# Climate Change Impacts on Agriculture in the Colorado River Basin

***KEY MESSAGE: Agriculture is the largest component of the Colorado River Basin economy, with U.S. states in the basin generating over $60 billion in crops and livestock each year. In the coming decades, climate change is predicted to increase water scarcity in the basin, significantly reducing an already dwindling resource. As the major consumer of Colorado River water, agriculture is expected to face major negative impacts. Existing water policy fails to adequately address this challenge, requiring today's policymakers to act decisively in order to maintain agriculture in the Colorado River Basin.***

The Colorado River is a vital freshwater resource for the inhabitants of the southwestern U.S. and Mexico. Approximately 30 million people rely at least partially on the river and its tributaries for fresh water (USBR 2012). The Colorado flows approximately 1,450 mi (2,330 km) from the Rocky Mountains to the Gulf of California, gathering water from a 243,100 $mi^2$ (629,600 $km^2$) drainage basin (Figure 1). Nearly 90 percent of the river's flow is snowmelt from headwaters in Colorado, Utah, Wyoming, and New Mexico. From there, the river travels through Arizona, Nevada, and California before flowing between the Mexican states of Baja California and Sonora into the Gulf of California.

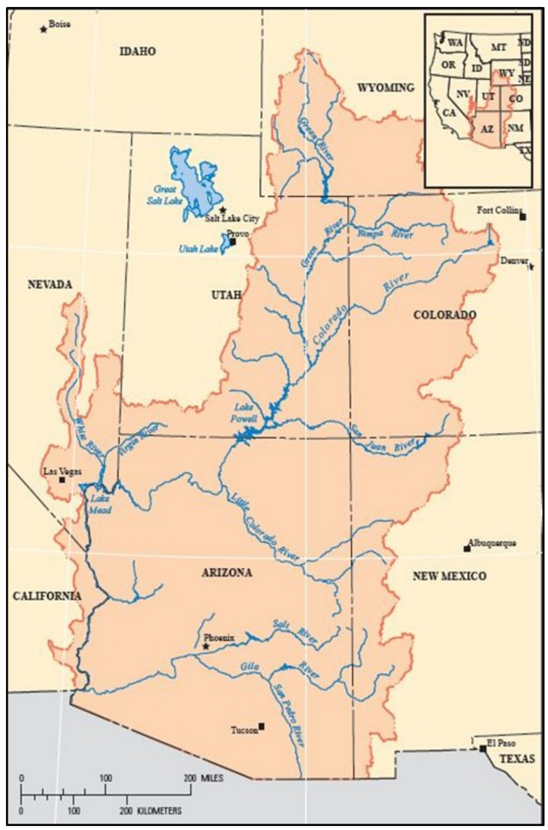


**Figure 1. The Colorado River Basin. Source: USEPA 2014.**

### *Agriculture in the Colorado River Basin*

Agriculture is a major component of the Colorado River Basin's economy. Currently, the basin has about 3.5 million acres (1.4 million hectares) of cropland in production each year (Cohen *et al.* 2013, NASS 2009). Of that, approximately 60 percent of the acreage supports forage crops and pasture, which are used to support a prosperous livestock industry (Cohen *et al.* 2013). This acreage provides significant economic inputs to both the U.S. and Mexico. In 2012, the seven U.S. states located in the Colorado River Basin produced roughly $37 billion in crops and $24 billion in livestock (USDA 2014). Overall, U.S. basin states produce approximately 15 percent of all crops in the U.S. and approximately 13 percent of all U.S. livestock (USBR 2012). In 2009, the Mexicali Valley, an agricultural region in Mexico that relies heavily on Colorado River water, produced $2.9 billion in crops (Kavel 2011).

Agriculture at this scale requires massive amounts of water. Much of the Colorado River Basin has an arid climate, with some regions receiving less than three inches of precipitation per year (Cohen *et al.* 2013). These water-scarce conditions make rain-fed agriculture extremely difficult, if not impossible, in many areas (Figure 2). As a result, over 90 percent of the harvested croplands and pasturelands in the basin require irrigation (Cohen *et al.* 2013, NASS 2009). In order to provide enough water to irrigate 3.5 million acres (1.4 million hectares) of cropland in the basin, as well as 2.5 million acres (1.0 million hectares) of cropland in areas adjacent to the basin, approximately 8 million acre-feet (9.9 $km^3$) of Colorado River water must be diverted annually (Cohen *et al.* 2013, USBR 2012). When evaporative losses are included, that equates to about 70 percent of the basin-wide historic flow rate (1906-2011) of 16.4 million acre-feet (20.2 $km^3$) (Cohen *et al.* 2013, USBR 2012). While overall irrigated acreage and agricultural water demand are predicted to modestly decrease in the coming decades, agriculture will remain the dominant consumer of Colorado River for the foreseeable future (USBR 2012)

