Water Yields from Forests: An Agnostic View[1]

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Abstract: Although experimental watershed studies have consistently shown that water yield can be increased by removing trees and shrubs, programs to increase water yield on an operational scale have consistently failed. Failure has been related to overstated goals and benefits, unrealistic assumptions, political naivete, and the emergence of new interest groups. There is every indication that management of vegetation for increased water yield will continue to be impractical.

Can water yields be increased through management of vegetation? Nearly all studies clearly show that the answer is yes. Will operational programs to increase water yields be successful? History has clearly shown that the answer is no, and there is little reason to believe that future attempts at an operational scale to increase water yields will be successful. This paper will outline some of the reasons for these contentions.

Only since about the turn of this century has serious scientific thought been directed to the influence of forest manipulation on water yield. The first forest watershed study in the U.S. was started at Wagon Wheel Gap, Colorado, in 1909. In the early 1930's additional research was started at San Dimas in southern California, Sierra Ancha in Arizona,and Coweeta in North Carolina. By the 1940's a body of knowledge was emerging to the effect that cutting forests and subsequent regrowth can have a substantial effect on water yield. This information was translated in the 1950's into a number of grandiose regional and statewide proposals to increase water yields through vegetation treatments, primarily in water-deficient areas. Few, if any, of those proposals were ever implemented. Unforeseen social and environmental issues began to emerge in the 1960's. Also, research results from the 150 forested experimental watersheds under study were showing that many of the earlier assumptions were not generally applicable. By 1970, about 2000 papers had been published defining the forest's influence on water yield, floods, and water quality (Anderson and others 1976).

Bosch and Hewlett (1982) summarized the results of 94 catchment experiments world-wide, They reported that although there was extreme variation in results, in no case was a reduction of vegetation associated with a reduction in water yield, and conversely, in no case was an increase in vegetation associated with an increase in water yield. They concluded that the potential for vegetation treatment to increase water yield was greatest in coniferous forests, less in deciduous hardwoods, and least in brush and grass areas. In addition, yield increases were greatest in highrainfall areas, and, within a given area, tend to be greater in wet years than in dry years (Ponce and Meiman 1983). There is no potential for increasing water yield in areas having less than about 15 inches of annual precipitation, and marginal potential when precipitation is between 15 and 20 inches (Hibbert 1983; Clary 1975).

OPPORTUNITIES AND PROGRAMS FOR INCREASING WATER YIELD

About 70 percent of California's water flows from the coniferous forests which occupy about 21 percent of the State's land area (Colman 1955). Another 13 percent of the water flows from the low elevation woodland-brush-grasslands which occupy about 18 percent of the State, and 13 percent of the water originates from the nonforest alpine areas which represent 3 percent of the State's land. That leaves only 5 percent of the State's water to come from the remaining 58 percent of the land area. It would appear from these data that the opportunity for managing wildland vegetation to increase water yield in California is promising.

The idea of increasing water yields from the State's most efficient water-producing lands, the high-elevation alpine areas, can be abruptly dismissed. Opportunities for increasing water yields from the alpine zone is limited by both physical and legal constraints (Kattelmann and Berg 1987). Nearly all of the alpine lands in California are in National Parks, wilderness areas,) or areas administratively reserved from management. Vegetation is so sparse and the growing season so short that any management for water yield in those small areas where it is permitted would be limited to practices of managing drifting snow with structures. This is not new. When Colman (1955) proposed a new research program of snowpack management in California in 1955, he stated that there was little opportunity for water yield management in

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the alpine zone.

At the other elevational extreme, the low elevation woodland-brush-grasslands are the places where historically most interest in water yield enhancement has been directed--in California as well as throughout the arid Southwest. In the southern part of California, these lands lie above the water-deficient agricultural and urban areas where the demand for additional supplies, and the cost of obtaining them, is high. Not only is less water available from these lands, but they are also the areas where the size, number, and distribution of storms, and resultant streamflow, is the most variable. In 3 to 5 out of 10 years, streamflow is less than half the normal (Anderson 1963). The occasional wet years are often characterized by large storms that not only recharge the soil and provide between-storm streamflow, but produce floods and accelerated erosion. These storms result in unusable sediment-laden water that threatens life and property.

In areas where annual precipitation is less than about 15 inches, streams are usually ephemeral, and most streamflow is the result of surface runoff during intense short-duration rainfall. Under these conditions, attempts to increase water yield by treating vegetation have been unsuccessful) because soil water recharge is quickly lost to invading pioneer vegetation. A technique known as water harvesting, in which surface runoff is deliberately increased by reducing infiltration, has been applied on a small scale to provide stock water and local irrigation water (Cooley and others 1975). Such treatments may be the only source of water and may be economically justifiable in limited applications. But, on a broad scale, water harvesting would be impractical because of cost, increased erosion potential, and storage capacity required to retain the flash flood produced by the treatment.

In areas where annual precipitation exceeds about 15 inches, numerous plot and small watershed studies throughout California and the Southwest have demonstrated the ability to increase water yield through vegetation manipulation. In the 1950's, a number of large-scale operational projects were planned, and several were actually begun. All of the projects have failed for several reasons. It is instructive to review those reasons to anticipate what the future holds for water yield improvement in the woodland-brush-grassland areas.

