Fire and Rain: The Consequences of Changing Climate on Rainfall, Wildfire and Agriculture

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The following is a guest post by TOD reader Doug Fir. 'Doug' graduated in the 70's with a BS and a MS in Fisheries, Forestry, and Agriculture. Presently, he and his family work a small hay, timber and livestock operation. The policies impacting climate change legislation are linked in complicated ways to energy depletion. If anthropogenic induced climate change ends up being real and urgent, it will have direct impacts on energy and food production. For these reasons we periodically post thoughtful analysis on the topic of climate change here on theoildrum.com.

The consequences of climate change are often presented in the media as coastal flooding after the melt of Greenland or Antarctic ice. That is the headline most often seen, however the real problems will be much more extensive. I'd like to look at some of those problems, in particular those of wildfire and agriculture, and provide a little background to better illustrate their severity.

Wildfire

One of the more dramatic effects will be the increase in the number, size and severity of wildland fires, of which we recently had a taste in California. "I think we can demonstrate higher severity, larger fires and certainly over the last seven to eight years, more frequent fires and a longer fire season," noted Abigail Kimbell, chief of the U.S. Forest Service. Fire is a natural process, releasing carbon compounds and bound nutrients, usually contributing to the health of an ecosystem in the less intense fires. Ponderosa pine, a major species in much of the west, is classed as fire tolerant, needing light fire to open the seed cones. However, climate change, compounded by years of fire suppression leaving elevated fuel loads, has set the stage for megafires. Steven Pyne, in his book Worldfire, notes four items in his prescription for large fires-abundant fuel and ignition, drought, and wind. Climate change, by changing precipitation pattern intensity and temporal distributions, will provide these.

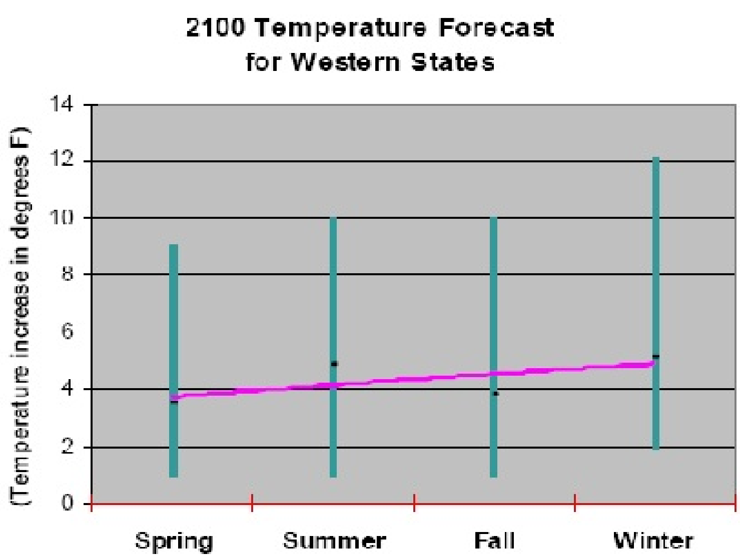
Looking back at the worst wildland fires of the US, drought created the overall fire danger, the fuel situation and wind determined their size and severity. The Wisconsin Pestigo fire, October 8,1871, burned 1.2 million acres and killed over 1200 people, including the over 400 buried in a mass grave from the town of Pestigo. It was one of 3 major fires that day in the the Lake States, including the Great Chicago Fire and the Port Huron fire, the latter killing over 200. In common, the wildland fires had abundant fuel from leftover slash in the logging and agricultural activities of the North Woods.

