

## TRENDS AND PATTERNS OF WATER USE IN US COTTON PRODUCTION

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### Abstract

This study compared water use and productivity in cotton production in western U.S. states and the United States in general across 30 years, based on data from USDA's Farm and Ranch Irrigation Survey, a follow-on survey to the Census of Agriculture. From 1984 to 2013 (the most recent survey year) water applications to cotton in California, Arizona, and New Mexico fell by more than 3.9 million acre-feet (MAF). This 71-percent reduction in water use is equivalent to 68% of total residential water use in the region. Western states also saw reductions in water applied per acre of cotton and water applied per cotton bale produced. From 1984 to 2013 the total amount of water applied in total U.S. cotton production fell 48%, while total irrigated cotton production remained relatively constant. Nationally, the amount of water applied to produce a bale of irrigated cotton fell 56% between the two Census years, while water applied per acre fell by 38%. Absolute water applications outside the western states increased by 0.4 MAF, but nationally absolute water applied to U.S. cotton fell by 3.5 MAF (48%).

### Introduction

Western states ended 2015 anticipating a fifth year of drought, raising public concerns over water shortages. Some media sources have identified cotton production and commodity programs as major contributors to problems of western water scarcity (Lustgarten and Sadasivam, 2015; Akenzua, 2015). These reports fail to account for some basic realities of commodity programs and cotton's water use, however. First, several policy reforms began with the 1985 farm bill, and continued in subsequent farm legislation, that "decoupled" commodity program payments from production and water use decisions. These reforms have made it easier for growers to shift between crops without forfeiting income-support payments and decreased incentives to alter plantings (and water use) as means of increasing them (Frisvold, 2004). Second, it is not a simple matter to examine effects of commodity programs on water use. How commodity programs ultimately affect water use depends on four effects: scale effects (total production), mix effects (which crops are grown), location effects (where they are grown), and intensity (water use per acre for a specific crop-location combination). While several earlier studies found positive scale effects of commodity programs, many did not consider crop-mix, location, or intensity effects (Frisvold, 2004). Analyses conducted subsequent to farm bill decoupling reforms illustrate the complexity of interactions between programs and water use. For example, studies of water use in the Edwards Aquifer estimated that commodity programs actually reduced use of irrigation water relative to a no-program scenario (Chowdury, et al., 2011; Schaible et al., 1999). This was because they encouraged shifts to less water-intensive cropping systems. Third, news stories fail to acknowledge the sizeable reductions cotton's water use in the West over the past thirty years. This analysis focuses on this third issue, the decline in cotton's water use in the West.

### Materials and Methods

This study compares water use in U.S. cotton production between 1984 and 2013 using data from the U.S. Department of Agriculture's (USDA) Farm and Ranch Irrigation Survey (FRIS) (USDA, 1984, 2014). The FRIS is a follow-on survey to the Census of Agriculture, which is conducted (roughly) every five years. The most recent survey was conducted in 2013. The FRIS is the most comprehensive survey of irrigation and agricultural water management practices conducted in the country. This analysis focuses on changes in cotton producer water use practices over the past 30 years, focusing on western cotton-producing states, California, Arizona, and New Mexico. Western water use trends are also compared with national trends. USDA (1984, 2014) reports commodity-specific water use practices as state-level aggregates. Water metrics examined include water application intensity, crop water productivity, water footprint measures, and changes in the absolute amount of irrigation water applied to cotton.

### Results and Discussion

#### Irrigation Application Intensity

Irrigation application intensity is the amount of water applied to a crop per unit of land area. Here, it is acre-feet of water applied per acre of cotton. An acre-foot is the volume of water needed to cover one acre of land to a depth of

one foot (equal to 1,233 m<sup>3</sup>) (Maupin et al., 2014). Over the past 30 years, irrigation application intensity has declined in all three western states (Figure 1). Application intensity fell by 3% in California, by 8% in Arizona, and by 29% in New Mexico. New Mexico also saw the largest absolute reduction (0.7 acre-feet) in application intensity.

