Global Warming and Land Use: The Adaptation Challenge[1]

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Introduction

Global warming, and the regional changes in climate it entails, will affect land use and land use planning in a variety of ways: First, policies meant to reduce global warming, aimed especially at reduced use of carbon-based energy and at keeping carbon out of the atmosphere, will alter many of the incentives and disincentives for particular urban growth forms and land use patterns. Second, climate change itself—that which is not prevented over the next century by energy policy changes---will directly and indirectly impinge on regional development and land use, and test the vulnerability, robustness, and adaptiveness of land use practices and patterns. Moreover, there is growing concern among climate scientists that human-induced greenhouse warming will result in abrupt and dangerous changes in, for example, storm intensity and heat wave frequency, risks that should be addressed in long-range community plans. These factors will interact in complex ways. Warming may make carbon sequestration in forest and soil less effective. Climate change may make species and habitat conservation plans less effective. Local efforts to mitigate GHG emissions might change the nature of local land use patterns. And concerns about growing hazards, like floods and droughts, will interact with both mitigation and adaptation.

This presentation addresses the impacts and adaptation side of global warming, with a focus on the American West.

The Practical Implications of an Uncertain Climate Future

The prospect of significant climate change undermines the basic notion of a "stable" base for many planning and regulatory regimes, particularly for water, habitat, and other climate-sensitive factors. Not only does climate change undercut planning principles, but it raises the specter of challenges to plans and regulations not "up-dated" with the latest climate norms. Imagine these scenarios:

- A series of floods makes residents, local officials, insurance companies and FEMA doubt the current accuracy of the designated 100-year floodplain. A reanalysis under the current climate, plus projected increases in intense precipitation events over the next 100 years due to global warming, indicates the floodplain is larger than first mapped (in the 1970s). New maps are issued and land use planners must expand floodplain ordinances to new, already developed areas (or the floodplain is reduced, and the city has to decide how to handle the additional, developable land).
- Increasing water temperatures in a local river reduces the population of an aquatic species and wrecks an HCP and recovery plan that the city, county, state and federal government have all approved. Given the virtual certainty that warming will continue, private landowners claim that they should be released from development restrictions.

[1] Prepared for the 17th Annual Rocky Mountain Land Use Conference, Rocky Mountain Land Use Institute, University of Denver Sturm College of Law.

- An ordinance requiring developers to certify the long-term water supply before a permit is issued, but now planners must decide whether (and how) climate change projections should be incorporated in the requirement.
- The city has adopted a plan to reduce its carbon footprint, and a mandate comes down to the planning staff, and the open space and parks department, to develop plans and ordinances that: (a) indirectly reduce GHG emissions via reduced driving, heating and cooling demand, and outdoor lighting; and (b) Allow the city to account for, and to increase, the carbon permanently stored in local ecosystems. But planners cannot be sure how local ecosystems will respond to climate change over the next few decades; an increase in wildfires might quickly release stored carbon, thus invalidating the city's carbon credits.

What's a planner to do? Might we actually need to implement the notion of adaptive planning we learned in college: Plan, monitor, re-plan---on a shorter cycle? Can we compel elected officials and permittees actually to accept requirements that include hedging for climate uncertainty? Why should anyone incur costs today to raise levees, buy additional water rights or more habitat, or build differently, due to expected climate change?

Climate Change and Land Use

Climate change itself (that which cannot be mitigated) will have direct and indirect effects on land use (Table 1). Although typically couched in terms of average conditions (mean annual or monthly temperature and precipitation), it is more useful to think of global warming as altering the frequency and intensity of climatic "events" to which we all respond: It will alter the frequency and intensity of wildfire, and thus directly affect forestry and land development. It will affect flooding and alter the designation of floodplains, which in turn affects land development. It will change the frequency, duration, and intensity of droughts, and thus alter the calculus of land uses affected by water supply, especially irrigated agriculture and urban landscaping. Coastal land use is especially at risk in terms of storm surge and sea level rise. In this case in particular land use trends (increasing development along the coasts) and climate trends appear to be heading for a nasty collision. Global warming has also been linked to changes in agricultural output, pest outbreaks, and spread of certain diseases.[2]

Table 1: Land use elements that may be sensitive to climate change.

Affected Element	Planning Response Element
Water supply adequacy, drought planning, public response to shortages and restrictions, municipal water use for parks, landscaping, etc.	Long range plans for greater, firmer supply; long-term agreements with farmers; conservation; and land use regulations that reduce water use.
Energy supply adequacy (especially to accommodate increased air conditioning)	Municipal energy supply planning; hydro-power;
Flood, storm water, and urban drainage	Floodplain mapping and regulation; conveyance and retention basin planning; floodplain land use regulation
Heat wave impacts	Emergency response planning; human services;

[2] See the U.S. National Assessment for a widely ranging impact study, including studies for several Western sub-regions like the Great Plains, Rockies, and Great Basin: http://www.usgcrp.gov/usgcrp/Library/nationalassessment/foundation.htm.

