

Supplemental Information - Global reorientation database 36 cases

A reorientation is a shift in broader societal priorities that drives reform of agricultural water management (Seijger and Hellegers 2023). Agricultural water management encompasses activities related to storage, distribution, consumption and drainage of water for crop production, fisheries and livestock (Molden 2007).

The database is ordered by continent: Africa, the Americas, Asia and Australia, and Europe. I am grateful to colleagues who helped with the analyses of specific regions¹.

The case-specific analyses are a condensed interpretation of changes presented in the cited references of the database. Each analysis ends with a 'Degree of reorientation' description, this is an assessment - informed by the cited references- of the changes achieved across policies, plans, land and water resources to support the particular reorientation.

Country and reorientation	Description	References
Africa		
<u>Angola</u> "from abandonment to rehabilitation and diversified agriculture"	<ul style="list-style-type: none"> • The oil-based economy has not delivered prosperity to Angola's entire population. Before the civil war, Angola was a major agricultural exporter, but during the civil war agricultural lands were abandoned and nowadays 70% of the rural population is engaged in subsistence farming. • Rehabilitation and diversification of agriculture is a top government priority, especially as the country has fertile soils, adequate water resources and a favourable climate. Donors such as IFAD, AfDB and the China EximBank endorse this priority and are investing in agriculture and water projects. • National policies regulating access to land have not yet transferred to local administrative levels. Land negotiations and conversions are therefore negotiated in an informal matter. • It is unclear what options farmers have to diversify their livelihoods, and what consequences changes would have for land and water resources. Conversion from forest lands to arable lands is already observed in central and southern Angola. [Degree of reorientation: large, agricultural rehabilitation is a top priority and agricultural expansion is taking place, although the effects on farmers' fields and on land and water resources require further research. Reorientation is ongoing.] 	(Cabral et al., 2011; Röder et al., 2015; Ovadia, 2018)
<u>Egypt</u> (Nile Delta and adjacent lands) "from Nile water for the old lands to Nile water for urban-agricultural expansions"	<ul style="list-style-type: none"> • The Nile is Egypt's most important water resource. The water supply and reuse systems in the Nile Delta are at their limits, because modern irrigation will not significantly increase (the already high) system efficiency of 75%. In addition, the price of food security is starkly increasing, as the costs of food imports compared to total merchandise exports nearly doubled in the last two decades. • The Government has a long tradition of running ambitious projects to reclaim desert land for urban and agricultural expansion. Projects like the 4 Million Feddan project, New Cairo, Al-Hamman Canal & Extensions, New Delta, require Nile and groundwater resources to equip these 'new lands' with sufficient water. Due to the highly limited water resources this represents a clash of interests between farmers in the delta (water for affordable food, mostly small farmers) versus State Government and military who want to attract investments for urban-agricultural expansions (property development, large modernized farms in the infertile dessert). • A direct consequence of these water requests is that Nile water resources are directed to those new development projects. 	(Sims 2018; Christoforidou et al., 2023; Shalby et al. 2023; Tawfik et al., 2024; Abdellatif et al., 2025)

¹ Maria Christoforidou for Australia, Iran, Morocco, Nepal, South Africa, Türkiye, US Great Plains; Uzbekistan; Petra Hellegers for Saudi Arabia; Juan Pablo Hidalgo Bastidas for Ecuador; Gaber Abdellatif for Egypt; Bas van Wijk for South Korea.

	<p>Drainage water treatment plants treat agricultural drainage water for those expansions, yet they deprive tail-end smallholder farmers of water resources. Also the ecological outflow to the Mediterranean Sea reduces as Nile-water is reallocated to the new lands. Groundwater underneath the delta is increasingly pumped to overcome water deficits.</p> <ul style="list-style-type: none"> • Evidence for the success of the new urban-agricultural expansions is poor: very few people like to migrate to newly built desert towns, and data on land actually taken into cultivation is notoriously vague. Scientific analyses emphasize little farm land is taken into cultivation due to a highly challenging soil-water environment and poor organizational support. <p>[Degree of reorientation: large as plans are in place, infrastructure is built to reclaim land, to clean and redirect Nile-water, and changes in surface and groundwater resources are significant. The impacts of reduced water supplies for delta farmers are largely unknown, and require further study and will present themselves more clearly in years with reduced rainfall in the Nile highlands and reduced inflows from the High Aswan Dam.]</p>	
<p><u>Morocco</u> (Saïss plain) "From unsustainable groundwater abstraction to surface water supply to protect farmer livelihoods"</p>	<ul style="list-style-type: none"> • The Saïss plain is one of the country's most productive agricultural regions, with over 82% of water in the basin being used for agriculture. Agricultural policies focused on intensification of production, and this enabled farmers to rapidly expand farm land and install drip irrigation through shallow wells and deep tube-wells. • Agricultural land use changed and expanded; between 1998 and 2019 irrigated agriculture increased strongly whereas range land decreased by 80%. • Water availability declined meanwhile; precipitation from an average of ~600mm in 1960 to around 450 mm in 2020) and spring flow declined by 40% between 2008-2020 due to declining rainfall and exploitation of groundwater. Groundwater levels in the Sais aquifer declined strongly with around 65 meters in 60 years. • The Saïss Water Conservation Project (SWCP), a 10year project (2017-2027), is currently under implementation. The project will provide 100 MCM of surface water from the M'Dez dam through a 135km pipeline to the Saïss agricultural area and is intended to conserve groundwater resources. It is unclear if regulations are co-implemented to curb groundwater pumping. <p>[Degree of reorientation: medium, high-profile project is under implementation but at this stage it is unclear if it will be a mere augmentation of water supply, or whether groundwater use is fully replaced by the supplied surface water. Alternatively, agricultural expansion may continue when there is no regulation to limit groundwater pumping. Future research is needed to assess how effective the water transfer is in replacing groundwater abstraction with surface water from the M'Dez dam.]</p>	<p>(Kuper et al., 2017; Hssaisoune et al., 2020; World Economic Forum, 2020; Mendoza, 2021; El Garouani et al., 2024)</p>
<p><u>Morocco</u> (Tadla Irrigation scheme) "from groundwater overexploitation to drip irrigation and groundwater sustainability"</p>	<ul style="list-style-type: none"> • In 2007, the National Irrigation Water Saving Programme was drafted and aimed to save water in agriculture across the country. For the Tadla Irrigation Scheme (100,000 ha), the programme aims to convert 88,7000 ha to drip irrigation. • Since 1980s, farmers in the scheme experienced severe water shortage, this has led to widespread drilling of individual wells so that farmers have access to both groundwater and surface water (in over 70% of the scheme). Key irrigated crops are cereals, lucerne, sugar beet, citrus, olives and vegetables. • Due to substantial subsidies for farm conversion (covering 80-100% investment costs) in the National Irrigation Water Saving Plan, drip irrigation rose rapidly in the Tadla scheme from 4,500ha in 2006 to 25,000ha in 2016. After the conversion farmers increasingly plant fruit trees (high-value crops) to compensate for running expenses of drip irrigation. Farmers 	<p>(Boularbah et al., 2019; Boundi and Yacine, 2021; Zaharaddeen et al., 2023)</p>

	<p>constructed small ponds to store water for drip irrigation purposes. The ponds offer farmers an opportunity to store water, either water that was supplied by the irrigation system or water that is pumped from the aquifer.</p> <ul style="list-style-type: none"> • Farmers continue to use groundwater after converting to drip irrigation to overcome surface water shortages. 2022 was an extremely dry year, with nearly no surface water for irrigation, so farmers dug wells up to 500 meters deep to get groundwater. • Conversion to drip was expected to reduce (agricultural) water use and reduce groundwater overexploitation. However, research shows that there is over-irrigation of crops (as much as twice the crop water requirements), instances of increased groundwater use, and no signs that the downward trend of groundwater depletion is reversed in the Tadla aquifer. Water stress is thus only temporarily resolved by the conversion to drip irrigation. <p>[Degree of reorientation: large; a major conversion to drip irrigation took place, yet the expected reduction in agricultural water use did not take place as farmers over-irrigate and intensify production]</p>	
<p><u>Niger</u> “from land degradation and malnutrition to reclaiming agricultural lands and food self-sufficiency”</p>	<ul style="list-style-type: none"> • Most of Niger’s agriculture is fully dependent on rainfall. Livestock is an important adaptation to aridity and variable rainfall. Water is a major constraint to development. • In response to the 2011-2012 food crisis, the “3N initiative” was established to reduce the impact of drought and desertification and enhance food self-sufficiency. • The traditional “zai” technique was promoted in which farmers dig pits to collect water and nutrients from compost. • Afforestation, sustainable irrigation systems and sustainable agricultural practices were promoted under 3N. Their effects on agricultural water management remain unclear. • An evaluation of other agricultural water management programmes indicates positive impacts of investments in private, small-scale land and water management (e.g., reforestation, rainwater harvesting, groundwater pumping) <p>[Degree of reorientation: small, policies have been set by the President’s Cabinet. Further research is needed to determine the extent that land degradation and malnutrition are being addressed and the policies’ impacts on agricultural production, farms, and land and water resources. Reorientation is ongoing.]</p>	<p>(Merrey and Sally, 2014; World Future Council, 2017)</p>
<p><u>South Africa</u> (Olifants River basin) “from development of water for the few to development for all and the environment”</p>	<ul style="list-style-type: none"> • Until the 1990s a very small race-based minority (largely white, active in commercial agriculture, mines and industry) benefited from the capture and development of water resources in the river basin whereas the extremely poor African majority (largely black) had little access to land or water. • The National Water Act of 1998 was an important water reform in South Africa, developed to achieve broader goals of post-1994 South Africa. The Act aimed to provide a framework for equity, prosperity and environmental sustainability. Two instruments were important to promote equity in water allocation: compulsory licensing (all water users declare quantity of water use, Government can reallocate water) and water markets (voluntary transfer of water use rights where users who do not need their water rights sell it to the ones who need additional water). • In the Olifants basin, a Catchment Management Authority to manage the water was proposed but not implemented. Evaluation studies conclude that inequity continues, as small-medium farmers are not encouraged or protected, and large-scale water users used the policy reform to strengthen their claims on land and water. • A land use change study indicated that between 2000 and 2013, rangeland area (primarily used for subsistence and semi-commercial farming) decreased by 36% while increases took place in agricultural (+20%), urban (+10%) and forest (+0.7%) areas, resulting in higher run-off (~47%) and less groundwater recharge (~59%). 	<p>(McCartney et al., 2004; Merrey et al., 2009; Liebrand et al., 2012; Thiam et al., 2015; Gyamfi et al. 2016)</p>

