Management of Natural and Environmental Resources for Sustainable Agricultural Development: Regional Diversity and Change Over the Pacific Northwest (Maritime, Rangeland, Riparian, Desert, and Forest)

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Abstract

Between 2000 and 2030, the population of the Pacific Northwest is expected to increase between 41 percent and 52 percent. With the possible additional stress placed on its water supply due to continued regional warming, the demand for water is expected to outpace the supply. Ecosystems will undoubtedly change and adapt but our ability to maintain or improve our quality of life will become increasingly problematic. Technology has kept up with changing demographics and changing climate since the Dust Bowl era. Agricultural yields continue to increase through better soil management, irrigation methods, genetic engineering, and environmental protection measures. By using new decision tools such as geographic information system (GIS), farmers, ranchers, municipalities, industry, and government now have the capability to maximize their access to renewable and limited natural resources. For example, the future success for rangeland management might very well depend on new hydro-meteorological networks (e.g., National Integrated Drought Information System) and new data (modeled) driven products.

Introduction

When the Clean Water Act (1977, 1990), Clean Air Act (1970, 1977), National Environmental Policy Act (NEPA, 1969), and the Endangered Species Act (ESA, 1973) (U.S. EPA, 2005) were introduced and subsequently amended by U.S. Congress, the national priority to provide citizens and wildlife with the healthiest environment possible had important implications and ramifications for each state. Besides mandates to better monitor all pollutants, states were directed to conform to new pollution standards as established and enforced by the Environmental Protection Agency (EPA).

Since then, many states have expressed dissatisfaction with the EPA on several counts. The first is that the federal government limits the amount of funding it provides to states to meet these requirements (unfunded mandates), and secondly, the pollution limits apply equally to all states; although each state has unique attributes such as population size, topography, types and amounts of industry, differing agricultural practices, and climate, just to name a few.

As the quality of life in the United States has improved due to technological advances in recent years, new markets have emerged. For example the leisure industry has witnessed an upturn in travel, recreation, and fitness activities. This in turn has helped promote healthier life styles as noted by a move to organic foods, environmental awareness and protection, and planned urban development. Conservation can now be thought of as a commodity (new paradigm). Gathering sociological forces are focusing attention at maximizing limited resources through public education, charitable contributions, and volunteerism. The scientific community has an important role to meet these urgent needs and changing requirements. However, to understand how to accomplish this support in an environment of conflicting and competing interests, we need to trace past and recent trends in order to best estimate future stakeholders' demands and expectations.

From 1965 to 1981, Presidential Executive Order 11331 authorized the establishment of the Pacific Northwest River Basins Commission. During this period, the Commission produced several reports that served as a comprehensive framework study of water and related lands. The value of this effort was not only to document and catalog all natural resources at the basin and sub-basin level, but to project how these resources would be used with future growth in population and economic development. In their 1972 report, they concluded that the population of the Seattle-Tacoma and Portland-Vancouver metropolitan areas would increase from 6.4 million in 1970 to 15.4 million by the year 2020 (Pacific Northwest River Basins Commission 1972). Total employment was expected to increase from 2.4 million in 1968 to 5.7 million in 2020. Municipal and industrial water requirements were expected to increase about 3 times, electric energy requirements over 10 times, recreation water demands over five times, and flood damage over four times by the year 2020 without additional zoning, control, and protection.

Although that 50 year forecast has yet to be completed and verified, increases in population due to increased immigration and longer life span were probably not in this Commission's arsenal of model projections. Additionally, the public's attitude concerning the environment and conservation has certainly gained momentum more quickly than expected with today's information highway (such as, the Internet and satellite television). Finally, climate change and its impact to the environment was certainly a factor not considered. For example, the 1970s was a decade in which global cooling was popularized by the April 28, 1975, *Newsweek* magazine article (Gwynne, 1975) and other sources (Wikipedia, 2008). The focus was to emphasize that "a drop of half a degree [Fahrenheit] in average ground temperatures in the Northern Hemisphere between 1945 and 1968" had occurred.

