# DRY-WET CYCLES AND SAGEBRUSH IN THE GREAT BASIN

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## INTRODUCTION

The Great Basin, also frequently called the cold desert or high desert, covers most of southeastern Oregon, Nevada, western Utah and extends into parts of northeastern California. Climate for this large region is characterized by cold wet winters and hot dry summers. The primary source of moisture for the northern half of the Great Basin of which 60 percent falls as snow, is from the Pacific Ocean, with low pressure centers moving across the region during fall, winter and spring. Mean annual precipitation for this region is 11 inches, commonly ranging with elevation from 6 to 16 inches, with extremes varying from 3-5 inches in some of the southern valleys to 60 inches in the highest mountain ranges (Flaschka et al. 1987). Annual lake evaporation rates range from 45 inches in the north to 90 inches in the south.

Climatic variability has always been characteristic of the Great Basin since its' formation. At the Squaw Butte Experimental Range, where mean annual precipitation is 11 inches, precipitation has ranged from 6.5 to 17.5 inches during the past 40 years. During this 40 year period, precipitation has fallen below 70 percent of the mean (8 inches or less) one year in five. In the past 380 years, evidence indicates dry years generally did not occur at random but in cycles.

Evidence of drought over the past 100,000 years indicates that some dry periods lasted several thousand years and caused major shifts in plant and animal species distribution throughout the Great Basin. In this paper we will discuss: (1) the occurrence of dry-wet cycles in the Great Basin during the past 10,000 years; (2) the general effects of dry-wet cycles in this semi-arid ecosystem; and (3) the response of big sagebrush to dry-wet cycles.

### Changes in Climate: A Look At The Past

To obtain a better perspective on current climatic conditions it helps to look back to the past. This perspective may also help us predict changes that will occur in the future with global warming. Evidence used to describe past climatic fluctuations include analyzing fluctuations of lakes, glaciers, and snow lines, soil deposition and erosion by water and wind, tree ring widths, pollen cores from lake bottoms, rat middens, the relative abundance of plant and animal fossils requiring wet or arid environments, and in historic time by weather measurements, runoff and lake levels.

Following the last ice age which ended approximately 10,000 years ago, climate throughout the Great Basin continued to fluctuate, with an extreme dry period, sometimes called the altithermal, persisting during 7,000 to 4,500 years B.P. (before present) (Figure 1). Following this arid period, climate became more humid, approximately 4,500 years B.P. and then cooler 3,500 years B.P. (Antevs 1938, 1948). Within the last 3,500 years, climate has continued to fluctuate, including a cooling of the Great Basin beginning in the late 1500's and ending in the mid 1800's. This cooling period, frequently called the Little Ice Age, was associated with high volcanic activity around the globe. During the past 3,000 years, however, the general trend in climate has been towards increasing aridity.

## Recent Climatic Changes

Since 1650, we can see a distinct pattern of dry-wet cycles, implicated by tree ring data (Figure 2). In general, dry periods have most frequently occurred in clusters of 3 to 10 years. An obvious exception to this is during 1850 to 1917, when drought was infrequent and precipitation was generally above normal throughout the northern half of the Great Basin. We can also observe a trend in Figure 2 towards a gradual increase in drought intensity as we approach the present. By the end of the Little Ice Age (approximately 1850), mountain glaciers reached their maxima. Increased warming, which accelerated glacial melt, and above normal precipitation during the late 1800's and early 1900's increased runoff, elevating lake levels throughout the Great Basin (Antevs 1948). This period coincides with settlement of the region. Expectations of farming and livestock-carrying capacities during this period would have exceeded those had the settlers moved in during another time period. It is also coincidental that settlement occurred after one of the driest periods in the Great Basin, the decade of the 1840's. This wet period, which occurred with settlement from 1850 through 1923, ended with the severest drought since 150 to 650 years in the Great Basin.

From 1900 to 1940 the globe experienced the first major warming trend since the beginning of the Little Ice Age (Neilson 1986). Following the severe drought of the 1930's the globe experienced some cooling in the 1940's and 1950's and an increase of precipitation in the Great Basin (Table 1). In this century periods of below average precipitation occurred in the 1930's, 1970's and since 1985.