	[degree of Reorientation: small, despite ambitions to reduce inequity, inequity in the Olifants basin continues and land and water resources are mostly used to the benefit a small minority. Further research is needed to assess allocation of scarce water across small and large water users in agriculture, industry, urban areas and nature.]	
<u>Sudan</u> “from wheat self-sufficiency to Africa’s breadbasket”	<ul style="list-style-type: none"> • The vast plains of Sudan are regarded as a promising area to increase wheat production. The government aims to become Africa’s breadbasket. • To promote wheat cultivation, the government has raised minimum prices for wheat. • Innovation platforms were created to scale up technologies, use of heat-resistant varieties, and seed production and distribution. • In the last five years, wheat production rose. Sudanese officials claim a 75% increase, from 0.47 to 1.11 million tonnes; a FAO study reported for 2020 a 30% increase of 0.72 million tonnes over the last five years. On some farms, yields doubled, from 2.5 to 5 tonnes per hectare. • Sudan is far from wheat self-sufficient, as 2.1 million tonnes of wheat were imported in 2019. • Wheat is mostly an irrigated crop, apart from a small rainfed area in Darfur. Malfunctioning of irrigation systems remains a major risk to farm production. <p>[Degree of reorientation: medium, policies and scaling programmes for wheat cultivation are in place and wheat production has risen, yet self-sufficiency has not been achieved and a status of net exporter of wheat is still far away. Further research should determine impacts on water resources. Reorientation is ongoing.]</p>	(African Development Bank, 2020; FAO, 2020)
<u>Tanzania</u> “from small-scale, undercapitalised and labour-intensive agriculture to commercialisation and expansion of agricultural land”	<ul style="list-style-type: none"> • With its Kilimo Kwanza plan (“Agriculture First”) government has promoted use of fertilisers, agrochemicals, machinery and improved seeds in various programmes and policy frameworks. Water has not been a central concern. • In 2008-2014, agricultural area expanded from 8 to 13 million hectares. Agricultural production increased too, by 8.6% per year. Economic land productivity hardly changed. Most of the increase is found in cereals and soy, with little or no increase in fruits, vegetables and cash crops (coffee, tea, tobacco). • Share of small-scale subsistence farming households has dropped (by more than 10% in 2008-2014), whereas medium-size farms have played an important role in agricultural expansion and commercialisation. • A system of water permits and water rights was set up. However, an inability to monitor and service water abstraction has remained, with a lack of penalties for illegal withdrawals. • With greater irrigation and agricultural expansion and commercialisation, water scarcity generally increases for smallholders and the environment. Also, land deals for large commercial farms have brought water grabbing, which deprives smaller and usually poor farmers of their water access. <p>[Degree of reorientation: very large, the agricultural sector has modernised and major change are observed in plans, policies, farming practices, and land and water resources. However, there has been little attention for water scarcity, environmental degradation and rising inequality in land and water access.]</p>	(Eeden et al., 2016; Wineman et al., 2020)
Americas		
<u>Argentina</u> “from mixed, diversified agriculture to agricultural expansion and monoculture export of soy and maize”	<ul style="list-style-type: none"> • Grazing lands have been converted into croplands for production of soybean, corn and wheat. Forest areas have been cleared for cattle and crop expansion. • Agricultural trade (especially soy and derivatives) is an income source and stabilising factor for the Argentinian economy. • Plans and policies have supported agricultural expansion for export, such as the lifting of export taxes, infrastructure investments under “Plan Belgrano” and a strategic plan for agriculture, livestock and agroindustry. 	(Peiretti and Dumanski, 2014; Lema et al., 2018; Piquer-Rodríguez et al., 2018)

	<ul style="list-style-type: none"> • Farmers have widely adopted no tillage (79% of area cropped to grain in 2010), which is beneficial for water infiltration and soil water storage, soil organic matter and crop production. They have also succeeded in reducing surface runoff and erosion. • Production of corn (+50%) and soy (+20%) rose in 2007-2016, though not as fast as envisioned in the strategic plan. <p>[Degree of reorientation: very large, Argentina has boosted the production of soy and maize, though environmental issues including water shortages and water pollution are slowly emerging on the agenda.]</p>	
<p><u>Brazil</u> (Mato Grosso) “from agricultural expansion to sustainable agricultural intensification”</p>	<ul style="list-style-type: none"> • The Mato Grosso region is a key rainfed agricultural area. Cultivation here has expanded since the 1970s. Soybean, cotton, corn are the main crops. The net cropped area rose by 43% from 2000 to 2006. • Deforestation, and fallow soils in the rainy season, have contributed to loss of biodiversity, modified watershed flows, erosion and water pollution. • Forest conservation policies have stimulated intensification of croplands and pasture. Policies to incentivise farmers are manifold and range from certification for compliance with environmental standards to licensing, control, and loans for pasture productivity. • After the soybean crisis of 2005-2007, farmers were encouraged to plant non-commercial crops for soil cover and to reduce erosion and water pollution. • To spare land, research institutes have promoted a soy-cattle rotation. • Agricultural intensification has so far failed to slow agricultural expansion, and soybean was planted on a record 10.2 million hectares in 2020. Agribusinesses continue to advance into the forest. <p>[Degree of reorientation: small, despite policies and plans to confine agricultural expansion, agriculture continues to expand into the Amazon. Further research is needed to assess impacts on water resources. Reorientation is ongoing.]</p>	(Arvor et al., 2012; Garret et al., 2018)
<p><u>Canada</u> (Saskatchewan province) “from rainfed agriculture to strongly expanded irrigation”</p>	<ul style="list-style-type: none"> • The Saskatchewan region accounts for the vast majority of Canadian grains, oilseeds and livestock production. Rainfed agriculture is dominant, but irrigated area is increasing. • For years, farmers have advocated irrigation expansion, although environmental groups express concern about pressure on water resources and the effects of construction of dams and reservoirs. • Government’s irrigation strategy is to expand the irrigable area, and this policy was formally approved in 2020. • The Saskatchewan authorities announced the launch of a more than US \$3 billion irrigation project for diverse high-value crops. This would more than double the irrigable land area in the province. <p>[Degree of reorientation: medium, with a recent irrigation strategy and major irrigation project approved changes are likely to occur at the farm level, affecting land and water resources. Reorientation is ongoing.]</p>	(Corkal et al., 2011; Saskatchewan Government 2020)
<p><u>Colombia</u> (Caucau River Valley) “from traditional mixed farming to sugarcane expansion and river pollution”</p>	<ul style="list-style-type: none"> • In the 1980s, government and elite landholders decided to devote all flatlands to agricultural intensification. Expansion of sugarcane agro-industry became a priority. Sugarcane cultivation boomed, while pasture lands strongly contracted and wetlands completely disappeared. • Sugarcane yields have been high (~115 tonnes/ha) thanks to irrigation, machinery and chemical fertilisation. However, climate change and soil degradation have diminished yields. • Observed irrigation volumes have been high, ranging from 1,200 to 2,000 mm for sugarcane. Combined with abundant use of pesticides and fertilisers, sugarcane expansion has directly influenced river pollution (urban effluents being another important source). Watershed flows have also been affected, and a loss of wetlands and biodiversity has been observed. 	(Velez-Torres, 2012; Marull et al., 2018)

