 180 451 ha and 307 098 ha were irrigated in the period 2001-2005 in the wet season and between 77 685 ha and 214 832 ha in the dry season (Ministry of Agriculture and Forestry in Lao PDR, 2005). Area irrigated with groundwater did not exceed 100 ha in 1995 (FAO, 2000) and statistics on the source of irrigation water also do not report groundwater use for the years until 2005 (Ministry of Agriculture and Forestry in Lao PDR, 2005). AEI irrigated with groundwater was therefore estimated at 200 ha. AAI was computed as the average of the irrigated area in the wet season considering the years 2001-2005 (Ministry of Agriculture and Forestry in Lao PDR, 2005), which resulted in 271 703 ha.

**Lebanon:**
Area irrigated with surface water and area irrigated with groundwater per district was derived from the Agricultural Atlas of Lebanon (Ministry of Agriculture, 2002), that is based on the results of an agricultural census undertaken in year 1998. Total AEI in this inventory was

104 009 ha and thus larger than AEI reported by FAO AQUASTAT for year 2000 (90 000 ha). AEI irrigated with groundwater was 54 070 ha (52%).

**Mongolia:**
Irrigated area in year 1993 comprised of 43 400 ha registered schemes using sprinkler irrigation, 13 900 ha of unregistered schemes using surface irrigation methods and 27 000 ha of traditional spate irrigation. However, in 1992 only 52% of the sprinkler irrigation area was operational (FAO, 1999). According to another report there were 43 000 ha irrigated area in 1990, of which 16 000 ha (37%) were irrigated with surface water (Tuinhof and Nemer, 2009). Likely these statistics referred to the registered schemes only. Based on this information it was assumed that 37% of the registered and unregistered irrigation schemes and additionally all of the spate irrigation areas are irrigated with surface water resulting in 57.3% of equipped area irrigated with surface water and 42.7% of AEI irrigated with groundwater.

**Myanmar:**
AEI was 1 555 416 ha in year 1995 (FAO, 1999) and increased to 1 842 000 ha in year 2000 and 2 073 000 ha in year 2003 (Irrigation Department, 2004). AEI irrigated with groundwater was 55 175 ha in year 1995 (FAO, 1999) and increased to 81 000 ha in year 2000 and 100 000 ha in year 2003 (Irrigation Department, 2004).

**Nepal:**
The extent of areas irrigated with ground- and surface water was derived for each district from the agricultural census database 2001/02 (Central Bureau of Statistics, 2003). AEI irrigated with surface water was computed as the sum of net irrigated area from seasonal canals, perennial canals, ponds and tanks while AEI irrigated with groundwater was similar to irrigated area from tube-wells and wells. Additionally it was assumed that there is a similar fraction of AEI irrigated with groundwater in categories “other sources” and “mixed”.

**Northern Mariana Islands (USA):**
In year 2002, 113 farms used public utilities as water supplier for irrigation, 15 farms used wells or cisterns and 6 farms used water extracted from rivers or streams (NASS, 2004e). Percentage area irrigated with groundwater was computed based on the number of farms reporting the different water sources and by assuming that the share of groundwater in the public supply system is 80%. AAI was derived from the agricultural census report of the USDA for year 2002 (NASS, 2004e).

**Pakistan:**
The main data sources to separate areas irrigated with groundwater and surface water have been a statistical yearbook published by the Ministry of Food, Agriculture and Livestock (MINFAL) referring to season 2004/2005 (MINFAL, 2006) and the National Water Sector Profile published by the Ministry of Water and Power (Ministry of Water and Power, 2002). These reports compiled by central government bodies contain statistics per federal state. Data were downscaled to the district level by using information provided by federal government bodies. The specific references are given below for each federal state. It is necessary to point out that some statistics were no more available for download at the time of the preparation of this report because important parts of the data infrastructure of Pakistan were offline (e.g. the servers of the Sustainable Development Networking Programme that hosted many databases and statistics at the district level). Statistics cited in this report that are no more available for download can be obtained from the authors on request.
***Balochistan:***

District data on the source of irrigation water were derived from an inventory reporting the water sources of the irrigation areas in season 1994/95 (Government of Balochistan, 2004). AEI irrigated from wells and tube wells was scaled so that the total sum of these areas for whole Balochistan were similar to the statistics published by the MAF for season 2004/05 (MINFAL, 2006). Total AEI was increased that way by 180 854 ha to 1 173 099 ha.