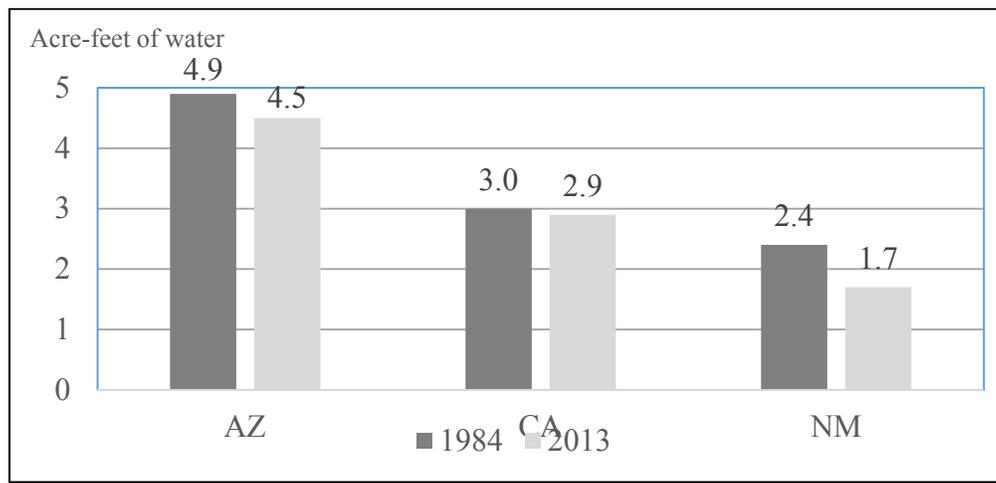


Figure 1. Acre-feet of water applied per acre of cotton in western states

### **Crop Water Productivity**

Crop water productivity is the physical amount of crop produced per unit of water used to produce it. Colloquially, this is sometimes referred to as the amount of “crop per drop” of water. Here, this is estimated as pounds (lbs.) of cotton produced per acre-foot of irrigation water applied. Ideally, one would like a measure of consumptive use of water. Water applied measures the amount of water withdrawn and delivered to a field, excluding conveyance and delivery-system losses or gains, while consumptive use refers to the amount of water actually consumed by evaporation, transpiration and plant growth (Gollehon and Quinby, 2000). Consumptive use measures how much water is literally used up and lost to the watershed. Water applied is greater than consumptive use because some portion of water applied to a field returns to streams and rivers as return flows or percolates down to groundwater aquifers. The FRIS, however, only reports irrigation water applied.

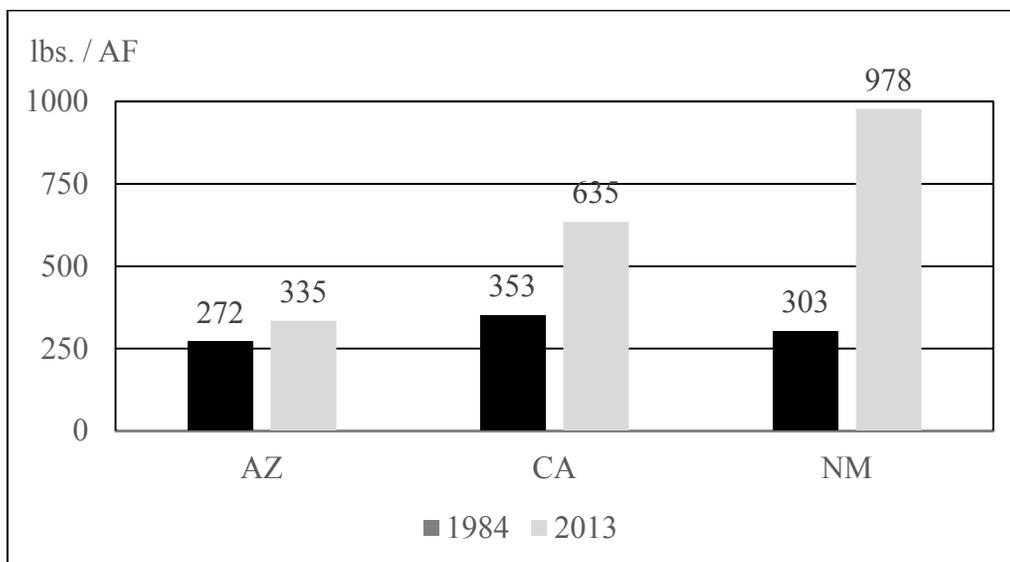


Figure 2. Pounds (lbs.) of cotton produced per acre-foot (AF) of water applied in western states

The amount of cotton produced per acre-foot (AF) of water applied has grown significantly in the three western states, by 282 lbs. /AF in California, by 63 lbs. /AF in Arizona and by 675 lbs. / AF in New Mexico (Figure 2). In percentage terms, cotton produced per AF of water applied rose 80% in California, 23% in Arizona, and by 223% in New Mexico. Why did cotton water productivity more than triple in New Mexico over the past 30 years? Mathematically, water productivity is just crop yield divided by water application intensity. From 1984 to 2013 the numerator (cotton lint yield) in New Mexico more than doubled (rising from 726 lbs. / acre to 1,662 lbs. / acre), while the denominator fell by 29%. In agronomic terms, New Mexico benefited from significant genetic improvements in Acala cotton varieties (increasing yields) while also shifting to a much greater extent (than California or Arizona) from gravity-flow irrigation more efficient sprinkler irrigation systems.