	<ul style="list-style-type: none"> • Inequality has increased due to land and water grabbing by national and regional elites, facilitated by state intervention and irrigation and river diversion projects. <p>[Degree of reorientation: very large, irrigated sugarcane expanded massively, and agricultural water management has contributed to river pollution and affected watershed flows and biodiversity.]</p>	
<p><u>Ecuador</u> (Los Rios and Tungurahua provinces) “from modernized productive agricultural models to the recognition of basic livelihood needs in agriculture”</p>	<ul style="list-style-type: none"> • Peasant organizations demanded since the 1990s that the state should take the lead in redistributing land and water resources, which until then were largely concentrated in the fields of farmers who are part of powerful agro-industrial groups. • This led to a constitutional reform in the National Constitution (2008) with Article 27, that was aimed to address a redistribution of water and land rights from the powerful to the marginalized. • Different programs started to implement this reform. The redistributions of land and water that took place, were mostly on marginal land and based on voluntary transactions. • A review of the reform in Los Rios and Tungurahua concluded that the reform only superficially changed the inequality in access to water, as effective water redistribution policies remained absent. In Los Rios water resources are increasingly concentrated for agro-industrial farming groups whereas there is no sanctioning on illegal grabbing of water. In Tungurahua, greater equity in access to water was found, but only by expanding agriculture into the nature areas (paramos) and not by redistributing agricultural land and water within the agricultural sector. <p>[Degree of reorientation: medium, a clear change in the national constitution to increase equity in agricultural water access, instances of greater equity in access to water are found but these are mere expansions of agricultural land and water instead of redistributions of land and water from powerful to marginalized groups of people.]</p>	<p>(Hoogesteger et al., 2016; Moreano et al., 2016)</p>
<p><u>Mexico</u> (Guanajuato) “from unlimited groundwater abstraction for irrigation to effective groundwater regulation”</p>	<ul style="list-style-type: none"> • The agricultural sector consumes 84% off all extracted groundwater. Due to over-abstraction (~40% more groundwater is pumped than recharged), groundwater levels have been dropping by 2-3 m per year. • A system of groundwater permits and tradable concessions was set up, yet implementation was incomplete. Enforcement has also lagged, resulting in legalisation of illegal wells and the boring of new ones. • Energy pricing was expected to motivate farmers to reduce groundwater use. Yet here again implementation has been weak, with many influential non-payers. • Self-regulation has also been stimulated, though this has mainly promoted knowledge exchange rather than collective action to curb groundwater use. <p>[Degree of reorientation: small, various regulatory mechanisms were set up but they have not been successful so far in regulating groundwater use.]</p>	<p>(Hoogesteger and Wester, 2017)</p>
<p><u>United States</u> (San Joaquin Valley) “from unregulated groundwater use for an agricultural powerhouse to reduced cropping area and sustainable groundwater management”</p>	<ul style="list-style-type: none"> • Farms in the valley produce half of California’s total farm output and are strongly dependent on irrigation. There is a serious overdraft in most of the aquifers in the valley. • Farmers have already switched from flood to drip irrigation. Further reductions in agricultural water use could be achieved by reducing croplands by 200,000 ha. This measure is not favoured by farmers. • A main vehicle to reduce groundwater use is the Sustainable Groundwater Management Act which aims to stabilise current groundwater levels up to 2040. • Users have formed “groundwater sustainability agencies” responsible for overseeing groundwater sustainability plans, measuring groundwater use, charging fees and attaining groundwater balances. 	<p>(Hanak et al., 2017; Stokstad, 2020)</p>

	<ul style="list-style-type: none"> • So far, implementation has focused on expansion of usable water supplies, alongside voluntary efforts to increase recharge or reduce demand. <p>[Degree of reorientation: small, the policy ambition to stabilise groundwater levels up to 2040 is rather modest, though many voluntary efforts are ongoing to curb groundwater use. There are no clear signs as yet that groundwater use is diminishing across the valley. Reorientation is ongoing.]</p>	
<p>United States (Great plains)</p> <p>“from freedom to farm with unrestricted groundwater use to groundwater conservation for a sustainable agricultural production”</p>	<ul style="list-style-type: none"> • The Great Plains is one of the main agricultural regions of the United States. In the US agriculture is characterised since the 1996 federal farm legislation as ‘freedom-to-farm’ with fewer subsidies (from target price to market price levels, limiting acreage for crops) and an increased (export) market orientation. For 2017-2021 about one-third of the nation’s two million farms receive regular subsidies, although the ratio is higher for larger farms. • In the Great Plains agricultural production intensified. From 2008-2018, cropland coverage increased with 5-10% over the majority of the Great Plains, often in lands that were previously regarded unsuitable for cultivation. Increases in crop land come from expansions in rainfed farming, as the irrigated area in the ten Great Plain states dropped with 6% over 2008-2018. Rainfed farmers thus expanded, but also intensified as they shifted their predominant wheat-fallow system (42%) to more intensive planting rotations of wheat-corn-fallow (43%) and even continuous cropping (15%). • Irrigated agriculture (mostly corn, sorghum, winter wheat, soybeans and cotton) requires more groundwater than is replenished. Hence, protection of groundwater is called for to sustain agricultural production, and many Great Plain states intensified groundwater management strategies. Successes are mostly found in the north of the Great Plains (Nebraska, Wyoming suspended drilling new wells, mandatory metering, restricting groundwater pumping). In the central and southern states of the plains groundwater declined strongly, on average by 14-m in Texas, 9-m in Kansas, 6-m in Oklahoma, and 5-m in New Mexico and Colorado for 1980-2007. It is estimated that much of the southern, and parts of the central plains will have insufficient water for irrigation in the next 20-30 years. <p>[Degree of Reorientation: medium, rainfed farming expanded and intensified due to freedom to farm, whereas groundwater strategies have not mitigated groundwater level declines across the central and southern High Plains. Expansion in rainfed farming increases production in short term, with onset of climate change it will be a challenge to continue rainfed farming on an expanded area]</p>	<p>(Harrington and Dubman, 1998; Rosenzweig and Schipanski 2019; Evett et al., 2020.; Lambert et al., 2020; Edwards, 2023)</p>
<p>Asia and Australia</p>		
<p>Australia (Murray-Darling Basin)</p> <p>“from irrigating the Murray dry to increasing water flows for the environment”</p>	<ul style="list-style-type: none"> • The Murray-Darling Basin covers 1 million km² and contains about 70% of Australia’s irrigated land area. The mean annual runoff is some 24,000 MCM. Large fluctuations occur in river flow due to high temporal and spatial variability in rainfall. • Irrigator influence has been very large for over a century in the basin as water infrastructure was free or subsidised, and water licences were also free initially. The strategy of ‘irrigation-first’ or ‘irrigating the Murray dry’ has been very effective. River flow dropped due to major irrigation extractions, outflow to the sea is about 40% when there would be no irrigation. The current outflow is not sufficient to keep the river open to the sea, dredging keeps the river mouth open. • The Water Act (2007) recognised the overuse of agriculture and related adverse impacts on the environment, and called for an increase in water flow for the environment. Environmental flow requirements were prioritised over social and economic considerations. The Act had to be implemented by a Basin Authority which had to design and implement a Basin Plan with diversion targets for agriculture and environment on the best 	<p>(Adamson and Loch, 2014; Grafton et al., 2020; Beasley, 2021)</p>

	<p>available scientific knowledge. The target for environmental flow was – informed by science- initially set as a range from 3900 – 7600 MCM. This target was due to politics lowered to 2750, 2680 and eventually set at 2075 MCM. This water target should be reached by means of voluntary buy-back of water entitlements from irrigators (capped by 1500 MCM), investments in water infrastructure to more efficiently supply water for the environment, and investments in on-farm measures to improve water use efficiency.</p> <ul style="list-style-type: none"> • Several independent reviews by scientists and a Murray-Darling Basin Royal Commission conclude that current efforts are not effective and unlawful. The reduced water targets for environment are not effective to restore biodiversity in the basin. The multi-billion dollars of public tax-money invested in water supply measures make a poor infrastructure investments as they reduce economic margins for remaining irrigators while future climate change outcomes (increase in temperature, reduction in rainfall) further reduces the economic margins, yet they were not incorporated. Efficiency gains in water use at farm level are not increasing return flows and thus further reduce environmental flow. • The water-reform approach that has been followed so far is characterised by a massive neglect of the rights of First People of Australia. Also, the best-available science was not included as scientific experts were often neglected in determining the environmental water target and effective measures (e.g. voluntary buy-back), scientific censorship took place on research institute CSIRO to make their findings align with intentions of the Basin Authority, and the Basin Authority remained untransparent which evidence was used to inform the target for environmental flow. Recommendations to improve water-reform (amongst others 44 recommendations by the Murray-Darling Basin Royal Commission) were by 2021 not been taken up. <p>[Degree of reorientation: very small; a Water Act, Basin Authority and multi-billion dollar plan were crafted but its implementation is not coming close to the water-for-environment target as infrastructure and efficiency gains reduce environmental flows and irrigators have increased the capture of flood water on agricultural fields.]</p>	
<p><u>Australia</u> (wheatbelt region) “from wheat everywhere to a smaller more profitable agricultural sector”</p>	<ul style="list-style-type: none"> • Number of farm enterprises is steadily declining. Due to increasing scale and labour-saving technologies, agricultural employment is in decline with depopulation taking place in many inland rural areas. • Since 1953 farm returns have grown in real terms, mostly due to improved productivity (e.g., with the use of herbicides, increased crop and pasture options, farm machinery, fertiliser and new sheep breeds). • Efforts to enhance the environmental performance of agriculture, including water quality and quantity, have had limited effect due to social and political pressure and marginal public funds for environmental measures. • Despite regional strategic plans, the public sector does not seem to steer strongly in this reorientation, as the economic and political importance of the western wheatbelt is small. • Farm-level trend is towards increased farm size, but it is unclear how the reorientation affects land and water resources. <p>[Degree of reorientation: small, policies and plans are in place but with limited effect on water quality and quantity, and there is little insight on how land and water resources have been affected.]</p>	<p>(Kingwell and Pannell, 2005; O’Connor et al. 2005)</p>
<p><u>China</u> (North China Plain) “from unlimited water to capping groundwater</p>	<ul style="list-style-type: none"> • The area where groundwater is overexploited has steadily increased since the 1970s, affecting both shallow and deep aquifers over ~60.000 km². Groundwater use for agriculture accounts for two-thirds of the overexploitation. In addition, 75% of groundwater is polluted due to infiltration of contaminated water from agriculture, industry and urban areas. Due to falling 	<p>(Zheng et al., 2010; Jia, 2011)</p>