With increasing evidence of global warming (Frederick and Gleick, 1999), the relatively arid and semiarid western United States is vulnerable to modest changes in precipitation, resulting in proportionally large impacts on water supplies both in terms of quantity and quality. In mountainous watersheds, higher temperatures will increase the ratio of rain to snow, accelerate the rate of spring snowmelt, and shorten the overall snowfall season; leading to more rapid, earlier, and greater spring runoff. While the scientific community is beginning to have a better understanding of atmospheric phenomena such as El Niño, more research is required. However, because the temperature projections of climate models are less speculative than the projections of precipitation (e.g., increasing CO_2 correlates well with increasing surface temperatures), temperature-induced shifts in the relative amounts of rain and snow and in the timing of snowmelt in mountainous areas should be considered by resource managers in any coping strategies or scenarios.

The U.S. Department of Interior (2005) has projected potential water supply crises by 2025. The Pacific Northwest is expected to experience moderate water supply conflicts although conditions may be more extreme due to Endangered Species Act issues along the Columbia River due to various species of salmon and steelhead and a shorter mountain snow accumulation season. Other areas of the Rockies and Southwest are not expected to fair as well.

The boundary of the Pacific Northwest is defined differently depending on what agency is responsible. For example, at lower elevations, the U.S. Bureau of Land Management lands are confined to part of Montana, southern Idaho, eastern Oregon, and nearly half of Wyoming. At higher altitudes, the U.S. Forest Service has domain over several National Forests (Cascades, Coast Mountains, most of western and northern Idaho, and the Rockies in Montana). From an eco-regions standpoint (Bailey, 2007), the Pacific Northwest boundary is defined by using physical, biological, and social considerations; and is broken into Maritime, some Mediterranean, and Temperate regimes. For more on the U.S. eco-regions, see the U.S. Forest Service ecosystems Web site at: http://www.fs.fed.us/rm/analytics/publications/ecoregionsindex.html.

Generally, the Pacific Northwest is quite diverse as noted by the U.S. Department of Agriculture's (USDA's) plant hardiness zones that range with minimum annual temperature from -40 degrees C over the highest peaks and deeper valleys of the Rockies to 0 degree C along the immediate Pacific coast (USDA, 2003). However, for the purpose of this paper (Figure 1), this region is defined as the drainage of the Columbia and Snake Rivers and encompasses all of Washington, most of Oregon and Idaho, smaller portions of northwest Montana and Wyoming, and northern Nevada (drainage of 70 million hectares).

Figure 1: The boundaries of the Pacific Northwest in the United States.

During the last two U.S. national census' in 1990 and 2000, the percentage change in resident population for Washington, Oregon, and Idaho increased by 21.1 percent, 20.4 percent, and 28.5 percent, respectively (Perry and Mackun, 2001). This translates to more than a one million increase in population for Washington, between half to one million for Oregon, and between 100,000 and 500,000 for Idaho. While these increases are impressive, they pale in comparison to the 40 percent and 66 percent increases for Arizona and Nevada, respectively. Table 1 shows the population growth for select states across the West for the period 2000-2030.

Table 1: Expected population gains for selected western states from 2000 to 2030 (U.S. Census Bureau, 2005).

State	Pop Gain	Percent Change
Nevada	2,283,845	114.3
Arizona	5,581,765	108.8
Utah	1,252,198	56.1
California	12,573,213	37.1
Idaho	675,671	52.2
Washington	2,730,680	46.3
Oregon	1,412,519	41.3

These increases are significant since already stressed water supplies over the West will become increasingly dire during the next 25 years. The doctrine of priority water rights (i.e., first in is first served), a long held practice in the West, may become challenged as urban centers continue to grow. This in turn would greatly impact agriculture in the West.

Climate and Climate Change

The Earth's climate has undergone measurable change since the Precambrian Era (i.e., past 600 million years). During this period, there have been approximately four episodes in which the Earth has been exceptionally cold. Today, in spite of some global warming (~1 degree C during the past century), the planet is as cold as it gets in terms of the geological record. Of course, a half billion years ago the earth landmass looked quite a bit different than today while CO_2 was enhanced perhaps more than 10 times than its current value due to active volcanism. However, the climate system is a highly complex non linear open system in which we do not fully understand the countless interactions that take place temporally and spatially.