## Dry-Wet Cycles and Nutrient Availability

Water is considered the most limiting resource for plant growth in the high desert. During years of below-normal precipitation, plants compensate for limited water by reducing their leaf area or canopy. Death also increases, particularly in younger plants (e.g. sagebrush plants three years or younger), and little, if any, recruitment occurs. The overall aboveground effect of drought in a plant community is a reduction in both total plant cover and density.

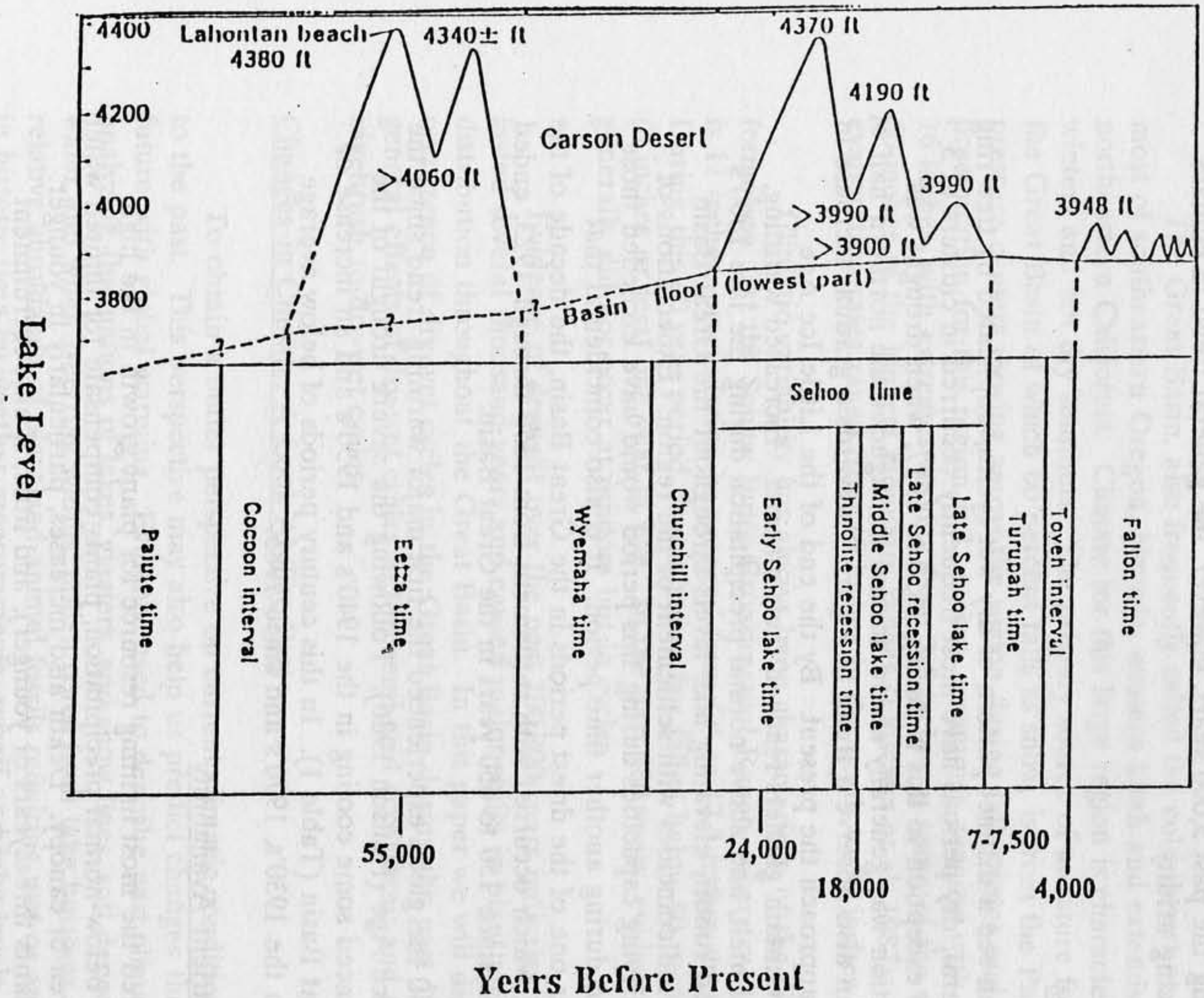


Figure 1. Elevation of Lake Lahontan during the past 100,000 years. The Wyemaha and Turupah time periods were warmer and drier than current conditions and periods of accelerated soil erosion. The Coccoon, Churchill and Toyeh intervals were warmer and wetter than current conditions and were important periods of soil formation in the Great Basin. Periods of elevated lake levels represent cooler and wetter periods than current (adapted from Morrison 1964).