<p>use for agriculture”</p>	<p>groundwater levels, river channels have dried up and wetland areas have shrunk.</p> <ul style="list-style-type: none"> • The government has set out to control groundwater exploitation through a system of water rights administration, well permits and pilots. • A suite of pilot projects was conducted: crop evapotranspiration reductions (e.g., switching from “thirsty” winter wheat to low water consumption cash crops), slightly saline groundwater practices, artificial recharge of groundwater (e.g., infiltration of excess surface water) and surface water transfers from the Yangtze River. • The outcomes of some pilots were promising. Agricultural water use was reduced by 225 mm/ha in Wuji village. There was also a construction ban on new wells in some places. It is unclear what combination of measures is most effective, how pilot insights can be scaled up, and what options farmers have as many of the pilots are experimental field sites and do not reflect farmer realities. <p>[Degree of reorientation: small, policies and plans are in place but limited changes are observed in groundwater levels. The challenge lies in scaling up seemingly successful pilots to the larger region. Reorientation is ongoing.]</p>	
<p>India (Ganges) “from a sluggish, polluted flow to a clean and continuous flow”</p>	<ul style="list-style-type: none"> • Due to agricultural expansion and intensification, widespread groundwater pumping, and industrial and sewage waste, the Ganges river system has become polluted and many streams flow only seasonally. • Hindus regard the Ganges as a sacred river, hence its cleansing has been a national priority since the 1980s. Different ambitious master plans have been launched, including most recently, the National Mission for Clean Ganga (2011) and Namami Gange (2014). • Projects have focused on sewage infrastructure, and much less on agricultural pollution and water use. These efforts are frequently criticised for not achieving their ambitious objectives due to insufficient sewage treatment capacity, corruption and weak enforcement. It is unclear what options farmers have to reduce both water use and pollution, while maintaining a sustainable income. • Interestingly, during the eight-week Covid-19 lockdown, water quality quickly improved as polluting industries were closed, agriculture water use and pollution was limited, and rainfall was higher than usual (~60% greater than average in most districts). <p>[Degree of reorientation: small, though ambitious plans are in place, it is unclear what options farmers have and whether land and water resources have been impacted. The Covid-19 pandemic demonstrated that Ganges water quality can rapidly improve.]</p>	<p>(Dutta et al., 2020; Sen, 2020)</p>
<p>Iran (Zayandeh-Rud) “from expansion to intensification of irrigated agriculture to increase food self-sufficiency”</p>	<ul style="list-style-type: none"> • Attaining food self-sufficiency is a key policy goal in Iran embedded in strategic plans and policies. In the Zayandeh-Rud basin, the government has since the 1950s been doubling the water supply (more dams, interbasin tunnels) to satisfy increasing water demands of an expanding irrigated agricultural sector. Since the 1960s the basin was closed as all water available in the river is abstracted (~80% for agriculture, 10-20% industry and households, <2% Gavkhuni wetland). • Major water transfer projects ended by 2010 as new water transfers like the Behesh Abad tunnel turned out to be very costly. Due to high population growth, urbanization and industrialization there is less surface water available for agriculture. • Farmers massively turned to groundwater to meet water demands of the crops. Groundwater policies and measures (registering, banning, metering, sanctioning) failed to prevent the overextraction of groundwater. Several aquifers are overexploited, and the total number of drilled wells steadily 	<p>(Molle et al., 2009; Nabavi, 2018; Zamani et al. 2019; Amiraslani and Dragovich, 2023)</p>

	<p>increase. The total extracted groundwater extraction was in the 2000s twice the surface water diversion.</p> <ul style="list-style-type: none"> • The government has been supporting intensification of agriculture, through subsidies on water, energy and fertilizers and guaranteed grain prices. This increased production and self-sufficiency, as Iran was in 2005 largely self-sufficient in wheat, rice and potato. Yet annual production strongly fluctuates – and so is food-self sufficiency – due to water shortages, land fragmentation, inadequate planning, rising costs of agricultural inputs (with some subsidies being removed). <p>[Degree of reorientation: very large, food self-sufficiency was largely achieved by agricultural intensification and overabstraction from groundwater. Continuous overabstraction of aquifers increases (future) vulnerability in water supply and thus food self-sufficiency]</p>	
<p><u>Jordan</u> “from agricultural intensification to a water secure Jordan”</p>	<ul style="list-style-type: none"> • Since the eighties agricultural production further intensified in Jordan. Groundwater has been severely over-abstracted in the Jordan Valley and Highlands to meet increasing water demands • In policies there is considerable attention for water security and illegal water abstraction, yet policies are not clear on which regulations will drastically reduce agricultural water demands. • Towards 2050 nearly all renewable surface and groundwater is needed for domestic use. Agriculture then becomes nearly entirely dependant on treated waste water. Treated wastewater thus becomes the main new water resource for agriculture. Present capacity of treated waste water is now 136 Million Cubic Metres (and should go to 800 MCM in 2050) and efficiency should increase from 30% to 80% in 2050. <p>[Degree of reorientation: small, regulations to reduce water demand for agriculture are not taking of and there is no fast adoption of agriculture irrigated by treated waste water.]</p>	<p>(Venot et al. 2008; Hellegers et al., 2023)</p>
<p><u>Kazakhstan</u> (Kazakhstan, Syr Darya river to North Aral Sea) “from a declining Aral Sea to sustainable natural resources management”</p>	<ul style="list-style-type: none"> • The Syr Darya river flows into the North Aral Sea, the Amu Darya river into the southern part of the Aral Sea. The Aral Sea has been shrinking in size and volume for decades resulting in a major environmental disaster. • Kazakhstan is leading efforts to restore the North Aral Sea. They are an active member of the Interstate Commission for Water Coordination of Central Asia who established an international fund in 1993 to save the Aral Sea. The fund resulted in several restoration projects. • In the North Aral Sea an earthen dike was constructed in 1992 to restore water levels, ecological and fishery conditions. The earthen dike was in 2005 replaced by the Kok-Aral dam, a 13 km hard-wall dam with spillway. • Since the dam construction restoration of the North Aral Sea is often claimed as a success, and contrasted with the further shrinking southern part of the Aral Sea. Water levels and volumes in the North Aral Sea have been increasing and stabilized over 2011-2020. Salinity of the sea decreased, and fish and fishery industry partly recovered. • Syr Darya river flow into the North Aral Sea over 2005-2014 shows a clear declining trend, caused by a combination of climate variability and increased water withdrawals for agriculture upstream in the basin. This means that the refilling of the North Aral Sea occurs due to a decreasing (excess) river flow, as agricultural water demands remained the same. • In 2024-2025 a follow-up project is under consideration to further enhance the ecological sate and volume of water in the North Aral Sea. <p>[Degree of reorientation: very large as the Kok-Aral dam ensured that Syr Darya water no longer emptied into the Aral Sea but was confined to the North Aral Sea while restoring water levels, water volumes, salinity and fish stocks in this sub-part of the shrinking Aral Sea region.]</p>	<p>(Massakbayeva et al. 2020; Liu et al. 2024; Water Diplomat 2025)</p>
<p><u>Nepal</u></p>	<ul style="list-style-type: none"> • The Andhi Khola irrigation scheme was set up in 1982 (finalized in 1997) by the United Mission to Nepal (UMN), requested by the Government of Nepal. Initially it was conceived 	<p>(Van Etten et al., 2002; Chidi, 2016;</p>

<p>(Andhi Khola Irrigation Scheme) “from hydropower development to pro-poor benefits in irrigation”</p>	<p>as a hydropower project, yet donors indicated that the local community should also directly benefit, resulting in the inclusion of an irrigation system that would ensure benefits for the poor. The irrigation scheme was designed to supply an area of 282 hectares with year-round irrigation water which were previously rainfed.</p> <ul style="list-style-type: none"> • The main objective of the irrigation project was to design a scheme under which landowners and smallholders/landless people would benefit equally as usually irrigation developments strengthen existing inequalities among landowners and smallholders. • To facilitate this equal benefit distribution, the project was accompanied by both land and water reforms. The distributive land reform meant that larger farmers had to sell their land to smaller farmers. The water reform was a novel water allocation system of “equal water rights for all” in which tradable water rights could be earned by participating in construction and canal maintenance work. • Pro-poor objectives of the project largely did not materialize due to delays in land redistribution, limited participation of landless people and disproportional obligations for smallholders in negotiations over water rights compared to larger farmers. • Analysis in the Andhi Khola basin between 1999-2014 showed a reduction of around 20% in cultivated land. This reduction is attributed mainly to population decrease (outmigration) and altitudinal variation as the higher the altitude the higher the land abandonment. <p>[Degree of reorientation: large as the pro-poor irrigation project was implemented, several pro-poor benefits were recorded as the land and water reforms gave landless and land-poor farmers an opportunity to obtain land and water-rights, yet the benefits were not as large as envisaged and large areas of irrigated land were abandoned.]</p>	<p>Pradhan et al., 2023)</p>
<p>Russia (Tyumen region) “from recultivation to agricultural intensification, expansion and grain export”</p>	<ul style="list-style-type: none"> • In the post-Soviet period, adequate, fertile arable land has been scarce in Tyumen. Hence, farmers lease land in the neighbouring region. • The state has a strong influence on land management through formal rules (e.g., reporting obligations for pesticide and fertiliser use), incentives (e.g., to stimulate preferred cropping plans and grain varieties), awareness-raising and quasi-formal rules (e.g., encouraging a shift from forage crops to grains and faster harvesting dates). • Local food security arguments are used to justify increased grain production in Tyumen, though grain is Russia’s key agricultural export. Risks of crop failure due to insufficient rainfall are largely unrecognised by state advisory services. • The state strongly steers grain production, with preferential attention for large farms and little concern for environmental implications. <p>[Degree of reorientation: very large, state-central planning has prevailed with major changes at the farm level. Risks of water shortages and environmental pollution have received little attention.]</p>	<p>(Kühling et al., 2016; Griewald, 2018)</p>
<p>Saudia Arabia “from phasing out domestic wheat production to wheat imports”</p>	<ul style="list-style-type: none"> • Saudi Arabia is overhauling its agricultural sector to reduce water consumption. • In 2008 the country produced 85% of the wheat it consumed. From 2007 to 2011, the country reduced its wheat production by 53%, from 2,558,000 tonnes to 1,184,484 tonnes. • The aim is to reduce agricultural water consumption from 17 billion cubic meters (BCM) in 2014 (which is 88% of Saudi Arabia’s water consumption) to 5 BCM annually to make agriculture more sustainable. • In 2016, about 82% of non-renewable water consumption was in the agricultural sector, mostly from groundwater as desalinated sea water represents about 12% of all available water resources. 	<p>(Beer, 2014; Grindle et al. 2015; Alrwis et al., 2021)</p>