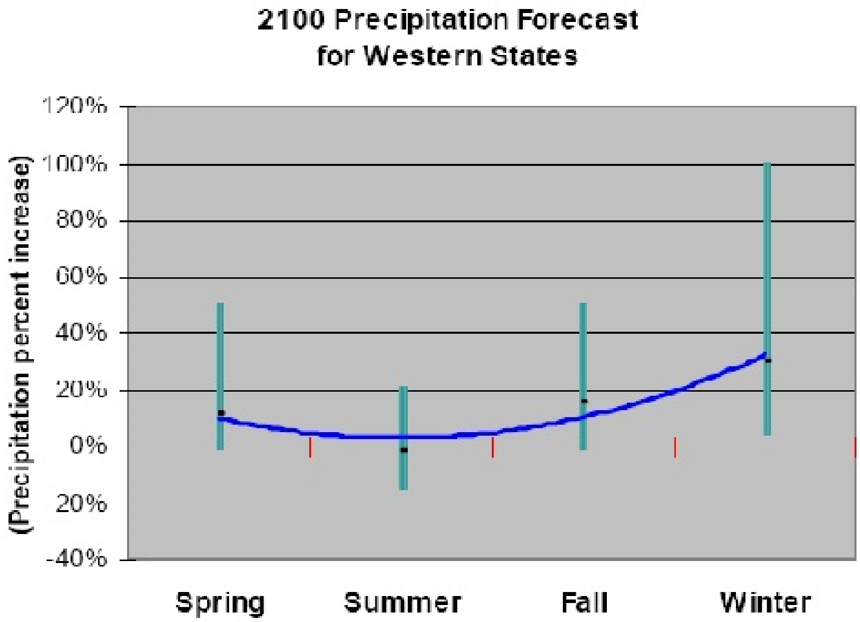
The largest fire within the United States broke out in 1910. Known as the 1910 Burn, it consumed over 3 million acres in Idaho and Montana. Straddling the northern Rocky Mountains, it raced from near Washington, over the Bitterroot Mountains and down through Montana, killing 86 people. Nearly 100 years later, vast areas of this fire are still nearly bare of regrowth. Intense fires such as this, as opposed to less fuel-heavy natural fire, degrade the soil. The hot burns can cause extreme depletion of nutrients and organic material, leaving a nutrient poor soil that retards forest regeneration and is very susceptible to further loss via erosion. In 1910, the prescription of abundant fuel had been met in the prior years of discarded logging slash, and was ignited in a droughty, dry summer. Similar fires raced through eastern Washington and north Idaho a decade later, again spurred by abundant logging slash. A collection of stories from the 1910 Burn are here.

We often fixate on what started the fire. In the examples above, debate continues over a meteor shower in 1871, railroads spewing sparks, campfires left unattended; even milking a cow has created controversy. I've fought range fires caused by railroads, campfires, accidental fires, or not so accidental ones. It can be in the early spring, or seemingly wet summer before haying, or in the fall when conditions are ripe. Give it a little wind, and it will jump roads and rivers. Studies from Yellowstone National Park show that while man-made fires account for an average of 6-10 fires, lightning will have caused 35 a year. It doesn't matter the cause, fires have always cropped up.

Climate Change Consequences

Current climate change predictions for much of the West show increased precipitation in the winter or spring, along with earlier and drier summers. The IPCC and Hadley Centre's climate model predict warmer temperatures and their trends indicate increased winter precipitation for the western states. See figures below. The Climate Impact Group of the Pacific Northwest predict "Temperature increases occur across all seasons with the largest increases in summer. Most of the models analyzed by CIG project decreases in summer precipitation and increases in winter precipitation with little change in the annual mean." Long term, 2100, vegetation models show varying woody potential of the west but all cite the greatly elevated fire risks as the vegetation responds to the changing climate. The Climate Change Center of California predicts that "Although climate model results are inconclusive as to whether California's precipitation will change over the next century, all climate models show increases in temperature."





It is difficult to predict site specifics for the region, as so much is also determined by a particular site's elevation and aspect. Should these predictions come to pass, it is a perfect recipe for wildland fires. The west in general already has this overall precipitation distribution, and the vegetation has been selected to survive this moisture regime of little rainfall until autumn. Growth is concentrated in the spring, by summer, tree survival is predicated in large part by tapping deep soil moisture. Longer and more intense summertime droughts will overcome this ability, killing the trees outright or initiating disease mortality. Little snowpack for insulation in the late fall coinciding with a cold snap is very stressful for many trees and has been implicated in climate change mortality for western larch, itself a species with a relatively wide climatic amplitude and hence believed more resistant to change.