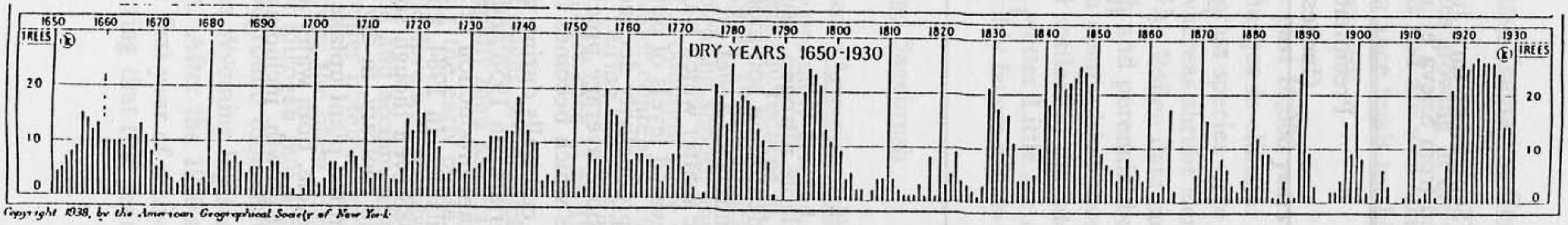


Figure 2. Estimated relative precipitation based on tree ring growth at various locations throughout the northern half of the Great Basin (from Antevs 1938). The Y axis is an index developed using tree ring growth representing wet (0) to dry (≥20) conditions.

Table 1. Mean crop-year precipitation by decade (September thru June) at the Squaw Butte Experimental Range. (Modified from Sneva et al. 1984).

| Years | Precipitation (Inches) |
|---|---|
| 1928-1937 | 6.6 |
| 1938-1947 | 11.0 |
| 1948-1957 | 11.0 |
| 1958-1967 | 10.2 |
| 1968-1977 | 8.2 |
| 1978-1984[1] | 11.7 |
| 1985-1990[2] | 7.5 |

[1] 7-year mean
[2] 6-year mean

Water also affects nutrient availability. Available nitrogen, usually the most limiting plant nutrient in the Great Basin, is dependent upon soil moisture, and is therefore influenced by dry-wet cycles. At the beginning of a wet cycle, increased levels of soil moisture stimulates decomposition of organic matter which transforms nutrients into usable forms for plant uptake and growth. Elevated levels of both water and nutrients stimulates plant growth. However, plant productivity declines in these semi-arid ecosystems following two or more seasons of above average precipitation. This is caused by a reduction in the availability of nutrients which becomes tied up in both live and dead plant material. Increased lignification of cell walls during wet years also reduces the decomposition rate of these plant materials. In 1958 and 1984, both the third year of three consecutive wet years, annual plant production at Squaw Butte declined even though soil moisture was readily available. In 1984, annual plant production was 25 percent less than in 1982 and 1983 even though soil water content was greater during the 1984 growing season. To the contrary, in dry years, available nitrogen levels tend to gradually increase due to limited plant uptake and decreased lignification of plant tissue. At the end of the dry-cycle, both water and nitrogen again become readily available, stimulating vigorous plant growth, including seed production.

Dry-Wet Cycles and Vegetation Composition

Plant species growing in the Great Basin have evolved under highly variable climatic conditions and are well adapted to compensate for dry-wet cycles. However, the competitive balance tends to shift towards one species over another during periods of drought and recovery.