	[Degree of reorientation: large, plans and strategies are in place and domestic production of wheat has drastically dropped. Further research is needed to determine whether the total water consumption of the agricultural sector has dropped as well.]	
<p><u>South Korea</u> (Gyeonggi-Do province) “from maximizing rice production to reducing irrigation and greenhouse gas emissions in rice fields”</p>	<ul style="list-style-type: none"> • Since the Korean War ended in 1953, South Korea invested strongly in irrigation infrastructure to increase irrigation schemes for rice and rice yields resulting in rice self-sufficiency in the 1980-1990s. • Nowadays the country is shifting from maximising rice production to dealing with climate change and urbanization, leading to a focus on reducing (irrigation) water use and greenhouse gas emissions in paddy rice fields. • To achieve these reductions, the government advocates a switch from traditional irrigation to intermittent irrigation (II), both with the help of policies e.g. Master Plan for National Water Management (2021), and by supporting farmers through projects and subsidies (e.g. Eco-friendly Direct Payment system (2025), Low-Carbon Paddy Water Projects (2024), Carbon-Neutral Programs (2023). • In the Majeong irrigation scheme in Gyeonggi-Do province, especially younger farmers with large farms adopted II. Farmers applying II are more involved in educational programs and trainings, and are trying to reduce irrigation water, even though irrigation water is free in Korea. Labour was the biggest barrier to apply II for both small-scale older farmers (weed growth) and for large-scale older farmers (fragmentation of land). • Field-level modelling of water balances and methane emissions indicated that with II, irrigation water applied decreases with 7.1% and CH₄ reduces with 21.8%. <p>[Degree of Reorientation: small, the ratio of farmers applying II is relative low with modest decreases in irrigation water and methane emissions. These reductions are smaller than potentially suggested in research due to high water levels and short little aeration events of some of the II practitioners. Reductions are also smaller due to a different status quo assumed in research studies; this case study assumed a period of midseason drainage during the growth stage similar to farmer practice, while other studies assume continuous flooding of the rice fields.]</p>	(Won et al., 2005; Kwater, 2021; Administration, 2021; van Wijk, 2025)
<p><u>Türkiye</u> (Konya River Basin) “from expanding state-supported farming to intensifying commercial farming”</p>	<ul style="list-style-type: none"> • The Konya river basin is often called the ‘breadbasket’ of Türkiye as throughout the 1980s cereals constituted half of the total agricultural production. Expansion of agricultural area peaked around 1995 to 30,000 km², after which it decreased to 22,000 km² in 2019. Around 8,000 km² are irrigated. • The government of Türkiye implemented neoliberal agricultural policies (Structural Adjustment Programme 1980, Agricultural Reform Implementation Project 2001) that promoted price liberalisation and strongly reduced low-priced, subsidised inputs (e.g. fuel, fertilisers) and crop-based support systems (e.g. for wheat, sugar beet). • These neoliberal policies had a clear effect on farming. Farmers had to produce for commercial (national and international) markets, and increased the use of fertilisers, irrigation water, and crops. Over 2000-2020 a twofold increase in crop production happened, with main increases in sugar beet +2.5 million tonnes, and maize + 1.5 million tonnes. • Demands for irrigation water nearly doubled over 2000-2019, from an estimated 1.8 MCM to 3.3 MCM. Water supply in the basin and water transfer from neighbouring catchments were not sufficient to meet these water demands, hence farmers increasingly rely on groundwater. Four out of five groundwater observation wells in the basin rapidly decrease since after 2000 with ~1m/year. <p>[Degree of reorientation: very large; agricultural policies for liberalisation had a major effect as the agricultural area reduced, farmers intensified especially sugar beet and maize production with increased use of fertiliser and irrigation water.]</p>	(Öztürk et al., 2018; Yilmaz et al., 2021; Ak et al., 2022)

<p><u>Uzbekistan</u> (Amu Darya river to South Aral Sea) "From cotton and food self-sufficiency to Aral Sea ecosystem conservation"</p>	<ul style="list-style-type: none"> • Due to the policy of "Cotton First" the Soviet Union pushed for the cultivation of cotton in (present) Uzbekistan to promote economic growth. Cotton production peaked in 2007. • In the past two decades a self-sufficiency policy has been replacing cotton for food crops such as wheat, corn, potatoes, rice, fruits and vegetables. • Discharge to the Aral Sea declined from 60 km³/year in the 50s to 10 km³/year in the period 2000-2010 causing a major environmental disaster to the ecosystem and communities around the Aral Sea. • Difficulties in transboundary water cooperation and expansion of irrigated agriculture lead to further declining discharges to the southern part of the Aral Sea. • Despite policy objectives and nature restoration programs, the discharge of the Amu Darya river into the Aral Sea in Uzbekistan is still shrinking in size and volume. <p>[Degree of Reorientation: very limited as discharge into the Aral Sea continues to decline]</p>	<p>(Loodin, 2020; Song et al., 2023)</p>
<p><u>Vietnam</u> (Mekong Delta) "from rice everywhere to high-value diversified crops"</p>	<ul style="list-style-type: none"> • Economic reforms from the mid-1980s led to diversification, especially in aquaculture. Yet investments in dikes, canals and pumping stations supported a rice intensification strategy. • With the Mekong Delta Plan (2013) a new vision was launched, focused on high-value agriculture and tailored strategies for the distinct agro-ecological zones in the upper, middle, and coastal delta. • A 10-year political process brought steadily growing support for the new plan among ministries and expert advisors in Hanoi and in the Mekong Delta. Legislation was adopted reflecting the idea of high-value diversification and less rice. A more detailed integrated regional master plan, and research pilot projects for alternative farming livelihoods (e.g., sustainable aquaculture, flood-based agriculture) have been devised. <p>[Degree of reorientation: medium, large changes are observed in policies and plans, and actor support for the diversification strategy has increased. However, a major gap remains between the envisioned and actual agricultural water management and resource use. Reorientation is ongoing.]</p>	<p>(Seijger et al., 2019, Vo et al., 2019)</p>
Europe		
<p><u>Bulgaria</u> "from state-led irrigation to privatisation, declining crop production and reduced water use"</p>	<ul style="list-style-type: none"> • Following the collapse of the central planning system and Zhivkov government in 1989, state-led farming and irrigation also collapsed. This led to a 90% drop in irrigated farmland and water use (1989-2007), and similar declines in fertiliser and pesticide use. Lands were abandoned and yields fell well below pre-1989 levels. • Commercial farming, property rights and markets did not take off. Instead supplementary farming grew from 14% pre-1989 to 53% in the 2000s. • There seems to have been limited public sector steering in this reorientation. State-led commercial farming collapsed, and various factors complicated agricultural growth (e.g., credit constraints, low returns on investment, acceptance of low farming incomes). <p>[Degree of reorientation: very large, as major changes occurred in both strategy and natural resources.]</p>	<p>(Petkov and Dimitrov, 1996; Meurs and Bogushev, 2008; Bachev, 2010)</p>
<p><u>European Union</u> "from polluting and resource-consumptive agriculture to agrifood chains with a neutral or positive environmental impact"</p>	<ul style="list-style-type: none"> • Abundant use of chemical pesticides and excess nutrients in EU agriculture have been a major contributor to soil, water and air pollution and loss of biodiversity. • The EU "Farm to Fork" strategy sketches a new approach spanning the entire food chain and envisioning a neutral environmental impact, while ensuring access to sufficient food for everyone. Moreover, the most sustainable food is envisioned to become the most affordable. • The EU Commission is set to work on regulatory frameworks (e.g., targeting sustainable food systems, carbon removal in the food chain and sustainable use of pesticides), action plans (e.g., for integrated nutrient management) and promotion of 	<p>(European Commission 2020)</p>