***N.W.F.P. and F.A.T.A.:***

Irrigated area from canals, tanks, tube wells, wells, lift pumps and others were available at the district level for season 2006/2007 (N.W.F.P. Bureau of Statistics, 2007a; N.W.F.P. Bureau of Statistics, 2007b). It was assumed that areas irrigated from wells and tube wells represented areas irrigated with groundwater while areas irrigated from canals, tanks and lift pumps represented areas irrigated with surface water. Percentage irrigation from groundwater was computed by assuming that the contribution of groundwater in the group of others is similar to the contribution of groundwater when only considering the groundwater and surface water sources specified before. Total AEI was 959 691 ha, of which 168 900 ha were irrigated with groundwater.

***Punjab:***

According to the National Water Sector Profile (Ministry of Water and Power, 2002) AEI in Punjab is 8.62 million ha, while the irrigated area harvested (IAH) is about 14 million ha per year indicating a high cropping intensity on irrigated land. More than half of the IAH is supplied by canal wells and canal tube wells meaning that there is conjunctive use of groundwater and surface water. Percentage irrigation from groundwater was computed at the district level by using data related to the season 2005/2006 (Punjab Bureau of Statistics, 2007). Areas with conjunctive use were thus assumed to have 50% groundwater and 50% surface water supply. Furthermore we assumed that the fraction of AEI from groundwater is similar to the fraction of IAH from groundwater. AEI per district was estimated by subtracting the reported rainfed area from the reported net sown area in season 2005/2006 (Punjab Bureau of Statistics, 2008). AEI computed that way was 9 133 000 ha, of which 4 293 258 ha were irrigated with groundwater and 4 839 742 ha were irrigated with surface water.

***Sindh:***

According to the National Water Sector Profile (Ministry of Water and Power, 2002) AEI in Sindh is 5.39 million ha. AEI per district was estimated by subtracting the reported rainfed area in season 1997/1998 from the reported cultivated area (Sindh Bureau of Statistics, 2002). AEI computed that way was 5 369 589 ha. However, only small portions of this area are actually used, mainly because of the shortage of water supply from the Indus River System. In season 2004/2005 the net area sown was only 2.5 million ha in Sindh and the total harvested area was about 3.3 million ha (MINFAL, 2006). AAI and percentage of area irrigated with groundwater was computed at the district level by using data on the area supplied by canals related to the season 2004/2005 (Agriculture Department, 2005) and data on the area supplied by wells, tube wells, canal wells and canal tube wells related to the season 1994/1995 (Sindh Bureau of Statistics, 2002). Total AAI computed this way was 2 438 244 ha, of which 91 500 ha were irrigated with groundwater and 2 346 744 ha were irrigated with surface water.

***Northern Areas and AJ&K:***

It was assumed that the whole AEI is irrigated with surface water.

**Philippines:**

According to data contained in the AQUASTAT country questionnaire and originating from the Bureau of Soils and Water Management of the Department of Agriculture, AEI was 1 879 084 ha in year 2006, of which 106 697 ha were irrigated with groundwater, 1 477 703 ha were irrigated with surface water and 294 684 ha were irrigated with mixed surface and groundwater. By assuming a groundwater contribution of 50% to areas irrigated with mixed sources, total area irrigated with groundwater was 254 039 ha or 14% of total AEI. To

