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The United Nations World Water Development Report 2022

GROUNDWATER
Making the invisible visible

Facts and Figures

State of groundwater resources

The global volume of liquid freshwater (less than 1% of all water on Earth in liquid, frozen or vapour form) is estimated to be 10.6 million km³ (Figure 1). Approximately 99% of this consists of groundwater (Shiklomanov and Rodda, 2003).[1]

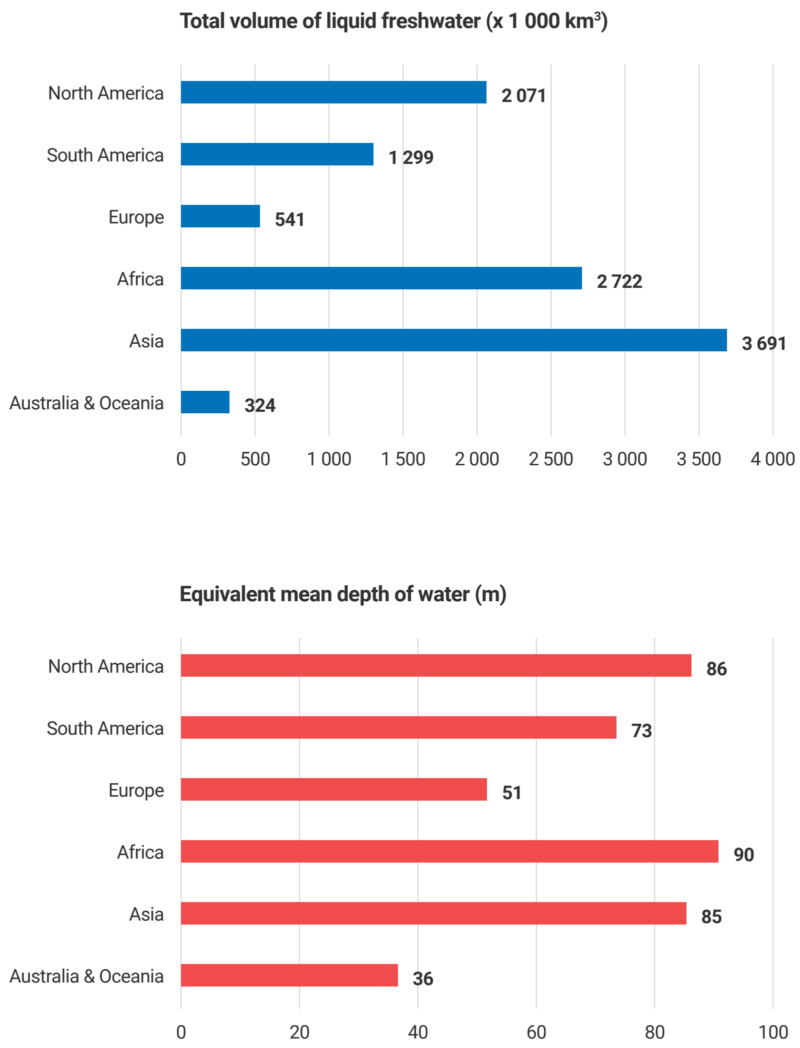
Freshwater withdrawal from streams, lakes, aquifers and human-made reservoirs has increased strongly during the last century, and is still increasing in most parts of the world. The rate of increase was especially high (around 3% per year) during the period 1950–1980, partly due to a higher population growth rate, and partly to rapidly increasing groundwater development, particularly for irrigation. The rate of increase is nowadays approximately 1% per year, in tune with the current population growth rate.

Groundwater supplies approximately 25% of all freshwater abstracted on Earth, but its share in consumptive water use is much higher, as are the overall benefits that it provides. The total global groundwater withdrawal during 2017 is estimated at 959 km³. Groundwater withdrawal rates have more or less stabilized in the United States of America (USA), most European countries and China.

Asia has the largest share in global freshwater withdrawal (64.5%). It is followed by North America (15.5%), Europe (7.1%), Africa (6.7%), South America (5.4%) and Australia & Oceania (0.7%).

A breakdown of groundwater withdrawal by water use sector shows that 69% of the total volume is abstracted for use in the agricultural sector, 22% for domestic uses, and 9% for industrial purposes. These percentages vary between the continents.

Figure 1 Estimated volumes of liquid freshwater present on the different continents



Source: Shiklomanov and Rodda (2003), based on data from Korzun (1974).

[1] For all sources cited in this document, please refer to the full report available at https://en.unesco.org/wwap.