	<p>sustainable practices, such as precision agriculture, agro-ecological practices and carbon-efficient farming and livestock.</p> <ul style="list-style-type: none"> • “Farm to Fork” is highly ambitious, as it envisions a food chain that contributes to a climate-neutral European Union by 2050. This goal is at odds with Europe’s current intensive farming practices, which are cheaper while causing more pollution of soil, water and the environment. <p>[Degree of reorientation: small, reorientation has started with formulation of the strategy. Agricultural water management practices have not yet been widely adjusted.]</p>	
<p><u>Germany</u> (lowland region) “from excessive use of manure to groundwater with good chemical status”</p>	<ul style="list-style-type: none"> • Due to intensive agriculture and fertilisation, Germany has since 2012 failed to meet the water quality targets set in European environmental directives (EU Nitrates Directive, EU Water Framework Directive). • Coordinated efforts to reduce agricultural pollution have been hampered by conflict between different state actors (particularly, the federal and state authorities) over economic and environmental interests, combined with limited incentives for farmers to adopt more environmentally friendly practices. • Measures to reduce nitrogen pollution are not widely implemented, and nitrogen concentrations remain too high. The EU Court of Justice ruled in 2018 that Germany must take stronger measures to combat nitrate pollution of water. <p>[Degree of reorientation: small, some plans and policies have been formulated but little change is observable on farmers’ fields and in land and water resources. Reorientation is ongoing.]</p>	<p>(Salomon et al., 2016; Kirschke et al., 2019)</p>
<p><u>Spain</u> (Guadalquivir) “from irrigation expansion to water savings and high-value crops”</p>	<ul style="list-style-type: none"> • After irrigation reform in 2002-2015, water abstraction diminished by ~30% and economic productivity of irrigation water increased by ~20% from €0.49 to €0.60/m³. • Supported by the Spanish government, the Andalusian irrigation plan prioritised modernisation of irrigation techniques, especially with investments in and adoption of drip and deficit irrigation and changes in cropping patterns (less cotton and corn, more olive and citrus trees). • Strict controls were introduced to reduce irrigated area and water use (e.g., a moratorium on irrigation expansion and reduction in water rights). • Although the river basin is closed, risks of growing water consumption remain and require policy enforcement. <p>[Degree of reorientation: very large, considerable change is observed in policies and plans, extending to farmers’ fields and land and water resources. Risks of over-consumption of water still remain.]</p>	<p>(Exposito and Berbel, 2017; Berbel et al., 2019)</p>
<p><u>The Netherlands</u> “from rapid removal of excess water and nutrients to soil-water conservation and biodiversity enhancement”</p>	<ul style="list-style-type: none"> • In 2001, the national and provincial government and water authorities agreed on a novel strategy focused on retention, storage and controlled removal of water and nutrients. • New approaches to drainage were tested, with pilots indicating that controlled drainage would be effective in reducing both peak flows and drought stress. • Water conservation measures were not widely implemented. In the recent dry years of 2018, 2019 and 2020, the media (again) provided extensive coverage of water conservation measures on agricultural fields. Emergency solutions were implemented (rubber balls in drains), as well as visionary measures (the “Veluwe Gieter”), and new research programmes were initiated (e.g., Droughts NL of Wageningen University). <p>[Degree of reorientation: small, mostly in policies and plans, much less in farming practices and land and water resources. Reorientation is ongoing.]</p>	<p>(Ritzema, 2015)</p>
<p>World</p>		
<p><u>World</u> “From feeding 5 billion people in 2000 on 1,200 million hectares to 8-9 billion people in</p>	<ul style="list-style-type: none"> • Growing more food with less land and water has been a core concern of agricultural developments worldwide. The Comprehensive Assessment of Water Management in Agriculture was the largest collaborative scientific effort on water for food in the early 2000s. Over 700 scientists were involved, it was led by the CGIAR global research partnership for food security and it was published in 2007. 	<p>(Molden 2007; Araus et al., 2021; Seijger et al., 2025)</p>

<p>2050 on 1,300 hectares”</p>	<ul style="list-style-type: none"> • The study assessed past trends and future scenarios for agricultural production, land and water use, and concluded that it is possible to feed 8-9 billion people in 2050 with minimal increases in land and water use. More food could be grown with less water by making productivity improvements in land (more tonnes per hectare) and water (more tonnes per m³ crop water evapotranspiration). Global trade and rainfed agriculture were the two most promising options to reduce future growth of land and water use in agriculture. Irrigation was expected to make a relative small contribution as the irrigated area is much smaller than rainfed area. • A recent evaluation for 2000-2020 shows that productivity gains largely did not materialize. Photosynthesis increases – the major determinant to improve crop water productivity – have been very marginal at crop level for decades. Land productivity gains also lagged, as increases in cereal yields were half of what was needed for minimal increases in agricultural land area. • Trade and cereal production was not consolidated in favourable (predominant) rainfed regions (North America, Europe, Russia), their arable land declined by 35 million hectares while arable land expanded by 74 million hectares in Africa, Latin America and Eastern Asia. Key rainfed areas thus shrunk in size, and an unexpectedly large area expansion of rainfed agriculture was found in sub-Saharan Africa with low yields. Irrigation expansion was quicker and more extensive than predicted in the optimal Comprehensive Assessment scenario. <p>[Degree of reorientation: very small; anticipated gains in land and water productivity and optimization of global trade have not materialized. The world appears to be on a path to produce sufficient food only with steadily increasing land and water use, at the direct expense of ecosystems.]</p>	
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References cited

- Abdellatif, G., Gaafar, I., van der Vat, M., Hellegers, P., El-Din El-Naggar, H., Garcia, A., Seijger, C., 2025. Impact of irrigation modernization and high Aswan Dam inflow on Nile water system efficiency and water reuse in Egypt. *Agricultural Water Management* 316: 109576.
- Adamson, D., Loch, A. (2014). Possible negative feedbacks from 'gold-plating' irrigation infrastructure. *Agricultural Water Management* 145: 134-144.
- African Development Bank, 2020. Sudan's record wheat harvest is proof that Bank agricultural transformation program will boost breadbasket goal. Available at <https://www.afdb.org/en/news-and-events/sudans-record-wheat-harvest-proof-bank-agricultural-transformation-program-will-boost-breadbasket-goal-38388> (accessed 04 January 2022)
- Ak, M. Y., Demirbilek, B., & Benson, D. (2022). Türkiye's water allocation regime under institutional change. In: *Water Resources Allocation and Agriculture: Transitioning from Open to Regulated Access*, pp.117-127, (eds.) Ruillard, J., Babbitt, C., Challies, E., Rinaudo.
- Alrwis, K., Ghanem, A., Alnashwan, O., Duwais, A., Alaagib, S., Aldawdhi, N. (2020). Measuring the impact of water scarcity on agricultural economic development in Saudi Arabia. *Saudi Journal of Biological Sciences* 28(10): 191-195. <https://doi.org/10.1016/j.sjbs.2020.09.038>
- Amiraslani, F., Dragovich, D. (2023). Food-energy-water nexus in Iran over the last two centuries: A food secure future? *Energy Nexus* 10:100189.
- Araus, J., Sanchez-Bragado, R., Vicente, R. (2021). Improving crop yield and resilience through optimization of photosynthesis: panacea or pipe dream? *Journal of Experimental Botany*, 2021. 72(11): p. 3936-3955.
- Arvor, D., Meirelles, M., Dubreuil, V., Bégué, A., Shimabukuro, Y., 2012. Analyzing the agricultural transition in Mato Grosso, Brazil, using satellite-derived indices. *Applied Geography* 32, 702-713. <https://doi.org/10.1016/j.apgeog.2011.08.007>
- Bachev, H., 2010. *Agricultural Water Management in Bulgaria*. University Library of Munich, Germany, MPRA Paper. <https://dx.doi.org/10.2139/ssrn.1662354>
- Beasley, R. (2021). *Dead in the water. A very angry book about our greatest environmental catastrophe... the death of the Murray-Darling Basin*. Allen & Unwin.