compute AEI at the province level, AEI in the National Irrigation System (NIS) and AEI in the Communal Irrigation system (CIS) was derived from an inventory provided by the National Irrigation Administration and related to year 2007 (National Irrigation Administration, 2008). This inventory reported also AEI of private schemes, but these data were related to year 1998. Therefore AEI in private schemes was computed as the difference between the total AEI in the National Irrigation System, the Communal Irrigation System and the Individual Irrigation System reported by the Agricultural Census 2002 (National Statistics Office, 2004) and AEI in the NIS and the CIS reported by the National Irrigation Administration for year 2006 (NIA, 2008). The so computed difference was then scaled to fit to the total AEI reported in the AQUASTAT country questionnaire, resulting in an AEI of 721 040 ha in the NIS, 559 045 ha in the CIS and 598 639 ha in private schemes. While irrigation in the NIS and the CIS is predominantly from surface water resources (river diversion and reservoirs), private irrigation schemes are supplied also by pumping from aquifers and surface water bodies (FAO, 1999). Therefore we assumed that in each province a constant fraction of 42.4% of the AEI in private schemes is irrigated with groundwater, while the AEI in the NIS and CIS schemes was assumed to be entirely irrigated with surface water.

**Sri Lanka:**
AEI in year 1995 was about 570 000 ha of which only 0.2% or 1140 ha were irrigated with groundwater (FAO, 1999). This information was updated by statistics on the use of agrowells collected by the agricultural census 2002 (Department of Census and Statistics, 2009). We assumed that the maximum of area irrigated by agrowells in the Maha 2001/02 and the Yala 2002 seasons reported for each district represented the area irrigated with groundwater (6828 ha in total).

**Syrian Arab Republic:**
Irrigated area with water supply from wells was 813 200 ha in year 2007 while government projects (mainly reservoirs) provided water for 358 400 ha and streams provided water for 224 800 ha (Central Bureau of Statistics, 2009). Since the category streams represents a mixture of surface and sub-surface water sources (rivers, springs), percentage area irrigated from groundwater was computed at the province level as 100 * AAI_WELLS / (AAI_WELLS + AAI_GOVERNMENT-PROJECTS) assuming that the water supply from government projects is from surface water.

**Tajikistan:**
AEI is 719 200 ha, of which 68 000 ha are irrigated with groundwater, 25 000 ha with reused drainage water and treated wastewater and 626 200 ha with surface water (FAO, 1997b). The figures refer to year 1994 but were confirmed by a more recent publication (Ministry of Land Resources and Water Management, 2003). According to this report AAI in year 2003 was 699 077 ha. Furthermore it is reported that the legislation of Tajikistan allows the use of groundwater for the purpose of irrigation only in exceptional cases when water from other sources is short.

**Thailand:**
Total AEI in year 1995 was 5 003 724 ha and area irrigated with groundwater was only 12 000 ha (FAO, 1999). Total AEI increased to 5 279 860 ha in year 2005 (Wongprasittiporn, 2005). In general, the whole area is irrigated in the main, wet season by using surface water resources. In the dry season, a second or third rice crop can be cultivated if the water supply is ensured. This is often realized by private shallow tube wells, resulting in dry season paddy areas that are larger nowadays than the potential area estimated before based on available (surface) water resources (Wongprasittiporn, 2005). Total area planted with a second rice crop

was 495 712 ha in year 1994 and increased to 1 584 446 ha in year 2006 (FAO RAP, 2008). Detailed statistics on the area irrigated with groundwater were not available but it was reported that almost all farmers in the Phitsanulok irrigation project (104 000 ha) have access to groundwater extracted by tube wells (IPTRID, 2003). Another area for which groundwater irrigation was reported is the Sukhotai irrigation project (FAO, 1999). We assumed therefore that the area irrigated with groundwater in the Phitsanulok and Sukhotai provinces is similar to the area planted with a second rice crop in season 2006, while for all the other provinces area irrigated with groundwater was set to 50% of the reported increase of the area planted with a second rice crop within the period 1994-2006.