Due to the huge volumes of groundwater, aquifers can serve as a buffer in times of water scarcity, enabling people to survive in even the driest of climates. Depending on their depth and geological setting, aquifers are comparatively well protected against pollution incidents on the surface. However, once groundwater becomes contaminated, it can be extremely difficult and costly to remedy.

Groundwater provides societies with tremendous opportunities for social, economic and environmental benefits, including potential contributions to climate change adaptation and to achieving the Sustainable Development Goals (SDGs). Its contribution to satisfying water demands is considerable.

Although most groundwater within a few hundred metres below the land surface is fresh, more than half of all groundwater under the globe's land surface is saline and therefore unsuitable for most types of water use.

Agriculture

Irrigated agriculture still accounts for 70% of freshwater withdrawals (FAO, 2020). Use for food processing is also significant, up to 5% of global water use (Boretti and Rosa, 2019).

In order to meet global water and agricultural demands by 2050, including an estimated 50% increase in food, feed and biofuel relative to 2012 levels (FAO, 2017), it is of critical importance to increase agricultural productivity through the sustainable intensification of groundwater abstraction, while decreasing water and environmental footprints of agricultural production (FAO, 2021).

Groundwater is a critical resource for irrigated agriculture, livestock farming and other agricultural activities, including food processing.

Studies in Africa, Asia and Latin America show that when poor farmers attempt to improve their livelihoods through smallholder agriculture or livestock farming, groundwater and small pumps are commonly involved, which benefit women in particular (Villholth, 2013a; Shah et al., 2007; Van Koppen, 1998).

The area of land equipped for irrigation globally has more than doubled since the 1960s (Aquastat, n.d.; Faostat, n.d.). An estimated 38% of the lands equipped for irrigation is serviced by groundwater (Siebert et al., 2013). Regions heavily reliant on groundwater for irrigation include North America and South Asia, where 59% and 57% of the equipped area use groundwater, respectively, while in Northern Africa it is 35% and in Sub-Saharan Africa only 5%.

Globally, an estimated 264 km^3 of surface and groundwater per year is used for fodder production for livestock, equating to about a fifth of total agricultural water consumed and less than a third of water used for food crops (Heinke et al., 2020).

The economic contribution of groundwater in agriculture has been estimated at about US$210–230 billion per year globally (Shah et al., 2007). Water productivity, in terms of crop yield per unit of water applied, is generally higher, up to a factor two, for groundwater than for surface water (Bierkens et al., 2019; Smilovic et al., 2015; Shah, 2007).

It is estimated that about 11% (or 25 km^3/year) of global groundwater depletion is embedded in international crop trade (Dalin et al., 2017), supporting food security and economic growth, but also significantly contributing to large-scale depletion of aquifers overlaid by productive land. Wheat, maize, rice, sugarcane, cotton and fodder are the principal crops contributing to groundwater depletion. These crops are also heavily traded, indicating highly unsustainable water footprints (Mekonnen and Gerbens-Leenes, 2020).

It is estimated that agricultural pollution has overtaken contamination from settlements and industries as the major factor in the degradation of inland and coastal waters (FAO, 2018a). In the European Union (EU), 38% of water bodies are under significant pressure from agricultural pollution (WWAP, 2015); in the USA, agriculture is the principal source of pollution of rivers; and in China, agriculture is responsible for a large proportion of surface and groundwater pollution by nitrogen (FAO, 2013).

In the USA, pesticide contamination of groundwater and eutrophication of freshwater are estimated to cost US$1.6–2 and US$1.5–2.2 billion per year, respectively (Pimentel, 2005; Dodds et al., 2009).

Many irrigated areas of the world are thus facing the twin problems of soil salinization and waterlogging. These problems currently affect over 20% of the total global irrigated area (Singh, 2021).

Human settlements

Nearly 50% of the global urban population is believed today to be supplied from groundwater sources (Foster et al., 2020a). In the case of the EU and USA, groundwater provides the public water supply for 310 and 105 million people, respectively.

Indirectly, groundwater contributes to urban poverty reduction by allowing water utilities to develop sources at much lower cost and allow lower connection charges.

In coastal areas, the over-exploitation of groundwater resources seriously exposes aquifers to large-scale saline-water intrusion, a phenomenon that will be further exacerbated by climate change-induced sea level rise.

Health

The percentage of the world population using safely managed drinking water services increased from 70% to 74%, but differences between and also within the regions are considerable (Figure 2). Similar statistics are available for sanitation services: use of safely managed sanitation services increased from 47% to 53% of the world population during 2015–2020. The Joint Monitoring Project (JMP) reports furthermore that, by 2020, 71% of the world population had basic handwashing facilities with soap and water available at home (WHO/UNICEF, 2021). The latter facilities have gained importance since the outbreak of the Covid-19 pandemic, because handwashing is indicated to reduce the transmission of viruses strongly (Brauer et al., 2020).

