Policies to Manage Agricultural Groundwater Use

UNITED STATES

The United States is the largest user of groundwater for agriculture among OECD countries. The agriculture sector accounts for two thirds of total U.S. groundwater withdrawals. However groundwater use and the challenges it faces vary tremendously by region. Groundwater is used intensively in specific States and aquifer systems, resulting in multiple negative externalities in some areas, but is also used in a relatively sustainable manner in other locations.

The Federal government has primary responsibility for groundwater management on Federal lands, and provides scientific research and financial support for groundwater management as well as regulatory oversight for groundwater quality. However, the States have primary responsibility for the design and implementation of groundwater withdrawal policies on private and State-owned land—including most lands used for agricultural crop production. As a result, multiple management systems are found among States using groundwater in agriculture. This heterogeneity is shown in the presentation of groundwater systems and policies for four selected multi-state regions: the Northern High Plains Aquifer, Southern High Plains Aquifer, Mississippi Alluvial Aquifer and Mountains and Pacific regions.

1. Main national governmental agency responsible for quantitative management of groundwater

Institution	Role
U.S. Geological Survey	USGS conducts monitoring assessments and analysis of groundwater aquifer systems to support groundwater management. The USGS "provides reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life." In addition, USGS groundwater activities are to "identify, measure, and assess the Nation's water resources." The USGS Groundwater Resource Program (GWRP) is the principal USGS Program for assessing issues related to groundwater resources at the regional scale.
U.S. Environmental Protection Agency (US-EPA)	The U.S. Environmental Protection Agency (EPA) "monitors and regulates public water systems and their groundwater wells." EPA also has general responsibilities to "protect human health and the environment."
U.S. Department of agriculture (USDA)	USDA conservation programs are intended to assist farmers in the sustainable use and protection of the Nation's natural resources, including groundwater. • The USDA Environmental Quality Incentives Program (EQIP) provides financial and technical assistance supporting irrigation water conservation. • The USDA Conservation Reserve Program (CRP), which retires environmentally sensitive lands from agricultural production, may help limit irrigation withdrawals in areas facing serious aquifer declines.

- USDA's Regional Conservation Partnership Program (RCPP), created with the 2014 Farm Bill, promotes coordination between USDA/NRCS and public/private partners to deliver land and water resource conservation assistance to producers and landowners across watershed or multi-county/state regions. The RCPP program may apply to both surface and groundwater resources. The RCPP encourages public/private partners to join in efforts with producers to increase the restoration and sustainable use of soil, water, wildlife and related natural resources on regional or watershed scales. Through RCPP, NRCS and its partners help producers install and maintain conservation activities in selected project areas.

USDA's Forest Service manages much of the nation's public forest lands. These lands encompass headwaters for major U.S. river systems, and are an important source of recharge for groundwater aquifer systems.

U.S. Bureau of Reclamation (BoR)

The mission of the BoR is to "manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public." BoR conducts geologic site characterization and evaluation analyses through its Engineering Geology Group. Also, BoR's Water Resources Planning and Operations Support Group conduct groundwater analyses. This Group provides technical services related to development and management of surface water and ground water supplies. Water resource engineers, surface water hydrologists and geohydrologists conduct water supply investigations for a wide-variety of studies related to water resource planning, management and project operation activities.

U.S. Army Corp Engineers (USACE)

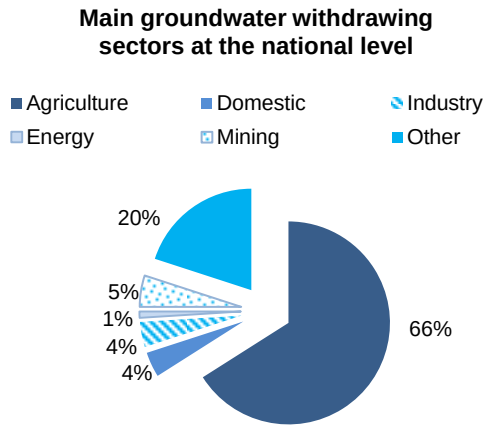
The USACE contributes to the national welfare and serves the public by providing the Nation and the Army with quality and responsive development and management of the Nation's water resources, protection, restoration, and management of the environment, disaster response and recovery, and engineering and technical services in an environmentally sustainable , economic, and technically sound manner through partnerships."