**Timor-Leste:**
According to an inventory of irrigation schemes, area equipped for irrigation is 72 159 ha, of which 43 252 ha are traditional schemes and the remainder technical or semi-technical schemes. However, in year 2002 only 34 649 ha (48%) were operational (Asian Development Bank, 2002). Irrigation water in many of the irrigated rice areas is available only when river water level from the source has increased to the level of the intake of the irrigation systems (Ministry of Agriculture, 2009). This indicates that surface water extracted from rivers is the major water source for irrigation, which is also in accordance to the situation in neighbouring Indonesia. Based on this information percentage of irrigated area from groundwater sources was estimated at 2%.

**Turkey:**
Irrigated areas supplied by wells, springs, streams, lakes, reservoirs and other sources were reported by the Agricultural Census 2000 at the province level (Turkstat, 2003). Total irrigated area reported by the agricultural census was 3 505 749 ha and thus significantly lower than the figures provided by the Directorate of State Hydraulic Works (DSI). According to the DSI statistics used in the FAO AQUASTAT country profile (FAO, 2009) area actually irrigated was 4 320 000 ha and area equipped for irrigation was 4 983 000 ha in year 2006. Furthermore the percentage of irrigated area supplied by groundwater was only 19% according to DSI but 48% according to the agricultural census information. In this inventory we used the information provided by the agricultural census for AAI and the percentage of AAI that is irrigated with groundwater. AEI was computed by selecting for each province the maximum of AEI in the Global Map of Irrigation Areas and AAI reported by the census. This resulted in a total of 4 714 535 ha. Then the so computed irrigated area per province was scaled so that the total AEI was similar to the statistics reported by DSI (4 983 000 ha). It was assumed that the AEI irrigated with groundwater was similar to AAI irrigated with groundwater as reported by the agricultural census while the difference between AEI and AAI was assumed to represent AEI irrigated with surface water that is currently out of use.

**Turkmenistan:**
AEI was 1 774 410 ha in year 1994 and about 2.5% of the AEI was irrigated with groundwater (FAO, 1997a). AEI increased to 1 843 000 ha in year 2003 (Stanchin and Lerman, 2007). It was assumed that percentage of AEI irrigated with groundwater did not change between 1994 and 2003.

**Viet Nam:**
AEI in year 2005 was 4 585 500 ha, of which 3 200 000 ha were actually irrigated (Nghia, 2005). AEI irrigated with groundwater is unknown but the extraction of groundwater was reported to be less than 1 billion $m^3$ $yr^{-1}$ compared to total extractions of about 50 billion $m^3$ $yr^{-1}$ and most of it is for domestic supply of urban centres. Abstraction of groundwater for irrigation is exceptional (Worldbank, 1996). It was therefore assumed that only 1% of the

irrigated area of Viet Nam has groundwater supply, which is also in good agreement to available statistics for neighbouring countries.

**Yemen:**
Irrigated area supplied by wells, springs, dams and reservoirs, flood waters and water tank cars per governorate was derived from the statistical yearbook 2007 (Central Statistical Organisation, 2008). Since the area irrigated by using flood waters (spate irrigation area) varies significantly from year to year it was decided to use the maximum of flood irrigated area of the years 2004-2007 as derived from the statistical yearbooks for these years (Central Statistical Organisation, 2005; Central Statistical Organisation, 2006; Central Statistical Organisation, 2007; Central Statistical Organisation, 2008). Wells and springs were assumed to represent groundwater sources; floods, dams and reservoirs represented surface water sources while irrigation from water tank cars and other sources represented non-conventional sources.