Based on a report by Barr (1956a, 1956b) an action program was proposed that was expected to increase water yield by 285,000 acre-feet per year through several forms of vegetation treatment covering over 3 million acres, including the eradication of noncommercial ponderosa pine forests from 200,000 acres (Cortner and Berry 1978). Additional treatments were proposed for spruce-fir, pinyon- juniper, and streambed phreatophytic vegetation types. Later, another project to clear and convert phreatophytes from riparian zones in Arizona projected that water yield could be increased as much as 600,000 acre-feet per year (Fox 1977). Primary supporters of these programs were the Arizona water interests and State and Federal land management agencies. These proposals engendered criticism and were eventually terminated because of overstated program goals, unrealistic and untested assumptions, political problems of accomplishing the treatments, failure to recognize new interest groups, and questions of who pays the costs relative to who receives the benefits.

OBSTACLES TO WATER YIELD INCREASE

The water yield goals of these early action programs were based on averages obtained in controlled experiments on plots or small watersheds. The projected water increase was obtained by multiplying the average increase for each vegetation type by the area and summing. The result was a great overestimation of potential yield increases. Later, more cautious analyses reduced projections because only part of any vegetation type can be treated economically. The economics are related not only to the cost of land treatment, but to the value of the water, both of which change with time and location. Physical conditions such as poor access, steep slopes, and unstable lands reduce treatable areas and lower potential yield increases. And, consideration of other resources and social or political constraints, which in the 1950' s were often overlooked, has become a primary limitation to single-purpose land management plans.

Even if the technical, social, and political constraints of increasing water yield are adequately addressed, the extremely complex legal question of who owns the water remains. In most of the areas where increased water is in greatest need, water rights are defined in terms of season, place, point of diversion, type of use, and return flow (Ponce and Meiman 1983). Any actual increased yield varies from year to year and season to season. The technical problem of documenting or proving to the satisfaction of the courts that water yield from any parcel of land has actually been increased is overwhelming. And, unless the landowner can receive a financial benefit to offset the cost, there is no incentive to spend money to increase water yields on private lands.

The logic of managing the woodland-brush-grass areas for increased water yield is to reduce transpiration losses by replacing deep-rooted trees and shrubs with shallow-rooted grasses. Once the grass depletes the shallow soil moisture, much of which would have been lost to surface evaporation anyway, it becomes dormant, whereas the deeper-rooted vegetation has access to a greater and more dependable supply of soil moisture. Unfortunately, most of the chaparral and woodland ecosystems in these areas regenerate quickly from sprouts or seeds if burned or mechanically cleared. Long-term conversion to grass requires that these regenerating shrubs be killed and periodically retreated, otherwise any water yield increases will rapidly decline, disappearing completely within about five years (Hibbert 1983). Nearly all of the attempted conversions from chaparral to grass have required the use of chemical herbicides in both the initial clearing and followup treatment to control regrowth, A typical experience in the Santa Ynez River drainage near Santa Barbara indicated that after two spray treatments only 25 percent of the brush was killed (Hansen 1968). After a third annual treatment, about 75 percent of the brush was killed, except scrub oak, where only 40 percent was killed. Restrictions on herbicide use have eliminated the feasibility of long-term conversion of chaparral to grass (O'Connell 1972; Clary 1975). Even in 1975, then Chief of the Forest Service John McGuire stated that a "major problem concerns the impact of chemical herbicide restrictions on water yield improvement programs," and “attempts to use other means, such as prescribed fire, have not been entirely effective” (McGuire 1975). Today, as we are well aware, the use of herbicides is much more constrained than a decade ago, and it does not appear that the restrictions will be reduced in the immediate future.

There are numerous undesirable side effects of water yield programs that are often overlooked in the zeal to reap the benefits of the action program. Degraded water quality from erosion is one such side effect that is a major constraint on land management practices. The relation between brushfires and erosion is well documented. The erosion rate from hillslopes is related to the erosion potential of the site and to storm severity. The erosion potential on steep slopes is further related to the contribution of roots to soil strength (Ziemer 1981). Removing vegetation or conversion from brush to grass reduces the frequency of deep, woody roots and increases the probability of accelerated mass erosion. Using computer simulations, Rice and others (1982) investigated the potential effect of different prescribed fire regimes on landslide erosion. The model was based on the average conditions in southern California chaparral. They estimated that using prescribed fire on a 15-year treatment interval would result in an increase of about 280 percent in the long-term soil slip erosion rate above the natural rate. The natural wildfire rate in their model was one fire every 32 years. No estimates were made for permanent conversion from chaparral to grass,* but assuming that conversion could be physically accomplished, a best guess is that the long-term erosion rate might be increased about 900 percent above the long-term natural rate. In many of the chaparral areas of California, the present costs of keeping sediment out of urban areas are astronomical. The thought that active management of these watersheds for water might increase the sediment volume by a factor of 2 to 9 is unsettling.