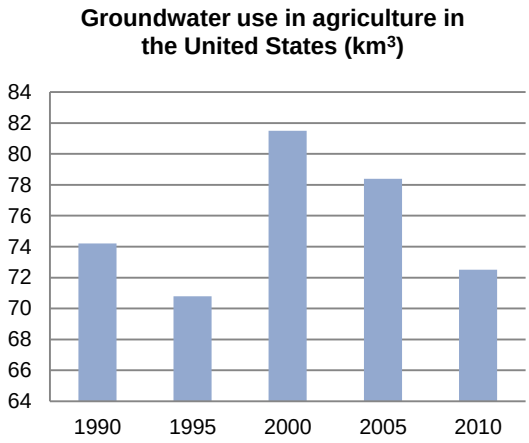
U.S. Bureau of Land Management (BLM)

BLM activities on public lands may also influence groundwater resources. Bureau of Land Management's (BLM's) multiple-use mission is to "sustain the health and productivity of the public lands it manages for the use and enjoyment of present and future generations." The BLM accomplishes this by managing such activities as outdoor recreation, livestock grazing, mineral development, energy production, and by conserving natural, historical, cultural, and other resources on public lands. BLM management decisions regarding these and other activities potentially affect water resources. The purpose of the BLM Soil, Water, and Air Program is to minimize harmful effects to water resources from land use activities, and to improve and enhance water resources through management. Water resources include surface water and groundwater sources. Water of sufficient quality and quantity is integral to the successful management of the public lands managed by the BLM.

2. Status and use of groundwater resources

- The annual groundwater use is estimated at 109.65 km^3 in 2010.
- Groundwater irrigation area 14 641 934 ha in 2008.
- Total irrigation area: 22 590 000 ha 2012.
- Groundwater withdrawals for irrigation 74.01 km^3 in 2005 and 68.33 km^3 in 2010.
- Total irrigation volume: 159.12 km^3 in 2010.





3. Inventory of national policies affecting agricultural groundwater use

Main types of instruments used to manage groundwater use in agriculture

Economic instruments

Irrigation programs

► Irrigation subsidies focusing on water use efficiency.

Other policies and programs affecting agricultural groundwater use

Agriculture water conservation programs	► Subsidies
Climate change adaptation programs	► Investment in agriculture R&D. ► Water infrastructure investment. ► Groundwater modelling and data development.
Energy programs	► Energy programs may indirectly affect groundwater withdrawals through changes in energy water demand and energy prices. US regions may be differentially affected, given regional differences in energy sources used.

Other sectorial or broader policies

Agriculture income support policies	► Biofuel production support In the past, farm income support payments indexed to crop production may have encouraged irrigated production of corn and other crops in some areas where groundwater irrigation is predominant. However, under current U.S. farm legislation, farm supports are largely decoupled from crop production.
Drought insurance programs	► Government subsidized plans for field crops The relationship between crop insurance enrolment and irrigation water use is unclear. Insurance is also now available for pasture.

4. Agricultural groundwater use at the regional level

4.1 Northern High Plains Region

This region generally includes the states of North Dakota, South Dakota and Nebraska. The primary groundwater aquifer in the region is the Ogallala Aquifer within Nebraska and the southern edge of South Dakota. The south-eastern corner of Wyoming and the north-eastern corner of Colorado also fall within the northern portion of the High Plains Aquifer. For response to this survey, we do not include the Colorado and Wyoming portions in the data summaries. This region represents approximately 15 to 20 percent of irrigated acreage in the U.S.

Agro-climatic zone	Climate change prospective (2030-2050)	Is groundwater expected to be significantly affected by climate change in 2030-2050?	Surface Irrigation
Semi-arid	No significant change in precipitation Hotter, more frequent floods, more frequent droughts	yes	Surface water is available and used for irrigation. It is used conjunctively and mainly sourced off farm.