- Beer, E. 2014. Saudi Arabia revamps farming to cut water consumption. Press item. Available at <https://www.foodnavigator.com/Article/2014/01/20/Saudi-Arabia-revamps-farming-to-cut-water-consumption> (accessed 04 January 2022)
- Berbel, J., Expósito, A., Gutiérrez-Martín, C., Mateos, L., 2019. Effects of the Irrigation Modernization in Spain 2002–2015. *Water Resources Management* 33, 1835–1849. <https://doi.org/10.1007/s11269-019-02215-w>
- Boularbah, S., Kuper, M., Hammani, A., Mailhol, J., Taky, A. (2019). The blind angle: Performance assessment of drip irrigation in use in a large-scale irrigation scheme in Morocco. *Irrigation and Drainage* 68(5): 925–936.
- Boundi, A., Yacine, Z. (2021). Variability of rainfall regime in an agricultural region with a semi-arid climate: Case of Tadra irrigated perimeter (continental Morocco). *Caspian Journal of Environmental Sciences* 19(1): 31–45.
- Cabral, A., Vasconcelos, M., Oom, D., Sardinha, R., 2011. Spatial dynamics and quantification of deforestation in the central-plateau woodlands of Angola (1990–2009). *Applied Geography* 31, 1185–1193. <https://doi.org/10.1016/j.apgeog.2010.09.003>
- Chidi, C., 2016. Determinants of cultivated land abandonment in the hills of western Nepal. *Studia Universitatis Babeş-Bolyai Geographia*: 101–116.
- Christoforidou, M., Borghuis, G., Seijger, C., van Halsema, G., Hellegers, P., 2023. Food security under water scarcity: a comparative analysis of Egypt and Jordan. *Food Security* 15(1), 171–185.
- Corkal, D., Diaz, H., Sauchyn, D., 2011. Changing Roles in Canadian Water Management: A Case Study of Agriculture and Water in Canada's South Saskatchewan River Basin. *International Journal of Water Resources Development* 27, 647–664. <https://doi.org/10.1080/07900627.2011.621103>
- Dutta, V., Dubey, D., Kumar, S., 2020. Cleaning the River Ganga: Impact of lockdown on water quality and future implications on river rejuvenation strategies. *Science of The Total Environment* 743, 140756. <https://doi.org/10.1016/j.scitotenv.2020.140756>
- Edwards, C. 2023. Cutting Federal Farm Subsidies. CATO Briefing Paper number 162.
- Eeden, A., Mehta, L., Koppen, B., 2016. Whose Waters? Large-Scale Agricultural Development and Water Grabbing in the Wami-Ruvu River Basin, Tanzania. *Water Alternatives*, 9. <https://doi.org/10.2307/j.ctvh8r2qk.15>
- El Garouani, M., Radoine, H., Lahrach, A., Oulidi, H. J., Chaabane, M. (2024). Analysis of the effect of climatic variability and increasing water demand on the Saïss aquifer, Morocco. In *E3S Web of Conferences* (Vol. 489, p. 01001). EDP Sciences.
- Evet, S., Colaizzi, P., Lamm, F., O'Shaughnessy, S., Heeren, D., Trout, T., Kranz, W., Lin, X. 2020. Past, present and future of irrigation on the U.S. Great Plains. *Biological Systems Engineering: Papers and Publications*. 680.
- Exposito, A., Berbel, J., 2017. Agricultural Irrigation Water Use in a Closed Basin and the Impacts on Water Productivity: The Case of the Guadalquivir River Basin (Southern Spain). *Water* 9, 136. <https://doi.org/10.3390/w9020136>
- European Commission, 2020. Farm to fork strategy. For a fair, healthy, and environmentally-friendly food system, European Union, Brussels.
- FAO, 2020. FAO Crop and Food Supply Assessment Mission to the Sudan, FAO, Rome.
- Garrett, R., Koh, I., Lambin, E., le Polain de Waroux, Y., Kastens, J., Brown, J., 2018. Intensification in agriculture-forest frontiers: Land use responses to development and conservation policies in Brazil. *Global Environmental Change* 53, 233–243. <https://doi.org/10.1016/j.gloenvcha.2018.09.011>
- Grafton, R., Collof, M., Marshall, V., Williams, J. (2020). Confronting a 'Post-Truth Water World' in the Murray-Darling Basin, Australia. *Water Alternatives* 13(1): 1–28.
- Griewald, Y., 2018. The Art of the State to Intervene: Insights Into Agricultural Land Management in Russia. *Ecological Economics* 151, 1–9. <https://doi.org/10.1016/j.ecolecon.2018.04.026>
- Grindle, K., Siddiqi, A., Anadon, L., 2015. Food security amidst water scarcity: Insights on sustainable food production from Saudi Arabia. *Sustainable Production and Consumption* 2, 67–78. <https://doi.org/10.1016/j.spc.2015.06.002>
- Gyamfi, C., Ndambuki, J., Salim, R., 2016. Hydrological responses to land use/cover changes in the Olifants Basin, South Africa. *Water*, 8(12), 588.
- Hanak, E., Lund, J., Arnold, B., Escriva-Bou, A., Gray, B., Green, S., et al., 2017. Water stress and a changing San Joaquin Valley, Public Policy Institute of California, San Francisco.
- Harrington, D., Dubman, R. 1998. Agriculture and New Agricultural Policies in the Great Plains. *Rural Development Perspectives* 13(1): 7–18.
- Hellegers, P., Halsema, G. van, Seijger, C., Borghuis, G., Christoforidou, M., Vervelde, B. 2023. Confronting the challenges of water scarcity in Jordan: Seeking viable, sustainable, and prosperous options for Agriculture & Water in 2050. Technical Background Report. Wageningen University and Research.
- Hoogesteger, J., Boelens, R., Baud, M., 2016. Territorial pluralism: water users' multi-scalar struggles against state ordering in Ecuador's highlands. *Water International* 41(1): 91–106. <https://doi.org/10.1080/02508060.2016.1130910>
- Hoogesteger, J., Wester, P., 2017. Regulating groundwater use: The challenges of policy implementation in Guanajuato, Central Mexico. *Environmental Science & Policy* 77, 107–113. <https://doi.org/10.1016/j.envsci.2017.08.002>

- Hssaisoune, M., Bouchaou, L., Sifeddine, A., Bouimetarhan, I., Chehbouni, A. (2020). Moroccan Groundwater Resources and Evolution with Global Climate Changes. *Geosciences*. 10(2):81.
- Jia, Y., 2011. Groundwater issues and management in the North China Plain, in: Findikakis, A., Sato, K. (Eds.), *Groundwater Management Practices*. CRC Press, Boca Raton, 13-24.
- Kingwell, R., Pannell, D., 2005. Economic trends and drivers affecting the Wheatbelt of Western Australia to 2030. *Australian Journal of Agricultural Research* 56, 553-561. <https://doi.org/10.1071/AR04196>
- Kirschke, S., Häger, A., Kirschke, D., Völker, J., 2019. Agricultural Nitrogen Pollution of Freshwater in Germany. *The Governance of Sustaining a Complex Problem*. *Water* 11, 2450. <https://doi.org/10.3390/w11122450>
- Kühling, I., Broll, G., Trautz, D., 2016. Spatio-temporal analysis of agricultural land-use intensity across the Western Siberian grain belt. *Science of The Total Environment* 544, 271-280. <https://doi.org/10.1016/j.scitotenv.2015.11.129>
- Kuper, M., Ameer, F., Hammani, A. (2017). Unraveling enduring paradox of increased pressure on groundwater through efficient drip irrigation. In: *Drip irrigation for agriculture: untold stories of efficiency innovation and development*. Editors: Venot, J. Kuper, M., Zwarteveen, M.
- Kwater, R. (2021). Fourth Biennial Update Report of the Republic of Korea under the United Nations Framework Convention on Climate Change. Cheongju, Republic of Korea: Ministry of Environment.
- Lambert, A., Hallar, A. G., Garcia, M., Strong, C., Andrews, E., & Hand, J. L. 2020. Dust impacts of rapid agricultural expansion on the Great Plains. *Geophysical Research Letters*, 47, e2020GL090347.
- Lema, D., Gallacher, M., Egas, J., de Salvo, C., 2018. *Analysis of Agricultural Policies in Argentina 2007-2016*, Inter-American Development Bank, Washington.
- Liebrand, J., Zwarteveen, M., Wester, F., van Koppen, B. 2012. The deep waters of land reform: land, water and conservation area claims in Limpopo province, Olifants Basin, South Africa. *Water International* 37(7): 7873-787.
- Liu, S., Long, A., Luo, G., Wang, H., Yan, D., Deng, X., 2024. What drives the distinct evolution of the Aral Sea and Lake Balkhash? Insights from a novel CD-RF-FA method. *Journal of Hydrology: Regional Studies* 56: 102014.
- Loodin, N., 2020. Aral Sea: an environmental disaster in twentieth century in Central Asia. *Modeling Earth Systems and Environment* 6(4), 2495-2503.
- Marull, J., Delgadillo, O., Cattaneo, C., La Rota, M., Krausmann, F., 2018. Socioecological transition in the Cauca river valley, Colombia (1943-2010): towards an energy-landscape integrated analysis. *Regional Environmental Change* 18, 1073-1087. <https://doi.org/10.1007/s10113-017-1128-2>
- Massakbayeva, A., Abuduwaili, J., Bissenbayeva, S., Issina, B., Smanov, Z., 2020. Water balance of the Small Aral Sea. *Environmental Earth Sciences* 79(3): 75. <https://doi.org/10.1007/s12665-019-8739-5>
- McCartney, M.P.; Yawson, D.K.; Magagula, T.F.; Seshoka, J. 2004. Hydrology and water resources development in the Olifants River Catchment. Working Paper 76. Colombo, Sri Lanka: International Water Management Institute (IWMI).
- Mendoza, A. 2021. Achieving water security through climate-resilient infrastructure. PreventionWeb. Published 16 December 2021. <https://www.preventionweb.net/news/achieving-water-security-through-climate-resilient-infrastructure> (Accessed on 19 March 2024)
- Meurs, M., Bogushev, A., 2008. Forward to the Past ? Agricultural Restructuring in Bulgaria. *Méditerranée*.
- Merrey, D., Lévyte, H., Koppen, B., 2009. Are good intentions leading to good outcomes? Continuities in social, economic and hydro-political trajectories in the Olifants River basin, South Africa. In: In Molle, F., Wester, P. (Eds.). *River basin trajectories: societies, environments and development*. Wallingford, UK: CABI; Colombo, Sri Lanka: International Water Management Institute (IWMI), pp. 47-74.
- Merrey, D., Sally, H., 2014. Improving Access to Water for Agriculture and Livestock in Niger: A Preliminary Analysis of Investment Options for the Millennium Challenge Corporation. <http://bitly.ws/nmtR> (accessed on 04 January 2022).
- Molden, D. (ed), (2007), *Water for food Water for life. A Comprehensive Assessment of Water Management in Agriculture*. Earthscan: London.
- Molle, F., Ghazi, I., Murray-Rust, H. (2009). Buying respite: Esfahan and the Zayandeh Rud River Basin, Iran. In Molle, F., Wester, P. (Eds.). *River basin trajectories: societies, environments and development*. Wallingford, UK: CABI; Colombo, Sri Lanka: International Water Management Institute (IWMI). pp.196-213.
- Moreano, M., Hopfgartner, K., Santillana, A., 2016. La política económica de la reforma a la gobernanza del agua y las implicaciones para la desigualdad territorial - El caso de Ecuador (Serie Documento de Trabajo N°201. Grupo Desarrollo con Cohesión Territorial, Programa Cohesión Territorial para el Desarrollo, Issue.
- Nabavi, E. (2018). Failed policies, falling aquifers: Unpacking groundwater overabstraction in Iran. *Water Alternatives* 11(3): 699-724.
- Öztürk, M., Jongerden, J., Hilton, A. (2018). The (re)production of the new peasantry in Türkiye. *Journal of Rural Studies* 61, 244-254.