## EUROPE (INCL. RUSSIAN FEDERATION)

**European countries included in the EU Farm Structure Survey 2003 (Austria, Belgium, Bulgaria, Czech Republic, Denmark, France, Greece, Hungary, Italy, Malta, Netherlands, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden):**
Areas irrigated with groundwater, surface water and mixed sources was derived from the farm structure survey 2003 (European Commission, 2009a) for 134 sub-national or national administrative units. The conversion of the original data categories reported in the farm structure survey to ground- versus surface water supply is reported in Table S2. Percentage of area irrigated with groundwater was computed as

$$100 * AAI\_GW / (AAI\_GW + AAI\_SW) \quad (3)$$

while percentage of area irrigated with surface water was computed as

$$100 * AAI\_SW / (AAI\_GW + AAI\_SW) \quad (4)$$

Total AAI was derived from the same inventory and AEI from the corresponding EUROSTAT data base (European Commission, 2009b).

**Table S2.**
Sources of irrigation water for areas irrigated in year 2003 according to the farm structure survey of the European Union and partitioning into area actually irrigated from groundwater (AAI_GW) and area actually irrigated from surface water (AAI_SW).

| FS2003 classification | AAI_GW (% of reported area ) | AAI_SW (% of reported area) |
|---|---|---|
| Groundwater | 100 | 0 |
| On-farm surface water | 0 | 100 |
| Off-farm surface water | 0 | 100 |
| Off-farm water from water supply networks* | 0 | 100 |
| Ground- and surface water | 50 | 50 |
| Groundwater and public network | 50 | 0 |
| Surface water and public network | 0 | 50 |
| Mixed surface water | 0 | 100 |
| Other sources or at least 3 mixed sources | 0 | 0 |

* For the island of Crete (Greece) "off-farm water from water supply networks" were assigned the category "Others". Consequently, percentage of irrigation from groundwater increased to 84% which is in good agreement to statistics reported by MEDIS (Katsikides et al., 2004).

**French over-sea departments (Guadeloupe, French Guiana, Martinique and Réunion):**
According to the farm structure survey undertaken in year 2003 the area irrigated from surface water was 4110 ha, the area irrigated from groundwater was 330 ha and the area irrigated from mixed sources or from the public network was 19 050 ha for the entire area of the French over-sea departments (European Commission, 2009a). The only department for which the related water use statistics (IFEN, 2009) explicitly reported a use of groundwater in agriculture was Réunion (5.6 $km^3$ $yr^{-1}$ groundwater use as compared to 59.3 $km^3$ $yr^{-1}$ surface water use in year 2005). The main extractions of groundwater were reported in general for the domestic sector. The fraction of municipal water supply from groundwater was about 47 % for Réunion, 13 % for Guadeloupe and 7 % for Martinique (IFEN, 2009). Based on these statistics and considering the importance of public networks in irrigation water supply, area irrigated with groundwater was estimated at 20% for Réunion, 10% for Guadeloupe and 5% for Martinique and French Guiana.

**Albania:**
It was reported that all irrigation is from surface water except of 1000 ha land in hilly regions where water from springs is being used for irrigation (World Bank 1999). Area equipped for irrigation was 188 450 ha and area actually irrigated was 102 670 ha in year 2006 (Institute of Statistics, 2008).

**Andorra:**
Based on the situation in neighbouring administrative units percentage of AEI irrigated with groundwater was estimated at 25%.

**Belarus:**
Irrigation water is provided mainly by retention tanks. About 77% of the area is reported to be irrigated from these reservoirs. Other water sources are canals and groundwater (FAO, 1997a). Based on this indicative information percentage of AEI irrigated with groundwater was set to 15%. AEI is about 115 000 ha although a large part of the infrastructure is actually not being used (Apatski et al., 2003). Based on the reported ratio of irrigation water

extractions in years 1990 and 2003 (Ministry of Natural Resources and Environmental Protection, 2003) AAI in year 2003 was estimated at 25 900 ha.