It is known from proxy data of tree rings over Wyoming that during the past 700 years, droughts have existed, sometimes lasting for multiple decades. While droughts have been considered to be severe in the early 1900s, 1930s, 1950s, and the early 21st Century, they are considered to be mild when compared to the mega droughts of the 13th and 17th centuries. Certainly, the most recent drought over the West has affected more people than all the prior documented droughts. However, without today's technology, the Native Americans of the Southwest had no chance to survive during extended dry spells one- half millennia ago.

Recent national climate trends show that much of the Southeastern United States has been cooling by a few degrees during the past three decades while the West, especially the Southwest is warming. Part of this cooling in the Southeast is explained by increasing cloudiness and warming in the Southwest by the urban heat island effect and desert irrigation. Increased water vapor (also a greenhouse gas) keeps nighttime temperatures higher. Precipitation on the other hand is generally increasing across the United States. The greatest increases are in the Gulf Coast due perhaps to hurricane frequency. The General Circulation Model (GCM) predicts that with global warming, precipitation should increase. While this appears to be happening over the north central and western third of the country, it is far from happening everywhere.

As the CO_2 level rises, remote satellite imagery reveals that independent of temperature, the mid latitudes are showing an explosion of vegetation (greening). This would be expected since CO_2 is the essential source for plant fertilization.

The Pacific Northwest experiences average annual precipitation from less than 25 cm over portions of eastern Washington and Oregon and southern Idaho to totals in excess of 450 cm over the higher elevations of the Cascades and Coastal Mountains. There is, however, large inter-annual variation in part due to the strengthening and location of the El Niño Southern Oscillation (ENSO). Perhaps more important than precipitation amounts are the timing of such events. Up to 89 percent of precipitation falls over the western mountains between the 6-month period from October through March (50 percent would be expected with a normal distribution). Thus the importance of mountain snow pack is vital for water supplies. If the snow accumulation season is shortened, there is less opportunity for spring runoff and capture. The reverse occurs over the Great Plains when spring moisture exceeds normal expectations by nearly double. The timing of these precipitation events is critical for dry land farming/ranching. Studies show that native cool grass growth used for livestock foraging is independent of precipitation that falls during other seasons.

The Pacific Northwest contributes to 15 percent of the U.S. production of winter wheat. However, the success for a surplus harvest depends on critical temperature thresholds in the fall and spring. If the U.S. climate is expected to change so that it experiences larger temperature and precipitation swings from the long-term average, wheat and other crops not only in the Pacific Northwest will become more vulnerable.

Why are the lower elevations of the intermountain West so arid? This is clearly illustrated by looking at how precipitation is a function of elevation over Wyoming (Curtis and Grimes, 2004a). With extreme low surface relative humidity, strong winds, and high temperatures, evapotranspiration (ET) values are extremely high due to evaporation exceeding precipitation by up to four times. While most land is below 2,286 meters of elevation, less precipitation reaches the ground than at higher elevations. ET is lower and precipitation exceeds evaporation above 2,286 meters. Mountains therefore become our natural reservoirs for water storage and release.

Changing Agriculture and Conservation Practices

The agriculture industry is in constant flux as irrigated and dry land farming contends with urban growth and a diminishing water supply. Smaller farms (i.e., less than 500 acres and annual sales of less than U.S. $10,000) are being sold to larger corporate farming enterprises or to land developers. Any improved efficiency in these corporate farms could be lost to the expansion of the suburbs into more rural areas. The landscape is also changing due to the current western drought which has caused the historical lowest levels of water storage and capacity on the Colorado River. Additionally, restrictions imposed by the Endangered Species Act on activities along the Columbia River has forced many a land stakeholder to rethink about their livelihoods or to move on.