This dominance is being challenged, however, by several other sectors, particularly growing municipalities throughout the basin. Since the latter part of the $20^{th}$ century, there has been an increase in competition for water in and around the basin. Explosive population growth in urban areas of the southwestern U.S. and Mexico have dramatically increased the demand for municipal water deliveries from the Colorado River. Between 1990 and 2008 alone, the population at least partially reliant on municipal deliveries from the Colorado River and its tributaries increased by 10 million people (Cohen 2011). Overall, annual U.S. municipal deliveries in the basin have nearly doubled in last 40 years, increasing from approximately 1.7 million acre-feet (2.9 km$^3$) in 1971 to approximately 3.3 million acre-feet (4.1 km$^3$) in 2010 (USBR 2012). Currently, municipal water deliveries account for nearly 15 percent of total Colorado River use (Cohen 2011), but with a predicted 62 million people relying on the Colorado River for domestic and industrial supply by 2060, that percentage will increase dramatically in the coming years (USBR 2012).

**Figure 2. Irrigated crops along the Colorado River in Arizona. Source: Walton 2013.**

As demand for Colorado River water increases, the limits of that supply are becoming increasingly apparent (Figure 3). Between 2002 and 2011, annual consumptive uses and losses averaged 15.4 million acre-feet (19.0 km$^3$) (USBR 2012). At the same time, streamflow has been lower than historical averages, resulting in multiple years where demand has exceeded supply. The basin's combined reservoir capacity of nearly 60 million acre-feet (74.0 km$^3$) , 85 percent of which is in Lake Mead and Lake Powell, has prevented major water shortages in lower basin areas, but there have been periodic shortages in areas of the upper basin above these major reservoirs (Christensen & Lettenmeier 2007, USBR 2012). As competition for this increasingly scarce resource grows, irrigators are finding it more and more difficult to maintain their share of the Colorado River's water.

### *Impacts of Climate Change on Agriculture*

In the coming decades, climate change is expected to increase temperatures and alter precipitation patterns in the Colorado River Basin. Climate studies using an array of general circulation models and future atmospheric carbon dioxide scenarios estimate that by 2075 basin-wide temperatures will increase between 4.9 to 7.9° F (2.7-4.4° C) relative to recent historical averages (Christensen & Lettenmeier 2007). Modest increases in winter precipitation and decreases in summer precipitation are also predicted for the basin, accompanied by a reduction in snowpack of up to 38 percent (Christensen & Lettenmeier 2007, USBR 2012).

These higher temperatures and altered precipitation patterns will have several impacts on agriculture in the basin. Irrigators will have to divert more water to grow the same types and quantities of crops due to higher crop evapotranspiration rates. Traditional planting and harvesting times will have to be altered to accommodate longer growing seasons. Yield variability will increase as precipitation patterns become more capricious (Campbell *et al.* 1997). And most importantly, a larger proportion of basin-wide precipitation will not reach the river and its reservoirs. By 2075, basin-wide run-off is predicted to decrease by 8-10 percent relative to historical rates. This decrease will be accompanied by an 8-11 percent decrease in streamflow and a 10-13 percent decrease in reservoir storage (Christensen & Lettenmeier 2007).

This reduction in water supply could potentially translate into major economic losses for the basin's agricultural producers. Studies employing economic models using climate change data predict that a 2.7° F (1.5° C) increase in temperature accompanied by a 10 percent decrease in precipitation could reduce agricultural welfare by 32.2 percent in the Colorado River Basin, while a 4.5° F (2.5° C) increase paired with a 10 percent decrease could result in a 41.3 percent decrease (Hurd *et al.* 1999, Hurd *et al.* 2004). Such losses equate to tens of billions of dollars, which could have a catastrophic effect on both the regional and national economies.

### *Current Policy Situation*

For many years, policy governing the use of the Colorado River allowed enough flexibility for most needs to be met, especially by agriculture. As water demands outstrip supply, however, those waters are now over-allocated by existing agreements. Allocation of the Colorado River is governed by a series of 12 major and a series of minor federal and state laws, treaties, court decisions, and compacts collectively known as the Law of the River. The Colorado Compact of 1922, the cornerstone of the Law of the River, split the basin's water between the Upper Basin states (Wyoming, Utah, Colorado, and New Mexico) and Lower Basin states (Arizona, Nevada, California), apportioning 7.5 million acre-feet (9.3 km$^3$) of water per year to each. The subsequent addition of the US-Mexico Treaty of 1944 allocated another 1.5 million acre-feet (1.9 km$^3$) of water per year to Mexico, bringing total Colorado River allocations to 16.5 million acre-feet (20.4km$^3$) per year. These treaties were created in an especially wet period, so short-term stream flow data overestimated how much water would be available in the future. As mentioned above, the Colorado River's current historical annual stream flow average (1906-2011) is approximately 16.4 million acre-feet (20.2 km$^3$), with current averages being even lower (USBR 2012). In effect, the Colorado River is over-allocated. The Law of the River has functioned in recent years only because the Upper Basin states have not fully developed their portion of the Colorado's waters (USBR 2012). Yet as water demand increases and climate change reduces supply, this once theoretical over-allocation is becoming reality in the form of drained reservoirs, failed water deliveries, and stakeholder conflict. Policymakers must address this issue, because soon farmers and ranchers will need to deal with a world where there is less water available for agriculture.