The maximum increase in water yield will result from removing vegetation that transpires at the maximum rate and for the maximum duration. The most favorable locations are riparian zones and other areas where vegetation has access to groundwater. Unfortunately, these are precisely the areas where the opportunity for environmental damage is greatest and the management of vegetation is most constrained. The California Forest Practice Rules severely limit the ability to manage riparian zones for increasing water yield. There is a requirement to leave a minimum of 50 percent of the canopy cover within a buffer zone ranging from 50 to 200 feet from the stream, depending on slope. Local restrictions are much greater adjacent to urban areas. Even so, nearly every proposal to harvest timber or otherwise modify vegetation is contested for numerous reasons, whether in riparian zones or on the upper hillslopes.

Outside of the riparian zones, the next preferred locations for vegetation treatment to maximize water yield are areas having deep soil and the greatest soil water storage, These are the areas where tree growth and the value of the land for producing timber on a sustained basis are best. They are also, however, the places where the potential for logging-related mass erosion is greatest (Rice and Pillsbury 1982). Consequently, economic and environmental factors will probably limit the ability of the land manager to clear these commercial timber lands for water production.

If the climax coniferous vegetation in the riparian zone is removed, there should be an increase in water yield. However, as pioneering phreatophytes such as alder and cottonwood invade the area, Harr (1983) found that summer flows declined to levels below that experienced before cutting. He estimates that these lowered summer flows will persist for several decades, until the streamside phreatophytes are again overtopped by the conifers. Also, there is some evidence that young, vigorous forests transpire more water than mature or old-growth stands (Black 1967; Knoerr 1960). If this is true, long-term estimates of water yield increases, even though modest, may be overstated.

Probably, the areas where vegetation treatment for water yield would be least contentious are those where timber site is moderate to low. Unfortunately, such areas usually have shallow soils and/or deficient rainfall and the potential for increasing water yield is small.

CONCLUSIONS

From the foregoing discussion, it is clear that the options of vegetation management specifically for water are limited. A substantial amount of vegetation has been removed from commercial forest areas in the normal process of harvesting timber. In 1970, Rothacher estimated about 6 billion board feet of timber was being harvested annually from 200,000 acres in the Pacific Northwest, mostly by clearcut logging. The maximum water yield increase from the 94 catchment experiments reported by Bosch and Hewlett (1982) was 26 inches at Coweeta in North Carolina, but comparable increases, up to 24 inches per year, were reported from experimental watersheds in western Oregon, Surely, there should be ample evidence of substantial water yield increases resulting from this intense level of vegetation removal in Oregon and Washington, an area where water yield increases should be most responsive to treatment. Unfortunately, there is no such evidence on a regional scale.

Although it has clearly been shown that vegetation treatments can increase water yield on plots and small experimental watersheds, there is less assurance that such yields can be observed at downstream points of use. First , transmission losses through untreated portions of the routing system may decrease the added water. In arid regions, the added streamflow may encourage the growth of riparian phreatophytes, and if the distance from the treated area to the point of use is substantial, all of the increase may be lost enroute. Second, if the treated area is a small proportion of the watershed area above the point of use, the increased flow may not be detectable --even if transmission loss is negligible. This is the issue of scale.

Scale is an important problem in water yield enhancement. When both spatial distribution of the harvest and rotation age are considered, the potential water yield increase on a watershed basis becomes much more modest. Taking information from experimental catchments and land inventories, Harr (1983) estimated that the potential sustained increase in annual water yield related to forest practices in western Washington and western Oregon would be about 2.7 percent, using a 120-year rotation, and 4.7 percent, using a 70-year rotation. Kattelmann and others (1983) made similar estimates for Sierra Nevada watersheds. They estimated that streamflow could be increased 2 to 6 percent, assuming that the National Forest lands were managed almost exclusively for increased water yield while meeting the minimum requirements of applicable laws. If multiple use/sustained yield guidelines are followed, they estimated that water yield can be increased about 1 percent above current levels. These projected yield increases, if they do occur, will probably not be detected. An excellent streamflow record is expected by the U.S. Geological Survey to have an error up to about 5 percent (Rothacher 1970). The projected water yield increases are within this error. Also, this increased yield is not uniformly distributed seasonally or throughout the rotation. Most of the annual increase occurs in the winter high-runoff season and during the wetter years, rather than during the summer season and drought years,r when the additional water is needed.

It may be technically, politically, and socially possible to treat small watersheds on a scale of several hundreds of acres for increased water yield, but large-scale projects were not possible even before the present level of land management constraints. And, if an action program is possible, how does one document any increased yield resulting from land treatment? Very few small watersheds in California, except a handful of experimental watersheds, are gaged. For example, within the 1700-square mile Santa Ana River basin, one of the more intensively gaged drainage basins in California, there are 31 stream gaging stations, but only 4 of those gage watersheds having an area of leas than 10 square miles. Any water increases resulting from treatment, then, must be estimated by extrapolation of experimental data, or be based on model estimates--both having substantial error. By the time the increased flows combine with unmeasured flows from untreated watersheds, there is virtually no chance of observing or proving that any increase occurred.

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