From 1997 to 2002, large regions east of the Cascades have seen a marked decrease in farm acreage. Irrigated lands have also decreased especially in Idaho and in western Montana and Wyoming. Certainly, the severity of the current western drought in 2002 was a major contributing factor. While some crops, such as alfalfa showed some increases in yield, potatoes and all wheat crops showed a decline. A mixed trend was also seen in the cattle industry. Beef cows declined while milk cows were on the increase. Whether these trends will change is highly problematic. However, by better understanding successful farming techniques and emerging technologies, these stewards of the land will have a fighting chance at helping to feed the nation and the world. The following are some examples of successful farming techniques.

Understanding plant moisture requirements is a critical component to water resource management. Field studies show that about 40 percent of the total moisture intake by plants is extracted by the plant's roots from zero to 15 centimeter (cm) depths; 30 percent from 15 to 30 cm; 20 percent from 30 to 45 cm; and 10 percent from 45 to 60 cm (Curtis and Grimes, 2004b). Each soil type has an inherent available water holding capacity which can vary from 2.5 cm per hectare for loamy sand to 6.2 cm for silty clay loam. Consequently, a 60-cm root zone will typically have an irrigation water requirement that can vary between 3.75 cm (153,300 liters per hectare) for a coarsely textured soil to 60 cm (255,515 liters per hectare) for a finely-textured soil. Most flood irrigation systems are between 45 to 70 percent efficient, therefore 7.5 cm (306,618 liters per hectare) is a recommended application.

Local experience recommends that irrigation should be applied when 30 to 50 percent of the available water is depleted in the zero to 30-cm root zone and when about 15 to 30 percent is depleted in the 30- to 60-cm root zone. It takes about 48 hours for the surface moisture to recharge the soil to a 60-cm depth for most soils. As a general guideline, a fully mature tree at peak water consumption can remove 0.5 to 0.75 cm of moisture per acre per day. This translates to irrigating between eight and 10 days if no precipitation occurs during this interval. Of course solar radiation, wind, humidity, temperature, precipitation, crop variety, soil drainage, and water quality are important factors for successful irrigation.

In 1997, thousands of square kilometers (km) of land were eroded by wind on croplands along the Snake River in southern Idaho and over the Columbia River in Washington and Oregon. While weather can contribute to top soil losses as witnessed during the Dust Bowl Era, erosion can be reduced through the employment of some basic techniques such as the use of snow fences, drip irrigation systems, and riparian restoration. There are numerous other examples as addressed on the Natural Resources Conservation Services (NRCS) Climate Data and Conservation Practices Web site (NRCS, 1998).

In the higher altitude valleys of the Pacific Northwest, a remarkable fact about blowing snow is that after being transported along the ground for 8 km, it has essentially lost all its moisture through a process called sublimation. In order to prevent any sublimation or evaporation of snow or melted snow, snow fences are employed not only to prevent snow drifts from blocking roads but to collect these drifts for later melt into holding ponds for livestock. Snow fences come in two forms and each has inherent pluses and minuses:

The conventional one-meter high slatted fence and the Wyoming Design board snow fence that stands 2.5 to 4.2 m high are the most popular structural fence designs. Their advantages include that they can be:

- Erected and put into use very quickly;
- Used at sites where vegetation is not practical.

Their disadvantages include:

- High establishment and annual maintenance costs;
- Life span of materials is 20 years.

The other form is the Living Snow Fence (vegetation) which has the following advantages:

- Much less expensive than structural fences (i.e., nearly seven times less);
- Life span is 50 years;
- Designed for wildlife habitat, livestock protection;
- Used as visual screens and helps to reduce soil erosion.

Their disadvantages include:

- Long-time lag before vegetation starts to trap snow;
- Barrier density may vary as vegetation grows at different rates;
- Vegetation is susceptible to damage from insects, disease, etc.