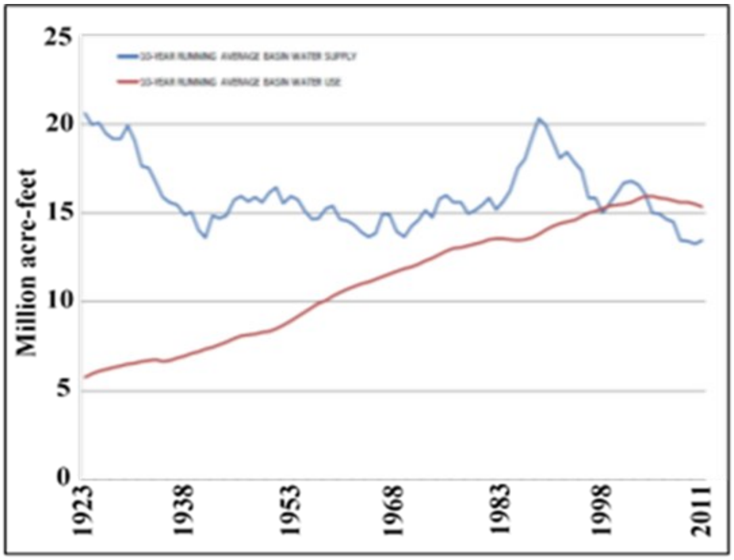


**Figure 3. Historical 10-year running average of water consumption (red line) and supply (blue line) in the Colorado River basin. Source: USBR 2013.**

***Ways Forward***

Decreasing agricultural water demand should be the primary goal of policymakers' efforts. This could be achieved in several ways. First, policymakers can foster the adoption of water-efficient irrigation systems, such as subsurface drip systems and micro-sprinklers, through incentive programs. Such irrigation systems allow farmers to produce a comparable amount of crop yield using less water. Yet due to the Law of the River's "use it or lose it" system, in which farmers must either use the water they are allocated or allow the remainder to flow downstream to other users, there is little incentive for farmer's to invest in high-efficiency irrigation systems, which can be prohibitively expensive. Cost-sharing programs have proven effective in persuading farmers to adopt more efficient irrigation methods, so policy supporting the expansion of such programs would be beneficial (Cohen 2011).

Policymakers can also help reduce agricultural water demand by promoting deficit irrigation. Deficit irrigation is the application of water below full crop evapotranspiration requirements during stress-tolerant growth stages. The practice has been shown to conserve water while maintaining yield in several crops grown in the Colorado River Basin, including the major forage crop alfalfa (Cohen *et al.* 2013). It is one of the most cost-effective and most easily applied methods available, yet is counter-intuitive to many farmers. Policy that educates farmers and incentivizes the practice would greatly reduce water demand.

Encouraging farmers to plant drought tolerant crop species is another way policymakers can ease the strain on water availability in the Colorado River Basin. If incentives are in place for farmers to switch to crops that require lower amounts of water per unit produced, more water will be available for other uses without major impacts to overall yields. For example, by switching the acreage growing irrigated alfalfa in the Lower Basin to sorghum, a relatively efficient, drought-tolerant biofuel, irrigators could save over 140,000 acre-feet of water annually (Chen *et al.* 2013).

Policymakers can also develop water-sharing programs, which will allow irrigators to sell, transfer, or lease water rights to urban areas. This creates a "win-win" situation in which water shifts from lower value agricultural uses to higher value urban uses (Jacobs 2011). While this would decrease overall crop production, it would also present an opportunity to reduce agriculture in exceedingly arid areas where evaporative losses are excessive and therefore production is relatively inefficient. Sharing programs already exist throughout the Colorado River Basin, but the process requires a lengthy adjudication process in which the parties must prove that transfers do not increase the amount of water consumed or injure downstream users. Policymakers could streamline and standardize this process, while building in safeguards to protect the rights of all basin consumers.

Creating policy to develop and maintain a sustainable agricultural system to account for climate change is a daunting task for basin policymakers. Fortunately, avenues of adaptation do exist. Policymakers must explore these options and re-imagine agriculture in and around the Colorado River Basin in order to address this looming threat.

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