### **Water Footprint**

Here, we measure the water footprint of cotton production as the amount of irrigation water applied per bale of cotton produced. Between 1984 and 2013, acre-feet of water applied per cotton bale produced fell 44% in California, 19% in Arizona, and 69% in New Mexico (Figure 3). The absolute quantity of water applied to produce a bale of cotton fell by 0.6 AF in California, 0.34 AF in Arizona, and by 1.1 AF in New Mexico.

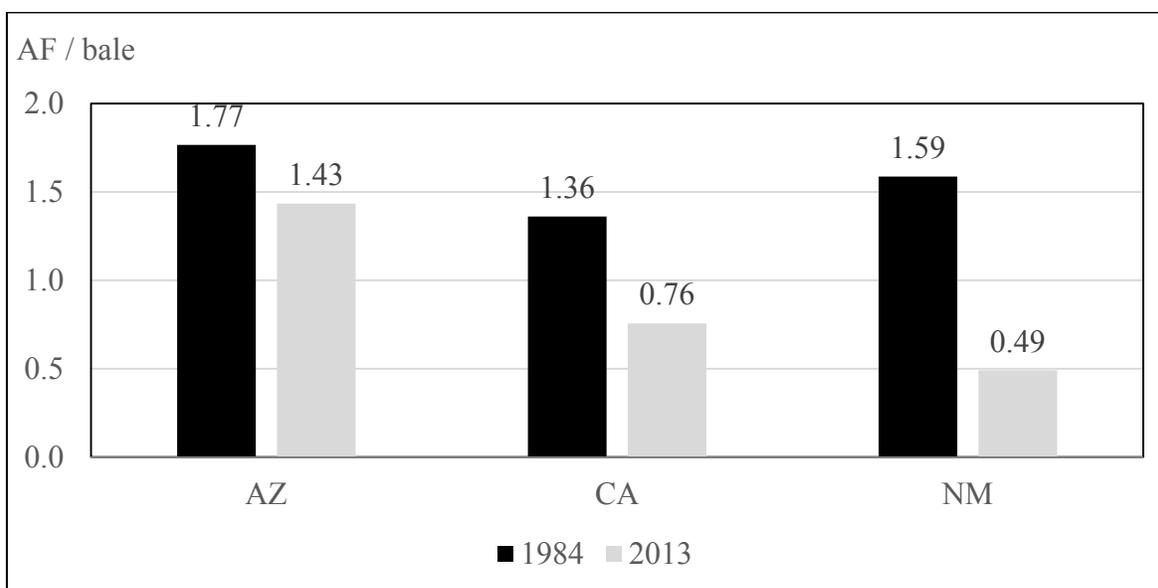


Figure 3. Acre-feet (AF) of water applied per bale of cotton produced in western states

### **Total Water Use**

Since 1984, acres planted to irrigated cotton have declined significantly in the western United States. Further, water applied per acre also declined (Figure 1). These two factors have led a large decline in the total amount of water applied to cotton production in the West. In 1984, 5.56 million acre-feet (MAF) were applied to western cotton (Figure 4). By 2013, this figure fell to 1.62 MAF. This constitutes a reduction of water applied to western cotton of 3.94 MAF, or a 71% reduction.

How significant is this 3.94 MAF reduction in cotton's water use? According to the most recent national survey of water use conducted by the U.S. Geological Survey (USGS), total water withdrawals for residential water use in California, Arizona, and New Mexico totaled 5.77 MAF in 2010 (Maupin et al., 2014). This means that the reduction in cotton's water use in the West over the past thirty years is roughly equivalent to 68% of the region's total residential water use. Put another way, the 3.94-MAF reduction in cotton's water use is equivalent to the annual water use of more than 30 million residents of the three western states.