Another technique that is gaining wide acceptance is the use of drip irrigation. Studies have shown that it uses 30 to 50 percent less water than conventional flood irrigation or sprinklers (Hutmacher, et al., 2001; Jifon, et al., 2005; Henggeler, 2004). This also helps to prevent soil erosion and nutrient runoff and weeds are discouraged to spread. Controlling moisture suppresses fungal diseases. For example, in Wyoming, 80 percent of water is used by agriculture and 90 percent of that is for flood irrigation. Clearly, a conversion to a drip irrigation system is essential in order to get an upper hand on dwindling water supplies.

Riparian restoration using vegetation is proving more effective than using structures to control stream and river flow. Vegetation heals itself and adjusts to changes in flow and landform. Besides enhancing wild life habitats, these restorations help to reduce erosion.

Field studies have indicated that climatic averages may no longer support dry land farming yield forecasts. In a 4-year period, increased variability in rainfall resulted in the same long-term average amounts, but impacted the ecosystem in two ways. First, the native grassland biomass was reduced by fewer precipitation events with greater rainfall amounts per event as compared to more events with lesser rainfall amounts per event. Second, plant species diversity increased.

Thus, these findings suggest that the prairie can exhibit rapid changes to its biodiversity even though the climate rainfall totals do not show long-term trends. In another study, increased spring minimum temperature was correlated with decreased net primary production by the dominant C_4 grass (grazing forage) and with increased abundance and production by exotic and native C_3 forbs. Thus this scenario may make a region more vulnerable (less tolerant) to drought and grazing. Finally, native biomass yields were shown to be moderately correlated to precipitation events from late March to mid May in Wyoming.

Land Use Changes

LANDSAT and other remote satellite platforms have been around long enough to clearly reveal that land is changing. In the urban setting of Puget Sound, Seattle's expansion into the surrounding rural areas is quite apparent from 1973 to 2000. In a rural setting, significant forest clear cutting over the northern California Coastal Range is striking from 1986 to 2000.

In the 1972 report by the Pacific Northwest River Basins Commission described earlier, it was projected that cropland will increase to over 137,000 hectares by 2020 but that forest land and rangeland will decrease by 277,000 and 374,000 hectares, respectively (Table 2).

Table 2. Cover and Land Use, 1966 with projections for 1980, 2000, and 2020 for the Columbia-North Pacific Region (1,000 hectares) (Pacific Northwest River Basins Commission, 1972).

Type	1966	1980	2000	2020
Cropland	3,410	3,532	3,509	3,547
Forest Land	14,070	14,000	13,898	13,793
Rangeland	9,628	9,393	9,357	9,254
Other Land	1,364	1,468	1,591	1,719
Total Land	28,472	28,392	28,354	28,314
Water Areas	313	392	431	471

Whatever the actual current numbers are regarding land use changes, impacts to our natural resources are occurring.

Current land use, as measured by building per square km, shows the densest population between the Coastal Mountains and the Cascades. Projected land use changes during the next 50 to 100 years may be subtle (Johnson, et al., 2007 and Kline, et al., 2003); however, encroachment into our National Forests and watersheds will have serious implications on balancing requirements between water supply and demand.

Hydro-meteorological Networks

The best defense for protecting our environment is our ability to monitor hydrological and meteorological elements in real time. The Pacific Northwest and the western half of the United States still lack a high-density monitoring capability. While there are several networks in use (e.g., AgriMet, SNOTEL, SCAN, RAWS, COOP, radar, USGS, rawinsondes, etc.), interoperability with respect to communication is still lacking. Soil moisture sensors, at the heart of modeling runoff, are slowly improving but there are budgetary issues to overcome. However, with the implementation of the National Integrated Drought Information System (NIDIS) (Western Governors Association, 2004), this framework architecture will maximize all environmental sensors that are available.

The New Paradigm

Traditional climate data includes average temperatures, total precipitation, and extremes, usually based on a 30-year period of record. These “Normals” are updated at the start of each decade and these values change with each update. While these data are beneficial for planning activities, average weather and climate conditions are seldom experienced, especially during shorter time intervals (i.e., hourly, daily, or even monthly). With computers, climate data can now be easily compiled to show statistical probabilities for a given weather element and as the period of observations increase, important trends can have important implications as discussed below.