Type of aquifer	Groundwater recharge rate	Groundwater quality concerns
Unconfined	0-5 inches/year	Growing and important

	Volume	Area	Number of farms
Groundwater use	7.72 km3 in 2008	3 324 351 ha in 2008	15 613 irrigated farms in 2008
Trends	Increasing	Increasing	Diminishing

These estimates are for the Northern High Plains Region (ND, SD, and NE). Nebraska accounted for 96% of the groundwater irrigated acres and applied groundwater use.

Groundwater supported agricultural activities in recent years

- Primary irrigated crops: corn and soybean, corn for grain/seed, corn for silage/green chop, sorghum for grain or seed, wheat, soybeans, beans(dry edible), other small grains (oats, rye, etc.) alfalfa, sugar beets, vegetables, potatoes.
- Orchards, vineyards, nut trees, pastureland, and all other crops.

	Total number	Increase in the past 10 years	Average
Estimated number of agricultural wells	83 561 wells (2008), 80 723 wells are used	Rapid	
Evolution of the depth of the water table (trend in the past 10 years)			Steady and increasing

Period of intense groundwater development

► 1960s, 1970s, 1980s and 1990s

Other uses of groundwater

	Minor	Major	Diminishing	Steady	Increasing
Domestic	✓				✓
Industry	✓			✓	
Mining	✓			✓	
Energy		✓			✓
Other	✓			✓	

Pumping related external effects

	Minor	Major	Growing	Steady	Reducing
Well yield reduction	✓				
Stream depletion		✓			

Core groundwater management approaches

Groundwater ownership	► Private and public
Groundwater entitlement characteristics	► Permanent, linked to land rights and transferable
Beneficiaries of entitlement	► Individuals, companies
Groundwater entitlement allocation doctrine	► Correlative rights

Recent groundwater management reforms

Reforms	Scope and objective	Degree of implementation as of 2014
Northern Plains – State of Nebraska Reform: Metering, Restrictions on withdrawals, new wells	Maintain base flows for surface system; inter-state litigation	Complete

Main types of instruments used to manage groundwater use in agriculture

Regulatory approaches

Groundwater management plans

► Mandated and voluntary

Coordination with surface water management

► Systematic partial and limited

Coordination varies significantly within regions identified**.**

Regulations on wells

► Approval of new well

Accounting for well space restriction

► Groundwater withdrawal restriction

Wide differences in well regulation across and within regions.

Regulation on irrigation land

► Regulations on irrigated areas

► Regulation on the expansion of irrigated areas

► Irrigated land buyout

Mandated metering or monitoring system for groundwater

► Mandated metering for agricultural and other users.

Not all Natural Resource Districts have completed metering but those with volumetric restrictions in place have.

Economic instruments

Economic instruments to regulate quantity: pricing

Generally no charges on privately pumped groundwater.

Groundwater markets

► Temporary entitlements are marketable.

► Water entitlement buy-outs are possible.

Collective management approaches

Collective management schemes

►Mandated by interstate water use agreements

►District or community based.

Other policies and programs affecting agricultural groundwater use

Agriculture water conservation programs

► Irrigated land easement, water right purchase.

Federal cost-sharing and technical assistance is provided primarily through USDA; Irrigated lands and associated water rights may also be retired under Federal conservation programs. States may contribute to technology adoption and land retirement programs.

Watershed conservation programs affecting groundwater use

► Acquired groundwater entitlement for water conservation.

USDA conservation programs may be focused on critical watersheds that target groundwater pumping withdrawals to preserve surface water flows and associated environmental benefits.

Supply side management approaches

Aquifer recharge programs

► Aquifer storage and recovery programs
► Groundwater banking

Several states permit various types of groundwater storage/banking programs.

4.2 Southern High Plains Aquifer Region

This region generally includes the Ogallala Aquifer within the States of Kansas, Oklahoma, and of Texas. The southeastern corner of Colorado and the eastern edge of New Mexico fall within this region. For the response to this survey, we do not include these two latter areas and we do not separate out irrigation in central and southeastern Texas that draws from other water sources. This region represents approximately 10 to 15 percent of irrigated acreage in the U.S.

Agro-climatic zone	Climate change prospective (2030-2050)	Is groundwater expected to be significantly affected by climate change in 2030-2050?	Surface Irrigation
Semi-arid	No significant change in precipitation hotter, more frequent floods, more frequent droughts	yes	Surface water is rarely available and used for irrigation. It is used conjunctively and mainly sourced off-farm.