**Bosnia and Herzegovina:**
Most of the larger public irrigation schemes in Bosnia and Herzegovina extract water from the Neretva River or its main tributaries, while small scale irrigation is often practised using groundwater (springs, wells, sub-surface streams in the Karst system). The actual extent of irrigation and therefore also the fraction of irrigation areas using groundwater is uncertain because of missing information on the extent of informal irrigation schemes and because a significant part of the irrigation infrastructure was destroyed in the last war (World Bank, 2003). Percentage of irrigated area from groundwater sources was estimated at 30% based on the description of the irrigation infrastructure in World Bank (2002).

**Croatia:**
Irrigated area as well as the number of farms irrigated from groundwater, surface water and from water supply networks was reported for each county and per farm size class by the agricultural census report 2003 (CROSTAT, 2006). Area irrigated from groundwater was computed for each farm size class as AAI_TOT * N_GW / (N_GW + N_SW) where AAI_TOT was the total irrigated area (ha), N_GW was the number of farms irrigated from groundwater and N_SW was the number of farms irrigated from surface water. Next, the sum of area irrigated from groundwater of all farm size classes was computed for each county. AAI irrigated with groundwater computed this way was 3413 ha while AAI irrigated with surface water was 5855 ha. It was assumed that AEI was similar to AAI since no separate statistics for AEI were available.

**Finland:**
The agricultural census 2000 reported a total area equipped for irrigation of 88 010 ha, in most cases irrigation water was extracted from lakes. Groundwater extraction occurred mainly in vegetable production because of the higher water quality of groundwater but statistics on the involved areas were not available (Pajula and Triipponen, 2003). Based on the qualitative information in this aforementioned report and considering the situation in neighbouring Sweden, percentage of irrigated area from groundwater sources was estimated at 15%. AAI was estimated at 15 000 ha.

**Germany:**
AAI and irrigation water use from ground- and surface water were derived from irrigation water use statistics related to year 2002 (Statistisches Bundesamt, 2004).For the federal states of Bayern (Bayerisches Landesamt für Statistik und Datenverarbeitung, 2004), Brandenburg (Amt für Statistik Berlin-Brandenburg, 2007), Hessen (Hessisches Statistisches Landesamt, 2003), Niedersachsen (Landesbetrieb für Statistik und Kommunikationstechnologie Niedersachsen, 2008), Nordrhein-Westfalen (Landesamt für Datenverarbeitung und Statistik Nordrhein-Westfalen, 2004) and Schleswig-Holstein (Statistisches Amt für Hamburg und Schleswig-Holstein, 2004) statistics at the county or district level were available. Percentage area irrigated from groundwater was computed as 100 * IWU_GW / (IWU_GW + IWU_SW) by using statistics on irrigation water use from groundwater (IWU_GW) or irrigation water use from surface water (IWU_SW) reported in the aforementioned publications. AEI was derived from the Global Map of Irrigation Areas (Siebert et al., 2006 and publications cited therein).

**Ireland:**

Irrigation is mainly practised for potatoes, vegetables and soft fruits (Baldock et al., 2000). Statistics related to irrigated areas and sources of irrigation water were not available. Based on data for neighbouring West England and Wales, percentage of irrigated area from groundwater sources was estimated at 20%.

**Lithuania:**
AEI was 1340 ha in year 2007 while AAI was 1000 ha (European Commission, 2009b). The percentage of area irrigated from groundwater was set to the percentage of irrigation water use from groundwater reported by EUROSTAT for the year 2007 (European Commission, 2009c).

**Luxembourg:**
Percentage of irrigated area from groundwater sources was estimated at 70% based on the statistics for neighbouring Belgian provinces.

**Montenegro:**
AAI was 2210 ha in year 2007. Average irrigation water use from groundwater within the period 2005-2007 was 7.3 $Mm^3$ $yr^{-1}$ while irrigation water extraction from surface water was only 25 thousand $m^3$ $yr^{-1}$ (Montenegro Statistical Office, 2008). Based on the ratio between irrigation water uses from the different water sources, AAI irrigated with groundwater was estimated at 2202 ha and AAI irrigated with surface water at 8 ha. AEI is not known and was estimated to be similar to AAI.