JMP does not specify the share of groundwater in water, sanitation and hygiene (WASH) services and their progress, but it is certainly considerable.

Industry and energy

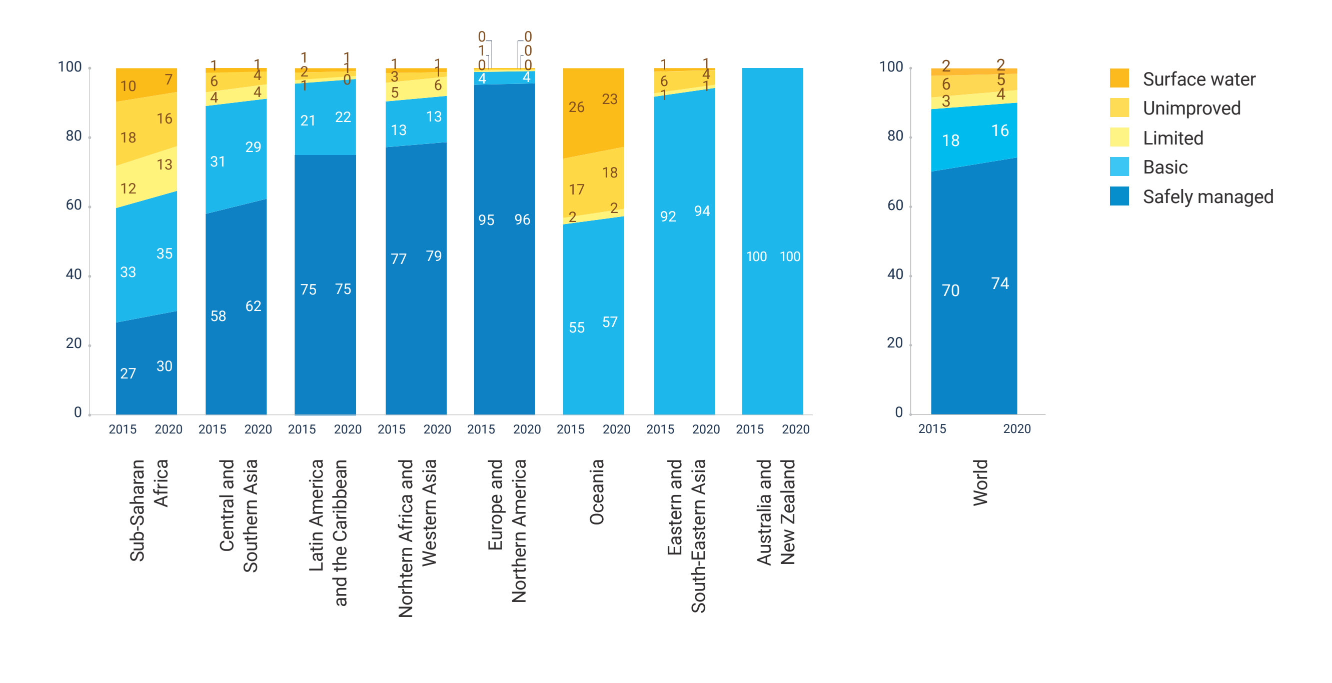
Statistics relating to water abstraction and use in industry are notably scarce. Industry and energy account for 19% of global freshwater withdrawals (Aquastat, n.d.). This number refers to self-supplied water (which includes groundwater). The data also point to big geographic differences, with industrial withdrawal varying from 5% in Africa to 57% in Europe.

In 2020, from 1,375 manufacturing companies worldwide disclosing to the CDP (formerly the Carbon Disclosure Project), more than half (54%) reported groundwater from non-renewable and renewable sources as being relevant for their direct operations. Of those, 46% have lowered their groundwater withdrawals, 32% maintained their withdrawals, and 21% increased their withdrawals from groundwater compared to 2019 (CDP, unpublished).

Various industrial processes make use of groundwater resources where surface water is limited in quantity but also where quality is important.

Pumping groundwater with electricity is about seven times more energy-intensive than surface water abstraction. Groundwater abstraction is consuming approximately 108 TW_h per year, representing about 0.5% of global electricity consumption.

Figure 2 Regional and global drinking water coverage, 2015–2020 (%)



Note: Five SDG regions had estimates for safely managed drinking water services in 2020.