Type of aquifer	Geological type	Groundwater recharge rate	Groundwater quality concerns
Unconfined and mixed	Sand and gravel	0-0.5 inches/year	Growing and important

	Volume	Area	Number of farms
Groundwater Irrigation	11.16 km^3 (2008)	3 060 000 ha in 2008	14 234 irrigated farms in 2008
Trends	Increasing	Diminishing	Steady

These estimates are for the Southern High Plains Region (OK, KS, and TX). Texas accounted for 62% of the groundwater irrigated acres and applied groundwater use.

Groundwater supported agricultural activities in recent years

- Primary irrigated crops: corn, sorghum and cotton, corn for grain/seed, corn for silage/green chop, sorghum for grain or seed, wheat, soybeans, beans(dry edible), other small grains (oats, rye, etc.) alfalfa, sugar beets, vegetables, potatoes
- Orchards, vineyards, nut trees, pastureland, and all other crops.

	Total number	Increase in the past 10 years	Average
Estimated number of agricultural wells	103 531 wells and 100 417 wells are used (2008)	Slow	
Evolution of the depth of the water table (trend in the past 10 years)			Steady and lowering

Period of intense groundwater development

► 1950s, 1960s, 1970s, 1980s

Other uses of groundwater

	Minor	Major	Diminishing	Steady	Increasing
Domestic		✓			✓
Industry	✓			✓	
Mining	✓			✓	
Energy		✓			✓
Other	✓			✓	

Pumping related external effects

	Minor	Major	Growing	Steady	Reducing
Pumping lift/cost increase		✓			
Well yield reduction		✓			
Stream depletion	✓				
Vegetative stress		✓			
Salinity	✓				

Core groundwater management approaches

Groundwater ownership	► Private and public
Groundwater entitlement characteristics	► Permanent, linked to land rights and transferable
Beneficiaries of entitlement	► Individuals, companies
Groundwater entitlement allocation doctrine	► Reasonable use and prior appropriation

Recent groundwater management reforms

Reforms	Scope and objective	Degree of implementation as of 2014
Southern Plains – Irrigation Management District Reform: Metering, Voluntary withdrawal restrictions(western KS), limited permitting	Extend useful life of aquifer for irrigated production and other uses	Partial

Main types of instruments used to manage groundwater use in agriculture

Regulatory approaches

Groundwater management plans
►Voluntary

Coordination with surface water management
►Partial and Limited
Coordination varies significantly within regions identified**.**

Regulations on wells
► Approval of new well
Accounting for well space restriction.
Wide differences in well regulation across and within regions.

Regulation on irrigated land
► Regulations on irrigated areas.
► Irrigated land buyout.

Mandated metering or monitoring system for groundwater
► Mandated metering for agricultural and other users.

Economic instruments

Groundwater markets
► Water entitlement buy-outs are possible.

Collective management approaches

Collective management schemes
While groundwater use is generally unregulated, a district in Kansas has elected to self-regulate.

Other policies and programs affecting agricultural groundwater use

Agriculture water conservation programs

► Irrigated land easement, water right purchase

Federal cost-sharing and technical assistance is provided primarily through USDA; Irrigated lands and associated water rights may also be retired under Federal conservation programs. States may contribute to technology adoption and land retirement programs.

Watershed conservation programs affecting groundwater use

► Acquired groundwater entitlement for water conservation.

USDA conservation programs may be focused on critical watersheds that target groundwater pumping withdrawals to preserve surface water flows and associated environmental benefits.

4.3 Mississippi Alluvial Aquifer Region

This region includes predominantly irrigated cropland areas within the states of Arkansas, Mississippi and Louisiana as well as the south-eastern corner of Missouri. This region represents approximately 10-15 percent of irrigated acreage in the U.S. The region relies on a combination of surface and groundwater sources.

Agro-climatic zone	Climate change prospective (2030-2050)	Is groundwater expected to be significantly affected by climate change in 2030-2050?	Surface Irrigation
Semi-humid	No significant change in precipitation, hotter, more frequent floods, more frequent droughts	yes	Surface water is occasionally available and used for irrigation. It is used sourced off-farm and on-farm.