**Norway:**
The percentage of AEI irrigated with groundwater was estimated by using the number of holdings irrigating by using ground- or surface water as reported for each county by the agricultural census 1999 (Statistics Norway, 2003). AAI was not reported by the census database, therefore we decided to use the related EUROSTAT statistics for year 2005 (European Commission, 2009b).

**Poland:**
90% of Poland's irrigation area is irrigated with surface water and 10% with groundwater (Mioduszewski et al., 2006).

**Republic of Moldova:**
Total AEI in year 2008 was about 228 300 ha (National Bureau of Statistics, 2008). However, large parts of the infrastructure are abandoned or out of use. AAI in years 1993-1995 was 49% - 67% of the AEI (FAO, 1997c) and the reported agricultural water use (AWU) in year 1992 was 775 $Mm^3$ (FAO, 1997a). In contrast, AWU in year 2008 was only 37 $Mm^3$ (National Bureau of Statistics, 2008). Therefore we estimated that the AAI in year 2008 was only about 10 000 ha. It was reported that, because of the low quality of available groundwater resources, all irrigation is from surface water (FAO, 1997c).

**Russian Federation:**
AEI was 6 124 000 ha in year 1990 and declined to 5 158 000 ha in year 1994 (FAO, 1997a) and 2 375 100 ha in year 2006 (Federal State Statistics Service, 2008a). AAI was 4 095 000 ha in year 1994 (FAO, 1997a) but declined to 939 200 ha in year 2006 (Federal State Statistics Service, 2008a). Consequently, agricultural water use was 15.3 $km^3$ $yr^{-1}$ in 1994 (FAO, 1997a), but only 8.8 $km^3$ $yr^{-1}$ in year 2006 (Federal State Statistics Service, 2008b). The dramatic restructuring of the irrigation sector results in serious difficulties to estimate the percentage of AEI irrigated with groundwater. In 1990, most of the land under irrigation was

commanded by reservoirs and open canals conveyed the water to the irrigation schemes. However, it was also reported, that projects planned for the period 1998-2003 were mostly based on extraction of groundwater for irrigation (FAO, 1997a). According to another report the percentage of surface water use is 90% for industrial water use, 92% for domestic water use but only 64% for agricultural water use (Kireycheva et al., 2006). Based on these statistics and considering the ongoing transformation of the irrigation sector AAI irrigated with groundwater was estimated at 36% of total AAI and AEI irrigated with groundwater was estimated at 20% of total AEI.

**Serbia:**

***Central Serbia and Vojvodina:***

Total area actually irrigated and related water abstractions of ground- and surface water was available for the years 2003-2007 for the regions of Central Serbia and Vojvodina (Statistical Office of the Republic of Serbia, 2008). Since the water abstractions varied significantly from year to year, percentage area irrigated from groundwater was computed based on average irrigation water uses in this 5 year period. In year 2001 AEI in the Vojvodina region was about 50 000 ha (Dragovic et al., 2005) while the average AAI between 2003 and 2007 was 23 399 ha. By using the ratio between AAI and AEI reported for the Vojvodina, AEI for Central Serbia was estimated at 7379 ha.

***Kosovo:***

Statistics on the source of irrigation water were not available for the Kosovo territory. However, large irrigation water extractions from surface water sources (rivers and reservoirs) are reported while because of the aquifer conditions groundwater use is limited to the western part of the country (OSCE, 2008). Other statistics indicate that small scale private irrigation is nowadays very important in Kosovo (Statistical Office of Kosovo, 2006; Statistical Office of Kosovo, 2003) and that the rural water supply in parts of the country is based on groundwater extractions (Statistical Office of Kosovo, 2007). Based on this indicative information Percentage of irrigated area from groundwater sources was estimated at 5% for the eastern part of the country and at 25% for the western part.