The wetter spring will encourage excessive grass and forb growth, only to quickly turn to tinder in the upcoming summer. With an arid climate, these fuels accumulate, and are of the most dangerous variety. Fire managers today prescribe piling and burning slash during the winter after a timber sale. Their primary concern is with material under 3 inches thick, just the size range likely to accumulate with wetter springs. The accumulation of the smaller fuels was part of the case in California fires this past autumn. Additionally here, a more intense fire quickly develops in part due to the density and higher oil content of much of the vegetation. The exotics cheatgrass and red brome, invading much of the west, have already been linked to faster fire cycles, and are cited as instrumental in elimination (by fire) of sage-bunchgrass communities. Although not specifically cited, I wonder about the role of knapweed, a very high oil content exotic which also is infesting the west.

Climate change, by altering precipitation patterns, changes the species composition in the forest. In interior western coniferous forests, the more water-loving firs are replaced by pines or Douglas fir during summertime heat and drought. As drought intolerant species are replaced, they are left to dry, providing fuel and awaiting the next conflagration. Disease outbreaks, as presently occurring with the pine beetle in the northern forests, leave wide swaths of fuel. Forest pathogens are showing a broader ability to infect multiple hosts when the trees are stressed. This is being seen in the west not only with the mountain pine beetle, but also with the spruce budworm shifting to Douglas fir and even hemlock, and with other pathogens. It won't be a peaceful succession to the next vegetation type. Fire will intervene to guide the process, and it will have abundant fuel.

Disease outbreak in western montane forest

Disease outbreaks present a two sided coin, a distinction noted by researchers at the Fire Science Laboratory in Missoula, Montana. Initially, in their weakened, often dessicated disease state and shortly thereafter, these stands pose the greatest risk for major, swift crown fires. As the needles and smaller limbs drop from the tree, the danger for rapid crown fire lessens, but this fuel is not removed. It is added to the ground, where it's potential for soil debilitating fire magnifies.

A Washington Post series in response to the recent California outbreak highlights a new facet of fire problems. Exurban development is a scene that "bloats with inflammable structures amid an overgrown biota.", according to Pyne. He states that in the new age, fires "rush out of the reserves and into the exurbs." The firefighting response changes, from fighting the fire's advance to saving lives and structures. With climate change, as the author Fitch notes, the problems will only intensify. The solutions offered appear dubious to me. Prescription burning will not fly within such a concentration of wealth. Moving out of the environment is suggested, but even the fire researchers are shown to to have a predilection for the exurban environment.

The problem is not confined to the west, and as the eastern droughts continue, these concerns will ignite there. Ron Neilson, a bioclimatologist at Oregon State and a member of the IPCC, states "The Southeastern United States appears to be among the most sensitive regions in the world to increasing temperatures. It could convert from forest to savanna or grassland through drought, insect infestation, and massive fire." The east, with its higher rainfall and humidity levels, has relied in the past more on microbial decomposition to recycle excess vegetation. Drought and fire will help that change.

The fire situation is summed up by Thomas Swetnam, director of the Tree Ring Research Laboratory at the University of Arizona. "I see this as one of the first big indicators of climate change impacts in the continental United States. We're showing warming and earlier springs tying in with large forest fire frequencies. Lots of people think climate change and the ecological responses are 50 to 100 years away. But it's not 50 to 100 years away--it's happening now in forest ecosystems through fire."

Agriculture

Climate change induced shifts in precipitation will have their greatest effects in agriculture and our food supply. It is difficult to underestimate just how tied agriculture is to moisture regimes. We ignored this earlier in our original cultivation of the plains in comparably wet years, which led to subsequent disaster. We also find it today in reliance on depleting aquifers for irrigation or shifting production. We are teetering on the edge of food supply, and the solutions are not near as easy as the response rolls off your tongue.