Type of aquifer	Geological type	Groundwater recharge rate	Groundwater quality concerns
Unconfined	Sand and gravel	0-10 inches/year	Growing and important

	Volume	Area	Number of farms
Groundwater irrigation	12.22 km3 (2008)	2 925 629 ha (2008)	7472 irrigated farms in 2008
Trends	Increasing	Increasing	Diminishing

These estimates are for the Mississippi Alluvial Aquifer region. For the purposes of these statistics, the total numbers for all four states are included even though some of the irrigation in these states occurs outside the aquifer region. Arkansas accounted for 54% of the groundwater irrigated acres and applied groundwater use.

Groundwater supported agricultural activities in recent years

- Primary irrigated crops: corn, soy and rice, corn for grain/seed, corn for silage/green chop, sorghum for grain or seed, wheat, soybeans, beans(dry edible), other small grains (oats, rye, etc.) alfalfa, sugar beets, vegetables, potatoes.
- Orchards, vineyards, nut trees, pastureland, and all other crops.

	Total number	Increase in the past 10 years	Average
Estimated number of agricultural wells	72 184 wells and 69 406 wells are used (2008)	Rapid	
Evolution of the depth of the water table (trend in the past 10 years)			Steady and lowering

Period of intense groundwater development

► 1970s, 1980s and 1990s

Other uses of groundwater

	Minor	Major	Diminishing	Steady	Increasing
Domestic	✓				✓
Industry	✓			✓	
Mining	✓			✓	
Energy	✓			✓	
Other	✓			✓	

Pumping related external effects

	Minor	Major	Growing	Steady	Reducing
Pumping lift/cost increase	✓				

Core groundwater management approaches

Groundwater ownership	► Private
Groundwater entitlement characteristics	► Permanent, linked to land rights
Beneficiaries of entitlement	► Individuals, companies
Groundwater entitlement allocation doctrine	► Reasonable use

Main types of instruments used to manage groundwater use in agriculture

Regulatory approaches

Groundwater management plans
►Voluntary

Coordination with surface water management
►Partial

Regulations on wells
► Approval of new well

Other policies and programs affecting agricultural groundwater use

Agriculture water conservation programs

► Irrigated land easement, water right purchase

Federal cost-sharing and technical assistance is provided primarily through USDA; Irrigated lands and associated water rights may also be retired under Federal conservation programs. States may contribute to technology adoption and land retirement programs.

4.4 Mountain and Pacific West Region

This region includes all of the western U.S. states: Washington, Oregon, California, Idaho, Nevada, Utah, Arizona, Montana, Wyoming, Colorado and New Mexico. Surface water is the predominant source of irrigation water in the region, with groundwater serving as a primary or secondary water source in many areas. This region represents between 40 and 45 percent of U.S. irrigated acreage, with about one-third to one-half of this acreage irrigated with ground water.

Agro-climatic zone	Climate change prospective (2030-2050)	Is groundwater expected to be significantly affected by climate change in 2030-2050?	Surface Irrigation
Semi-arid	Drier, hotter, more frequent floods, more frequent droughts	yes	Surface water is available and used for irrigation. It is used conjunctively and mainly sourced off-farm

Type of aquifer	Groundwater recharge rate	Groundwater quality concerns
Mixed	0-5 inches/year	Growing and important

	Volume	Area	Number of farms
Groundwater Irrigation	24.7 km3 in 2008	3 696 512 ha in 2008	42 949 irrigated farms in 2008
Trends	Trends for each category are widely varying across these states, reflecting in large part the conjunctive nature of ground water resources in this region.		

These estimates are for 11-States the Western Region (AZ CA CO ID MT NM NV OR UT WA and WY). California accounted for almost 50% of the groundwater irrigated acres and applied groundwater use.

Groundwater supported agricultural activities in recent years:

- Primary irrigated crops: alfalfa hay, orchards, vegetables, vineyards, wheat, corn for grain/seed, corn for silage/green chop, sorghum for grain or seed, wheat, soybeans, beans(dry edible), other small grains (oats, rye, etc.), sugar beets, potatoes.
- Orchards, vineyards, nut trees, pastureland, and all other crops.