Source: Adapted from WHO/UNICEF (2021, fig. 2 and 3, p. 8).

Desalination is up to one order of magnitude more energy-intensive than groundwater abstraction.

One of the main opportunities provided by geothermal energy is its contribution to decarbonizing domestic, commercial and industrial heating and cooling, which accounts for at least 40% of global energy consumption and CO_2 emissions (IEA, 2019b).

The relative growth in wind and solar energy has in recent years outstripped that of geothermal electricity, reflecting the lower cost and perceived risk of the former, and their shorter payback periods. However, geothermal power plants are, contrary to wind and solar energy plants, well suited to producing an electrical base load. Installed capacity is projected to grow by ~20% between 2020 and 2025 (Huttrer, 2021).

Climate change

An estimated four billion people live in areas that suffer from severe physical water scarcity for at least one month per year (Mekonnen and Hoekstra, 2016). Typical responses for areas where annual scarcity values exceed 1.0 include water transfers from neighbouring water-surplus areas (if available), or depleting stored water volumes of lakes, surface water reservoirs, and – above all – aquifers.

Climate change directly impacts the natural replenishment of groundwater. Substantial uncertainty persists, however, in global projections of the impacts of climate change on groundwater recharge.

The transition towards fewer but heavier rainfalls is expected to enhance groundwater recharge in many environments.

Managed aquifer recharge (MAR) is an effective technical intervention that makes use of the naturally available storage capacity of the subsurface. Excess water that otherwise would be lost is temporarily stored and made available for beneficial use at a later moment in time. The application of MAR has increased by a factor of 10 over the last 60 years, but there is still ample scope for further expansion, from the current 10 km³/year to probably around 100 km³/year (Dillon et al., 2019). MAR ranks under the most effective groundwater management interventions.

The impacts of receding alpine glaciers on groundwater systems are not well understood.

Global sea level rise has induced seawater intrusion into coastal aquifers around the world (Michael et al., 2013).

One of the greatest benefits of groundwater is its resilience to climatic variation. Groundwater is not reliant on the last 1–2 years of rainfall, but integrates rainfall over years and decades.

Financing for sustainability

Estimates of required investments to achieve SDG 6 vary due to the lack of accurate and reliable data, but there is a clear agreement (Hutton and Varughese, 2016; WWC, 2018; OECD, 2019b) that the current level of investment is insufficient to meet the agreed targets.

Projections of global financing needs for water infrastructure to achieve SDG 6 range from US$6.7 trillion by 2030 to US$22.6 trillion by 2050 (OECD, 2018). Estimates also show that governments and development agencies have insufficient funds to meet these requirements (Kolker et al., 2016).

Official Development Assistance (ODA) for water is around US$13 billion per year – far short of what is required and about 80% of countries reporting to the United Nations on SDG 6 say they have insufficient financing to meet the national water targets (United Nations, 2018).

Regional perspectives

Sub-Saharan Africa

About 400 million people in Sub-Saharan Africa do not have access to even basic water services (WHO/UNICEF, 2021).

Extensive hydrogeological investigation across the continent reveals that Africa possesses large groundwater resources. Groundwater resources in Africa are often considered as having the potential to bring about overall socio-economic transformation (Foster et al., 2012), to overcome current hydrologic variability (Grey and Sadoff, 2007) and to meet future demand.

With regard to climate change, groundwater is expected to be increasingly used as source of reliable water supply throughout Africa (Giordano, 2009; MacDonald and Calow, 2009).

Anthropogenic groundwater quality deterioration is also on the rise, caused by factors such as mining activities (e.g. South Africa), poor irrigation practices (e.g. in the Nile Valley and the Senegal River basin) and urbanization (e.g. Nairobi, Accra, Maputo, etc.) (Lapworth et al., 2017).

The agricultural sector accounts for about 30% of the gross domestic product (GDP) in Sub-Saharan Africa but employs about 65% of the population, the majority of whom are women (World Bank, 2018a), yet crops are produced almost entirely under rainfed conditions. Given the importance of the agricultural sector in Africa, any improvement in the sector has the potential of transforming the living conditions of the population.

Current use of groundwater for irrigation is limited, partly due to the cost implications associated with groundwater exploration and construction, and difficulties in financing.

The general lack of groundwater professionals impacts the staffing of institutions and of local and national government offices in many countries, hampering emerging initiatives to oversee effective groundwater monitoring, planning and development.

The funding gap between current spending and what is required to achieve SDG 6 is highest for Sub-Saharan Africa, where the achievement of universal water supply would require ten times more than the current level of investment of US$13.2 billion (Watts et al., 2021). A large proportion of this amount is required for operation, maintenance and rehabilitation of existing systems, which often fail to attract funding.