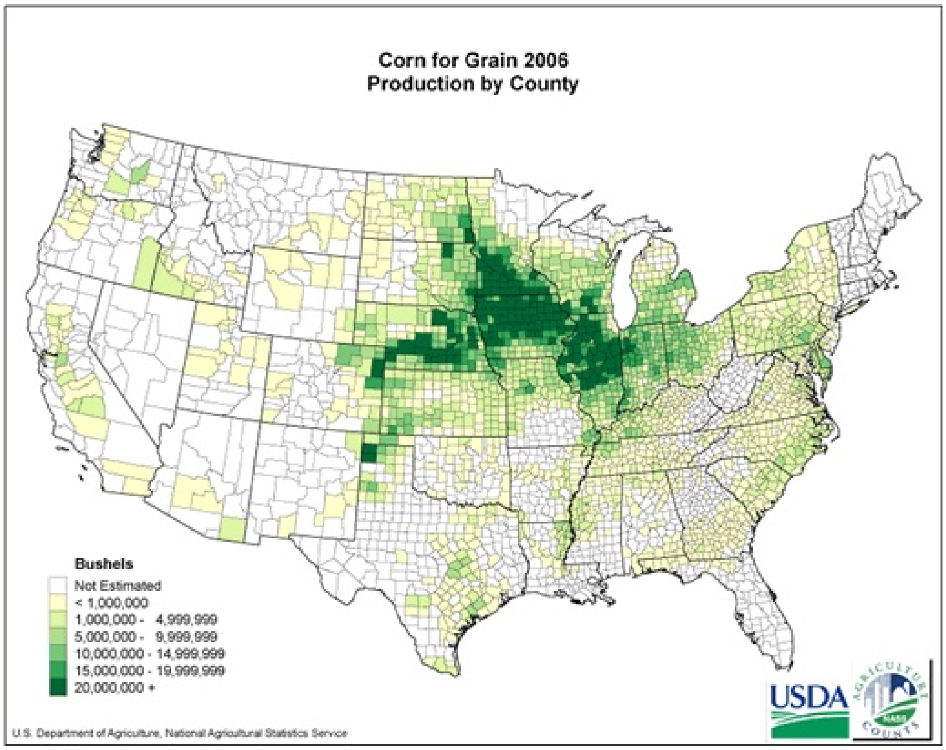
Worldwide, people obtain around 70% of their daily calories from grains, specifically corn, wheat, rice, millet, and sorghum. We are down to the the lowest grain stockpiles, around 57 days of consumption, according to Lester Brown of WorldWatch Institute. Any rainfall changes can quickly eliminate the surplus. Skeptics may cite increased yields from elevated CO_2 levels, but no amount of additional production from higher CO_2 can compensate for drought. In addition, corn is what is termed a C-4 plant, and is less responsive to increased CO_2. Preliminary research by Gill, Evans and others also indicate an upper, rather close limit to increased photosynthetic ability. They stress the flora has evolved at an average 220 ppm CO_2 over the last 10,000 years and that as CO_2 concentrations increase, "we see lots of changes in the way plants photosynthesize, the rate at which they lose water, how they use the nitrogen, and the microbial community in the soil." In part, the limit involves, at least in range and pasture, what is termed progressive nitrogen limitation, as the increased uptake ties up available nitrogen. As this proceeds, there can be a shift from microbial to fungal decomposition. The limitation presents many new problems for livestock grazing and carbon sequestration through biomass, although probably not important to fertilized agriculture.

A quick look at North America. Dryland agriculture is demarcated around 30 inches of yearly precipitation. Higher amounts allow the cultivation of corn and soybeans, less than this and yields drop precipitously. This relation between rainfall and yield should be underscored. From Iowa eastward we reap the bounty, farther west means either a shift to wheat or supplemental irrigation. Wheat dominates as you continue west, but the rainfall and yield decrease. Finally, there is strip farming, where it takes 2 years to grow a crop. Alternate strips, often a mile in length, are planted one year, while the adjoining strip is left fallow to accumulate moisture. This practice starts at about 15 inches precipitation, below around 10 inches and farming is not worth it. Rangeland, already interspersed, begins in earnest.