	Total number	Increase in the past 10 years	Average
Estimated number of agricultural wells	114 242 wells (2008) and 106 674 wells are used	n.a.	
Evolution of the depth of the water table (trend in the past 10 years)			Steady and lowering

Period of intense groundwater development

►1950s, 1960s, 1970s, 1980s and 1990s.

Other uses of groundwater

	Minor	Major	Diminishing	Steady	Increasing
Domestic		✓			✓
Industry		✓		✓	
Mining		✓		✓	
Energy		✓			✓
Other				✓	

Pumping related external effects

	Minor	Major	Growing	Steady	Reducing
Pumping lift/cost increase	✓	✓			
Well yield reduction	✓	✓			
Stream depletion	✓				
Vegetative stress	✓				
Salinity	✓	✓			
Aquifer compaction	✓				
Land subsidence	✓				

Core groundwater management approaches

Groundwater ownership	► Private
Groundwater entitlement characteristics	► Permanent, linked to land rights
Beneficiaries of entitlement	► Individuals, companies
Groundwater entitlement allocation doctrine	► Absolute ownership, reasonable use, correlative rights and prior appropriation

Recent groundwater management reforms

Reforms	Scope and objective	Degree of implementation as of 2014
Mountain/Pacific Region (AZ CA CO ID MT NM NV OR UT WA and WY) Reform: Restrictions on withdrawal, new wells, e.g. AZ, with other areas less regulated	Extend useful life of for irrigated production her uses	Partial

Main types of instruments used to manage groundwater use in agriculture

Regulatory approaches

Groundwater management plans
►Voluntary and mandated

Coordination with surface water management
►Partial and limited
Coordination varies significantly within regions identified.

Regulations on wells
► Approval of new well
► Groundwater withdrawal restriction
Wide differences in well regulation across and within regions.

Regulation on irrigated land
► Regulations on irrigated areas
► Irrigated land buyout

Mandated metering or monitoring system for groundwater
► Mandated metering for agricultural users.

Economic instruments

Groundwater markets
► Water entitlement buy-outs are possible

Collective management approaches

Collective management schemes

Arizona has had strict regulations since 1980, while groundwater use has been generally unregulated elsewhere. New groundwater legislation introduced in California in 2014 in response to multi-year drought.

Other policies and programs affecting agricultural groundwater use

Agriculture water conservation programs

► Irrigated land easement, water right purchase.

Federal cost-sharing and technical assistance is provided primarily through USDA; Irrigated lands and associated water rights may also be retired under Federal conservation programs. States may contribute to technology adoption and land retirement programs.

Watershed conservation programs affecting groundwater use

► Acquired groundwater entitlement for water conservation.

USDA conservation programs may be focused on critical watersheds that target groundwater pumping withdrawals to preserve surface water flows and associated environmental benefits.

Supply side management approaches

Aquifer recharge programs

► Aquifer storage and recovery programs
► Groundwater banking

Programs supporting the development of alternative water supplies

► Recycled water

Concerns for climate change have prompted calls for greater investment in water storage infrastructure and use of non-traditional supplies.

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- "A New Western Water Agenda: Opportunities for Action in an Era of Growth and Climate Change," by L. J. MacDonnell and D. D. Fort (February 2008). A report of the Western Progress Water Roundtable that sets out a brief overview of the existing water-policy framework, explores the changing role of water in the West, and identifies key issues for action.
- "Water Conservation in Irrigated Agriculture: Trends and Challenges in the Face of Emerging Demands" (Schaible and Aillery, 2012), ERS EIB-99 at: www.ers.usda.gov/publications/eib-economic-information-bulletin/eib99.aspx . This report highlights the challenges for irrigated agriculture due to increasing demands for water from competing uses population and economic growth; Native American water rights; instream environmental flows; energy expansion; and climate change impacts.

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This country profile was compiled by the OECD Secretariat and reflects information obtained in a 2014 OECD questionnaire on groundwater use in agriculture. Further information and analysis can be found in OECD (2015), *Drying Wells, Rising Stakes: Towards Sustainable Agricultural Groundwater Use*, OECD Studies on Water, OECD Publishing. The countries profiles for 16 countries of OECD are available for download at: *www.oecd.org/tad/sustainable-agriculture/groundwater-use.htm*