During the past 10,000 years dominance between grasses and shrubs has shifted, coincident with changes in climate. Pollen analysis, rat middens, soil profiles and fossil records indicates grass species were favored during the cooler, wetter periods (e.g. the last 3,500 years) whereas shrubs were favored during the warm arid periods (e.g. 7,000 to 4,000 years B.P.). Pollen data indicate in southeast Oregon cyclic shifts in dominance between sagebrush and perennial bunchgrasses during the past 8,000 years (Mehringer 1986). Vegetation composition covering the landscape, described by the explorers, fur trappers and early settlers in the late 1700's and early to mid 1800's, was established during the cooler, wetter Little Ice Age. A continued trend towards a more arid environment probably favors woody plant species (e.g. big sagebrush) and exotic annuals (e.g. cheatgrass).

Dry-Wet Cycles and Sagebrush

Big sagebrush (Artemisia tridentata), one of the most successful plant species in the Great Basin is probably favored by the reoccurrence of dry-wet cycles. Like most plants, sagebrush greatly reduces its overall growth during drought. For example, limited precipitation in 1990 significantly reduced sagebrush leaf and stem growth, development of flowering shoots, and canopy cover. In 1990, vegetative and reproductive shoot production were only 13 and 20 percent, respectively, of the previous 1989 season (soil water content in 1989 was near average and growing conditions were considered good). During the drought of the 1930's, sagebrush canopy cover declined in the cold desert (Pechanec et al. 1937).

Following drought, we predict big sagebrush will be more opportunistic, recovering more rapidly than associated perennial bunchgrasses on most sagebrush-steppe sites. During the early phase of the recovery period, plant cover and root biomass are low and levels of readily available nutrients are respectively high due to reduced competition and accumulation of available nutrients during the dry period. Big sagebrush has a greater potential growth rate than associated perennial bunchgrasses, allowing it to reoccupy the plant community at a more rapid rate. Research has shown that the addition of nitrogen into a cold desert shrub steppe community allowed the current years' aboveground biomass to increase only 150 percent for a perennial bunchgrass whereas Wyoming big sagebrush biomass increased 340 to 455 percent (Miller et al. 1991). After the 1930's drought, big sagebrush canopy cover increased 76.9 percent in the first year of recovery compared to perennial bunchgrass cover which did not increase during that first year (Pechanec et al. 1937).

We also predict that reproductive effort will increase for many plant species growing in the Great Basin following drought. Increased reproductive effort is probably a response to elevated soil resources, particularly nitrogen. Elevated nitrate levels have been shown to increase big sagebrush flowering shoot growth by 300 percent (Miller et al. 1991). Other researchers in the Great Basin reported the highest densities of big sagebrush closely matched or followed years when plant cover was lowest, that is following a drought (West et al. 1979). Reduced plant canopy cover and elevated nutrient levels following a drought provide an ideal environment for seedling establishment.

## CONCLUSION: MANAGEMENT IMPLICATIONS

In conclusion, both long-term and short-term dry-wet cycles in the Great Basin are natural phenomena and will continue. Under the current climatic conditions we expect the sequence of these dry-wet cycles to increase big sagebrush dominance across many landscapes throughout the Great Basin. The ability of established big sagebrush to rapidly increase its canopy size and reproductive effort following a drought makes it extremely competitive. The removal of livestock grazing is unlikely to influence this process. However, excessive livestock grazing is likely to enhance sagebrush invasion by reducing the ability of established perennial bunchgrasses to increase in cover and produce seed crops. Because of the competitive edge of big sagebrush, prescribed fire must play an important role to maintain a balance between woody and herbaceous vegetation. Pre-European settlement fire frequencies, 20 to 30 years in the wetter more productive sagebrush sites and 40 to 80 years on the drier less productive sagebrush sites, allowed herbaceous vegetation to dominate or co-domonimate many of these sites.

If an accelerated warming trend does occur in the Great Basin (Global Warming), accompanied with a decrease in precipitation, we can expect, based on past events, an increase in dominance of woody plants, a decrease in total plant cover and an increase in soil erosion. An increase in exotic annuals, such as cheatgrass, are also likely to increase in dominance. Reduced water yields will also fall far short of projected future demands in the Great Basin.

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