- O'Connor, M., McFarlane, M., Fisher, J., MacRae, D., Lefroy, E., 2005. The Avon River Basin in 2050: Scenario planning in the Western Australian Wheatbelt. *Australian Journal of Agricultural Research* 56, 563-580. <https://doi.org/10.1071/AR04195>
- Ovadia, J., 2018. State-led industrial development, structural transformation and elite-led plunder: Angola (2002-2013) as a developmental state. *Development Policy Review* 36, 587-606. <https://doi.org/10.1111/dpr.12249>
- Peiretti, R., Dumanski, J., 2014. The transformation of agriculture in Argentina through soil conservation. *International Soil and Water Conservation Research* 2, 14-20. [https://doi.org/10.1016/S2095-6339\(15\)30010-1](https://doi.org/10.1016/S2095-6339(15)30010-1)
- Petkov, P., Dimitrov, S., 1996. Irrigation in Bulgaria. *GeoJournal* 40, 405-411. <http://www.jstor.org/stable/41147013>
- Piquer-Rodríguez, M., Baumann, M., Butsic, V., Gasparri, H., Gavier-Pizarro, G., Volante, J., et al., 2018. The potential impact of economic policies on future land-use conversions in Argentina. *Land Use Policy* 79 57-67. <https://doi.org/10.1016/j.landusepol.2018.07.039>
- Pradhan, P., Yoder, R., Meinzen-Dick, R., Merrey, D., 2023. Adaptation to change in six farmer-managed irrigation systems in Nepal: Forty years of observations. *London Journal of Research in Humanities and Social Sciences* 23(5).
- Presidential Water Administration, Republic of Korea. Master Plan for National Water Management (2021-2030). <https://faolex.fao.org/docs/pdf/kor227143.pdf>
- Ritzema, H., 2015. Land drainage strategies to cope with climate change in the Netherlands. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science* 65, 80-92. <https://doi.org/10.1080/09064710.2014.994557>
- Röder, A., Pröpfer, M., Stellmes, M., Schneibel, A., Hill, J., 2015. Assessing urban growth and rural land use transformations in a cross-border situation in Northern Namibia and Southern Angola. *Land Use Policy* 42, 340-354. <https://doi.org/10.1016/j.landusepol.2014.08.008>
- Rosenzweig, S., Schipanski, M. 2019. Landscape-scale cropping changes in the High Plains: economic and environmental implications. *Environmental Research Letters* 14: 124088.
- Salomon, M., Schmid, E., Volkens, A., Hey, C., Holm-Müller, K., Foth, H., 2016. Towards an integrated nitrogen strategy for Germany. *Environmental Science & Policy* 55, 158-166. <https://doi.org/10.1016/j.envsci.2015.10.003>
- Saskatchewan Government, 2020. Saskatchewan Announces \$4 Billion Irrigation Project At Lake Diefenbaker. <https://www.saskatchewan.ca/government/news-and-media/2020/july/02/irrigation-project> (accessed 04 January 2022)
- Sen, S., 2020. *Ganges: The Many Past of an Indian River*. Yale University Press, London.
- Shalby, A., Emara, S., Metwally, M., Armanuos, A., El-Agha, D., Negm, A., Gado, T., 2023. Satellite-based estimates of groundwater storage depletion over Egypt. *Environmental Monitoring Assessment* 195: 594.
- Sims, D. 2018. *Egypt's desert dreams. Development or Disaster? The American University in Cairo Press: Cairo.*
- Seijger, C., Urfels, A., Christoforidou, M., Hellegers, P., Borghuis, G., Langan, S., Halsema G., 2025. More food, but less land and water for nature: why agricultural productivity gains did not materialise. *Agricultural Water Management* 307, 109229. <https://doi.org/10.1016/j.agwat.2024.109229>
- Seijger, C., Hellegers, P., 2023. How do societies reform their agricultural water management towards new priorities for water, agriculture, and the environment? *Agricultural Water Management* 277: 108104.
- Seijger, C., Vo, H., van Halsema, G., Douven, W., Wyatt, A., 2019. Do strategic delta plans get implemented? The case of the Mekong Delta Plan. *Regional Environmental Change* 19, 1131-1145. <https://doi.org/10.1007/s10113-019-01464-0>
- Song, S., Chen, X., Liu, T., Zan, C., Hu, Z., Huang, S., ... Sun, Y., 2023. Indicator-based assessments of the coupling coordination degree and correlations of water-energy-food-ecology nexus in Uzbekistan. *Journal of Environmental Management*, 345, 118674.
- Stokstad, E., 2020. Droughts exposed California's thirst for groundwater. Now, the state hopes to refill its aquifers. *Science*. <https://doi.org/10.1126/science.abc2671>
- Tawfik, M., Hoogesteger, J., Moussa, M., Hellegers, P., 2024. 'Squeezing Out' the Nile Delta's Drainage Water to Irrigate Egypt's Desert Land. *Water* 16(1):157.
- Thiam, D. R., Muchapondwa, E., Kirsten, J., & Bourblanc, M., 2015. Implications of water policy reforms for agricultural productivity in South Africa: Scenario analysis based on the Olifants river basin
- Van Etten, J., van Koppen, B., Pun, S., 2002. Do equal land and water rights benefit the poor?: Targeted irrigation development: The case of the Andhi Khola Irrigation Scheme in Nepal (Vol. 38). IWMI: Colombo.
- van Wijk, B. W. (2025). Reorientation of South Korea's agricultural water management from intensive to sustainable rice production: a case study on the impact of intermittent irrigation in the Majeong irrigation scheme. Master thesis, Wageningen University and Research. <https://edepot.wur.nl/700682>
- Velez-Torres, I., 2012. Water Grabbing in the Cauca Basin: The Capitalist Exploitation of Water and Dispossession of Afro-Descendant Communities. *Water Alternatives* 5, 431-449.

- Venot, J.-P., Molle, F., Courcier, R., 2008. Dealing with closed basins: The case of the Lower Jordan River Basin. *International Journal of Water Resources Development* 24(2), 247-263.
- Vo, H. T. M., van Halsema, G., Seijger, C., Dang, N., Dewulf, A., Hellegers, P., 2019. Political agenda-setting for strategic delta planning in the Mekong Delta: converging or diverging agendas of policy actors and the Mekong Delta Plan? *Journal of Environmental Planning and Management* 62, 1454-1474. <https://doi.org/10.1080/09640568.2019.1571328>
- Water Diplomat, 2025. Kazakhstan announces 42% increase in Northern Aral Sea. *Hydropolitics News and Intelligence*. 3 February 2025. Available at <https://www.waterdiplomat.org/story/2025/02/kazakhstan-announces-42-increase-northern-aral-sea>
- Wineman, A., Jayne, T., Modamba, E., Kray, H., 2020. The changing face of agriculture in Tanzania: Indicators of transformation. *Development Policy Review* 38, 685-709. <https://doi.org/10.1111/dpr.12491>
- Won, J. G., Choi, J. S., Lee, S. P., Son, S. H., Chung, S. O. (2005). Water saving by shallow intermittent irrigation and growth of rice. *Plant Production Science*, 8(4): 487-492. <https://doi.org/10.1626/pp.s.8.487>
- World Economic Forum. (2020). Saï's Water Conservation Project, Morocco. World Economic Forum. Published 20 September 2020. <https://www.weforum.org/publications/six-qualities-of-sustainable-infrastructure-in-action/saïss-water-conservation-project-morocco-e26f925a93/> (Accessed on 19 March 2024)
- World Future Council, 2017. Niger's 3N Initiative: 'Nigeriens nourishing Nigeriens'. <https://www.futurepolicy.org/healthy-ecosystems/food-and-water/nigers-3n-initiative-nigeriens-nourishing-nigeriens/> (accessed 04 January 2022)
- Yılmaz, G., Colak, M. A., Özgencil, İ. K., Metin, M., Korkmaz, M., Ertuğrul, S., ... & Jeppesen, E. (2021). Decadal changes in size, salinity, waterbirds, and fish in lakes of the Konya Closed Basin, Türkiye, associated with climate change and increasing water abstraction for agriculture. *Inland Waters*, 11(4), 538-555.
- Zaharaddeen, D., Shimizu, K., Yamazaki, Y., Nangia, V., Mansouri, A., Belaarabi, M., Ousstous, L. (2023). Impact of a Drip Irrigation System on Planning and Management of Water Delivery in a Large-Scale Irrigation Scheme in Morocco. *International Journal of Environmental and Rural Development* 14-1: 38-44.
- Zamani, O, Grundmann, P., Libra J., Nikouei, A. (2019). Limiting and timing water supply for agricultural production – The case of the Zayandeh-Rud River Basin, Iran, *Agricultural Water Management*, Volume 222: 322-335.
- Zheng, C., Liu, J., Cao, G., Kendy, E., Wang, H., Jia, Y., 2010. Can China Cope with Its Water Crisis?— Perspectives from the North China Plain. *Groundwater* 48, 350-354. https://doi.org/10.1111/j.1745-6584.2010.00695_3.x