**Switzerland:**

AEI is about 55 000 ha of which 43 000 ha are irrigated regularly and 12 000 ha are irregularly irrigated in dry years. About 16% of the area is irrigated with groundwater, 56% with surface water, 3% with water from public water supply and 25% with unknown sources (Weber and Schild, 2007). Based on this information AEI was set to 55 000 ha, AAI to 45 000 ha and the percentage of AEI irrigated with groundwater to 22% of total AEI.

**The former Yugoslav Republic of Macedonia:**

The total AEI irrigated with groundwater is estimated at about 5000 ha (Vukelic et al., 2006) while total AAI in year 2007 was 79 638 ha (State Statistical Office, 2008).

**Ukraine:**

AEI was 2 605 000 ha in year 1994 (FAO, 1997a) but declined to 2 177 000 ha in year 2006 (State Statistics Committee of Ukraine, 2007). AAI was 2 291 600 ha in year 1990 and declined to 731 400 ha in year 2003 (Kovalenko et al., 2006). The whole AEI is irrigated with surface water (FAO, 1997a, Kovalenko et al., 2006).

**United Kingdom:**

Irrigated area and irrigation water extraction by source of water was available for 8 regions covering the territory of England and Wales (Weatherhead, 2007). The data are related to year 2005. It was assumed that for each region the percentage of AAI irrigated with groundwater

was similar to the percentage of irrigation water use extracted from groundwater. In Scotland irrigation is mainly practised for potatoes, vegetables, grass and soft fruits (Macaulay Land Use Research Institute, 2009). Detailed statistics related to irrigated areas and sources of irrigation water were not available, but case studies for specific watersheds show that irrigation water is extracted from rivers, reservoirs and boreholes (Crabtree et al., 2002). Based on the survey data in Crabtree et al. (2002) percentage of irrigated area from groundwater sources was estimated at 20% while total irrigated area was estimated at 15 000 ha.

## OCEANIA

### Australia:

Irrigated area (AAI) in season 2005/2006 and the related water uses were available for statistical divisions, statistical subdivisions and statistical local areas (ABS, 2008). To preserve confidentiality, statistics were not reported for many statistical local areas. Therefore we used in general the data for statistical subdivisions (third level administrative units) except of subdivisions with more than 100 000 ha irrigated area where we used the data for statistical local areas (fourth level administrative unit). The statistics reported water uses from "surface water", "groundwater", "town or country reticulated mains supply", "recycled or re-used water from off farm sources" and "others". We assumed that the fraction of groundwater in "town or country reticulated mains supply" is similar to the ratio between "groundwater" and the sum of "surface water" and "groundwater" while "recycled or re-used water from off farm sources" and "others" were assumed to represent non-conventional water sources. The percentage of AEI irrigated with groundwater was computed as 100 * IWU_GW / (IWU_GW + IWU_SW+IWU_NC). AEI was computed as maximum between AAI and irrigated area detected in a land use data set (BRS, 2006). Total AEI computed that way was 3 343 448 ha, of which 753 978 ha (23%) were irrigated with groundwater. Total AAI was 2 541 079 ha, of which 537 030 ha (21%) were irrigated with groundwater.

### Fiji:

The extent of irrigation areas is about 4000 ha consisting of 3000 ha rice irrigation area using surface water extracted from three reservoirs and from rivers and 1000 ha irrigation area for other crops than rice using both, surface water and groundwater (Pacific Regional Environment Programme, 2003). Groundwater extractions are reported to be small but increasing. Based on this information percentage of irrigated area from groundwater sources was estimated at 10%.

### New Zealand:

Irrigation water use from surface and groundwater sources were available for regional councils (Lincoln Environmental, 2000). Irrigated areas reported in that study were updated by more recent statistics collected by the agricultural census 2007 (Statistics New Zealand, 2009) and the percentage of irrigated area from groundwater was assumed to be similar to the percentage of irrigation water use from groundwater reported for each region. AEI irrigated with groundwater computed that way was 195 174 ha while AEI irrigated with surface water was 424 119 ha.

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