Europe and North America

Some 75% of the EU's inhabitants depend on groundwater for their water supply (European Commission, 2008).

In the USA, the abstraction of fresh groundwater in 2015 was estimated to amount to 311.5 million m³/day, about 8% more than in 2010 (Dieter et al., 2018), while total freshwater withdrawals have been trending downward since 2005.

Out of the 36 countries sharing transboundary aquifers in the region, 24 have reported that operational arrangements cover 70% or more of their transboundary aquifer area (UNECE/UNESCO, 2021).

Latin America and the Caribbean

Due to the relative abundance of surface water and the limited level of groundwater use, less than 30% of the freshwater abstracted comes from groundwater sources. For the countries that do rely on groundwater, approximately half of the extraction is used for irrigation, a third is for domestic use and the rest is for industrial use (Aguilar-Barajas et al., 2015).

In countries such as Costa Rica and Mexico, groundwater supplies 70% of households in urban areas, and practically sustains all domestic demand in rural areas. It also represents 50% of the water used by the industrial sector (Campuzano et al., 2014).

Throughout the region there are shortcomings in groundwater's protection and monitoring, giving way to its intensive exploitation and/or contamination, ultimately endangering its sustainability (Campuzano et al., 2014) as well as the water access of the most vulnerable populations, who depend on these groundwater sources for their drinking water supply (WWAP, 2019).

Throughout the region, the most common groundwater quality problems are associated with unwanted elements of natural origin (mainly arsenic and fluoride), anthropogenic pollutants (nitrates, faecal pollutants, pesticides), various compounds of industrial origin (mining by-products, organochlorine solvents, hydrocarbons, phenolic compounds, etc.), and emerging pollutants, such as cosmetics, antibiotics, hormones and nanomaterials.

It is estimated that the number of conflicts related to groundwater pollution and depletion that started between 2000 and 2019 is more than four times higher than those started between 1980 and 1999 (ICTA-UAB, n.d.).

In the Caribbean, where surface water tends to be relatively scarce, groundwater represents about 50% of the water abstracted.

Climate change and variability, particularly the increased frequency and intensity of hurricanes, pose greater threats to Caribbean Small Island Developing States (SIDS), due to storm surge and well infiltration.

Asia and the Pacific

Asia and the Pacific is the largest region in the world in terms of both area (28 million km²) and population (4.7 billion). The region is the largest groundwater abstractor in the world.

The critical driver of groundwater development in the region is rising demand for water due to growing populations, rapid economic development and improving living standards. Utilization of groundwater resources has provided numerous benefits for irrigation, industrial activity, domestic use, drought resilience and livelihood enhancement.

These socio-economic benefits have been particularly crucial for the agricultural sector – a sector that is key to economic development in many developing countries in the region, and that accounts for an estimated 82% of total water withdrawals (Aquastat, n.d.).

The unsustainable abstraction of groundwater resources, coupled with the impacts of climate change, have led to aquifer depletion and increased water scarcity in a number of areas. Additionally, groundwater quality is under threat due to a variety of anthropogenic and geogenic drivers that further contribute to water stress in the region.

Climate change impacts precipitation variability in the region, further exacerbating pressure on groundwater resources, particularly in areas with semi-arid to arid climates and on Pacific SIDS, where groundwater forms the only reliable source of freshwater but is threatened by rising sea levels (Ashfaq et al., 2009; Asoka et al., 2017; Bouchet et al., 2019; Dixon-Jain et al., 2014).

The Arab region

The Arab region is one of the most water-scarce regions in the world.

This has pushed countries to draw upon other conventional and non-conventional water resources to meet their freshwater needs. Groundwater is the most relied-upon water source in at least 11 of the 22 Arab states and accounts for more than 80% of the freshwater withdrawals in Libya, Djibouti, Saudi Arabia and Palestine (Aquastat, n.d.).

All Arab states except for the Comoros draw upon one or more transboundary groundwater resource, with 42 transboundary aquifer systems covering almost 58% of the Arab region’s area.

Analysis from Gravity Recovery and Climate Experiment (GRACE) mission data has confirmed not only the significant decreasing trend in groundwater storage between 2002 and 2019, but also highlights the seasonal variability effect on groundwater storage combined with the excessive groundwater withdrawals in the dry period.

Furthermore, depletion of groundwater in aquifers and specifically in aquifers with non-renewable groundwater resources has been estimated at 317% of the renewable volume in the Member States of the Gulf Cooperation Council (Al-Zubari et al., 2017).

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