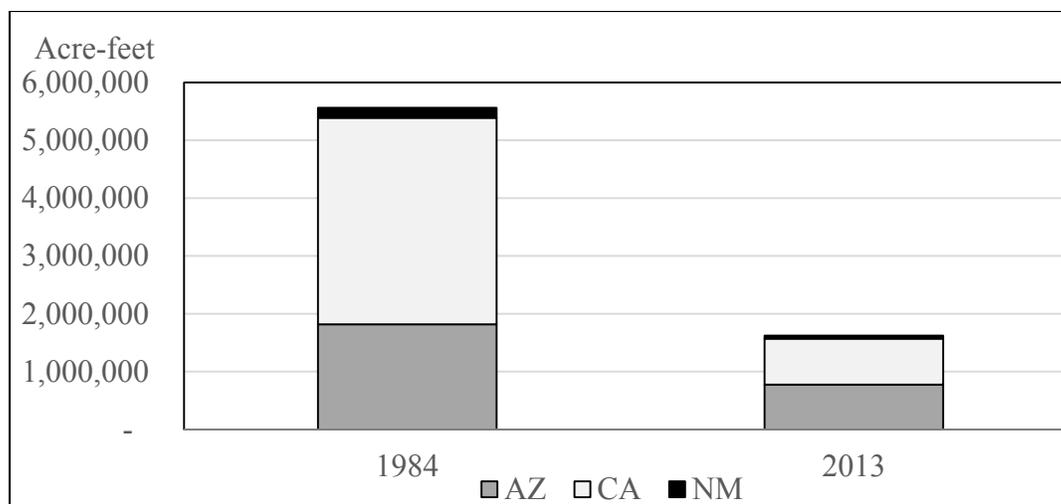


Figure 4. Acre-feet applied to cotton in western states, 1984 and 2013

Table 1. U.S. trends in cotton water productivity measures

Measure	1984	2013	Percent Change
Yield	837	1172	40%
Water applied per acre	2.1	1.3	-38%
Pounds of cotton / AF of water	399	902	126%
AF of water applied / bale of irrigated cotton	1.2	0.5	-56%
Total water applied (million acre-feet)	7.4	3.8	-48%

Source: USDA, 1984, 2014

### **National Cotton Water Use Trends**

Trends in national cotton water use followed a similar pattern to western cotton over the past thirty years (Table 1). Irrigation water applied per acre of irrigated cotton fell -38%, while cotton yields increased 40%. Together these changes meant that the amount of cotton produced per acre-foot of water more than doubled, while the amount of water applied per bale of cotton produced was cut in half. As in the West, the absolute amount of water applied to U.S. cotton declined. Total water applied to U.S. cotton fell by 48% between 1984 and 2013. Water applied to irrigate U.S. cotton fell by 3.51 MAF from 1984 to 2013 (Figure 5). While irrigation applications increased slightly outside of the western United States (a 0.43-MAF increase), large reductions in water applications in California, Arizona, and New Mexico have led to large net reductions in U.S. cotton's overall water use.

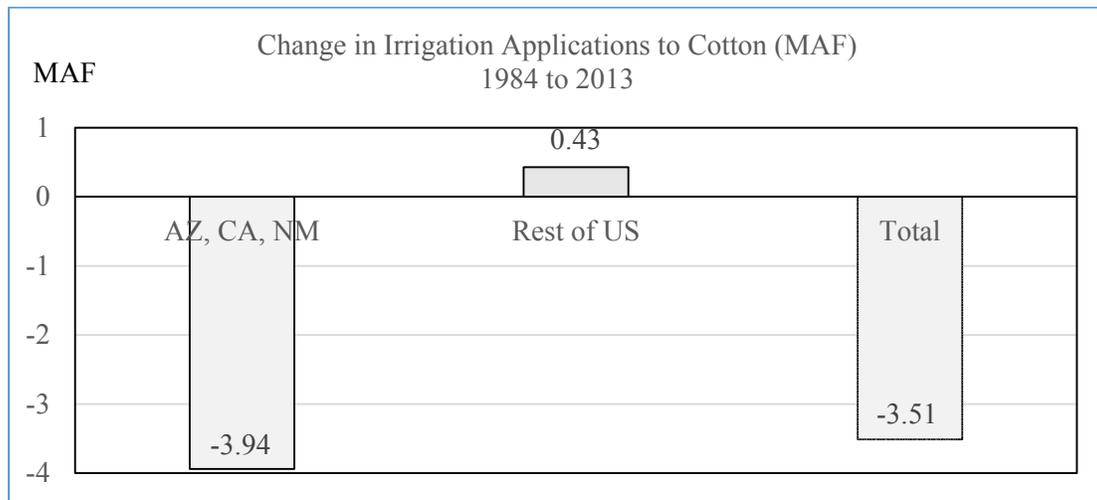


Figure 5. Reductions in water applied to U.S. cotton, 1984 to 2013

### Summary

Western cotton producers have dramatically reduced the amount of water applied to produce a bale of cotton over the past 30 years. Over this same time irrigation applications per acre of cotton and absolute water use have also declined significantly. Criticisms of cotton production in the western United States have, to date, failed to account for the fact that western cotton's water use has declined by 71% over the past 30 years. Rather than contributing to recent water problems in the West, cotton producers have been major sources of water conservation. Reductions in water use by western cotton growers over the past thirty years have exceeded water use of more than two-thirds of all residential water use in California, Arizona, and New Mexico.

### Acknowledgements

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