Montana strip farming. Half of the land is left unplanted to accumulate moisture for the following year.

Present mitigation efforts center around earlier planting to take advantage of increased temps and hopefully avoid withering midsummer extremes, crop species changes, shift of crops to more northern areas and finally additional irrigation. These mostly address the increased temperature aspect of climate change, not so much the drought or moisture deficits in major grain growing areas. Development of drought tolerant varieties is in its infancy. With only 5 grains supplying the bulk of our calories, the consequences of this agricultural loss are major..

The image of corn yields below highlights the problem of shifting grain production. Western counties, essentially along the state lines from Minnesota/North Dakota south to the Gulf, range from partial to complete irrigation. In the cornbelt of the midwest, high yields and total production are due to rain, but also to the amazing fertility of the soil. Irrigated production in the west such as along the Yellowstone River in Montana or the Snake in Idaho is evident, but these yields are well below those of Iowa. As we move production, we are unlikely to encounter such productive soils. The soils of the north are podzols, derived under coniferous forest and not near as bountiful.



With irrigation left to keep up our production, it seems analogous to oil if you will. Farming enters a sort of enhanced recovery, because we are unable to find significant additional arable land. Worldwide arable land per capita has decreased from 0.38 hectares per person to 0.28 hectares from 1970 to 1990, according to FAOSTAT, 1999. This difference has been made up primarily by irrigation. The irrigable land per capita has remained stable around 0.045, again according to FAOSTAT, 1999. We have been feeding the population increase in part by expanding irrigation acreage and to some extent increasing water use efficiency. Worldwide, we find 15% of farm land is irrigated.

There is a world of difference between irrigation practices in Asia and much of the rest of the world, and how the water is allocated. Asia accounts for 2/3 of the world's irrigated land. Nearly 70% of the grain in China, and almost 50% of India's grain come from irrigated land. In Asia there is mainly paddy irrigation of rice from surface water. To some extent, China and India have incorporated raised beds for corn and wheat within the paddy. However, the main crop remains rice in a traditional paddy system. While new varieties of rice from the Green Revolution have helped to triple yields, in both this and many other crop variety improvements, it often comes at the expense of root development. This makes the plant more susceptible to moisture stress. Reduced yields are becoming more common in dry season paddies due to insufficient irrigation water. These irrigation water supplies are dependent on rainfall to replenish either lowland streams and reservoirs, or mountain snow pack.

Most importantly, agriculture in the US is largely dryland, with irrigated land representing only a little over 15% of farmed land acreage. As might be expected due to its cost, it is concentrated in high value crops. The fact that irrigation represents represents a little less than 50% of the total

US farm value is misleading, for the statistic is derived from the dollar value, not food or caloric value.

Percentage of United States Cropland Acreage Under Irrigation, 2002*

Rice	100
Orchard	82
Potato	82
Vegetables	69
Dry Beans	34
Alfalfa	30
All Hay and Silage**	16
Sorghum	10
Corn for grain	16.6
Soybeans	7
Wheat	6
Oats	5

*Computed values from USDA 2002 Census of Agriculture, Farm and Ranch Irrigation Survey

**Includes alfalfa, chop, silage, tame and wild hay.

Excluding rice, in itself a small US crop, grains are largely not irrigated in the US. Our farm grain productivity relies on rainfall, in spite of the extensive irrigation infrastructure. This is not likely to change with present water conditions. Although the thrust of irrigation technology and research is for increased efficiency, I doubt it can compensate for regional droughts. In addition, there are louder and louder voices clamoring for a piece of irrigation water, the largest recipient of water in the US and worldwide. Irrigation practices also have many other drawbacks, including climate change concerns heightened from rice production and the salinization of cropland. Irrigation appears woefully inadequate to address the agricultural concerns of climate change.