In Wyoming, forage production of non-irrigated grasslands is strongly tied to precipitation events at a specific time of year. For example, at Saratoga, Wyoming, biomass yields are directly correlated to precipitation that falls during the period of April 12-19 and is independent of precipitation that falls at other times of year. This simple relationship provides a reliable management tool for herd distribution since it takes up to 16 hectares to feed one cow in this arid regime. Timing is everything.

In another study over the Great Plains, the distribution of precipitation over time has an important impact on grazing and biodiversity (Knapp, et al., 2002). Although during the same period a similar amount of precipitation had occurred, when there were more events of lesser amounts per event, forage grasses were decreased, and more plant species developed. In this case, frequency and intensity of precipitation proved to be more important than precipitation amounts.

Finally, a study has revealed that as night temperatures increased over the Great Plains, forage grasses decreased, became less tolerant to drought, and resulted in poorer grazing opportunities (Alward, 1999). Climate trends suggest that the ecology of a region may be more or less adaptive to small changes with certain climate parameters. Thus, when using climate data, there is a need to start thinking about how to use it differently. Averages, totals, and extremes may not provide enough information to describe ones environment.

Exciting work is underway that establishes a methodology for the systematic quality control of SNOw TELementry (SNOTEL) using a probabilistic-spatial approach. By using Parameterelevation Regressions on Independent Slope Model (PRISM) spatial gaps in climate data can be accurately estimated with surrounding existing weather stations (Figure 2; Daly, et al., 2002). A bibliography of the PRISM papers can be found at the following Web site: http://www.prism.oregonstate.edu/docs/index.phtml.

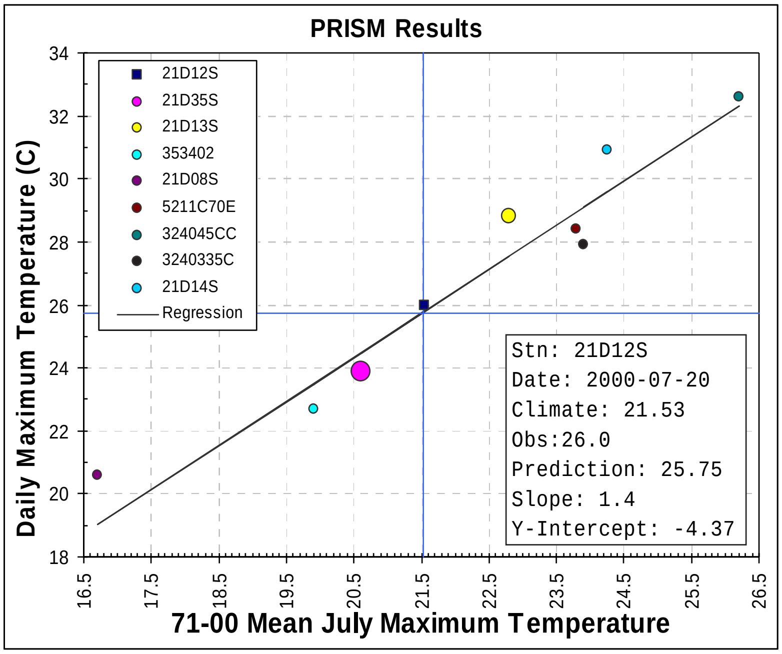

Figure 2: Example of one station's temperature as compared to other neighboring stations (Daly, 2007).

Conclusion

The socioeconomic implications of both climate and non-climate impacts on water supply and demand will depend in large part on both the ability to adapt to change and on whether water managers and planners take action. With the uncertainties associated with increasing federal regulation of the environment, changing demographics and technologies, and budgetary realities, we need to re-examine infrastructure design assumptions, operating rules, and contingency planning under a wide range of climate conditions than has been traditionally performed. Maintaining options and building in flexibility are important for designing efficient water programs in the context of climate change. Additionally, future climate products need to incorporate all sensors and their associated networks, and these data must be customized for each stakeholder's unique requirement.

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