Air pollution	Transportation planning
Ecosystem, habitat, and wildlife	Open space, land conservation, wetlands, and species planning
Urban forestry, and long-term viability of selected tree species.	Greenspace planning; parks planning and management;
Pests and disease (e.g., West Nile and Hantatvirus)	Mosquito control, other pest management, forestry,

Temperature Impacts

Warming, probably throughout the year (though in some areas more in winter than summer and others more in summer than winter) appears inevitable over the next century (and has already been occurring in much of the West).

What could this mean for settlement and land use? Almost by definition a warmer climate is one with more heat waves, and the probability of a heat wave of certain magnitude can increase dramatically even for small increases in mean temperature depending on the shape of the distribution of seasonal temperatures (heat waves are the tails of temperature "bell curve" or statistical distribution). It is difficult to say how more intense heat waves might affect human populations in the West: the research on heat wave mortality clearly shows that temperate cities experience more impacts than places that are hotter average,[3] so while it may seem obvious that Phoenix and Las Vegas will suffer, such cities may be better adapted than, say, Portland. Indeed, the largest impacts on, say, infrastructure, energy demand, use of cooled public buildings, and emergency and medical services will likely occur in Western cities with moderate average summer temperatures, places where many homes are still built without air conditioning (e.g., Colorado Springs with average summer temp of 68 degrees, compared to Phoenix's 90 degree average).

Warming (along with any drying that might occur, see below) threatens certain agricultural land uses in the West, though it may also create opportunities of agricultural expansion in some areas (e.g., those limited by length of growing season). The projected lengthening of the growing season may not matter in desert locales but would be quite noticeable in mountain and northern places. It is worth noting that two of the most costly climate impacts on Western agriculture in the past few decades have been billion-dollar cold waves in California. The West (more than the rest of the US) also hosts a significant range-based livestock system that is ineluctably sensitive to climate variability and, presumably, any climate shifts. Overall, agricultural land use *per se* would appear to be sensitive to climate, and there is some evidence in the regional impacts literature that cropping, especially irrigated cropping, will decline, and that the productivity of range will decline. So that the land devoted to agriculture will shrink. But what would that mean for the land market, urban form, and metropolitan land use planning?

Precipitation Impacts

Precipitation trends are less certain than temperature trends. Scenarios vary depending on the model one chooses and the time period examined. But precipitation and temperature interact to create regional hydrology, and analysts can say with some certainty that even with stable precipitation, the West's hydrology tends to yield reduced runoff at relatively small temperature

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[3] See the climate and health chapter in the National Assessment: http://www.usgcrp.gov/usgcrp/Library/nationalassessment/foundation.htm; the Northeast Regional Assessment at the same website; and Laurence Kalkstein, various pubs, at: http://www.udel.edu/SynClim/lg-vita.html

increases (because ET is such a big share of our water balance). And, because warmer temperatures, especially in the southern Rockies and the Sierra and Cascade, can alter the ratio of rain to snow, the snowpack is likely to decrease even if runoff stays the same or goes up (meaning less water stored in snow at any given time). The timing and rate of runoff will change; indeed, runoff could more often occur simultaneously with the precipitation (because it falls as rain instead of snow) in some locales, while where there is snowpack it will accumulate more slowly in the fall and melt faster in the spring, yielding a peak runoff that retrogrades in the calendar.

In some cases this may yield more flooding (this has shown up in several studies of California runoff), especially if another expectation---more intense individual precipitation events—also emerges in the warming world. The California studies definitely suggest more flooding in the winter (a serious problem already). Yet climate warming in the interior West almost certainly means overall diminished, or at least less reliable, runoff and, thus, less reliable water supplies. I am on record doubting that water shortages will be a brake on western growth in the foreseeable future, though I am something of a lone voice in this view.[4] My argument is that decades of subsidized water development for agriculture has created a situation in which there's a lot of water in relatively inefficient use in the West, water that shifts to municipal uses relatively easily as the market demands. Global warming will intensify that trend, and may already have quickened the pace of transfers if recent dry spells reflect a warming signal and, of course, as water planners (who use admirably long planning horizons) take climate change into account.

But even if total supply in the Interior West does not put the brakes on urban growth, the water resources future of the region is made precarious by climate warming, reduced snow packs, increased evaporation, and the threat of overall reduced runoff. Even as they purchase agricultural water, municipal systems are likely to find themselves declaring shortages more often (M&I water users require greater reliability of supply than do many agricultural users, so a larger amount is needed to meet firm yield criteria). The great challenge for urban supply managers in a changing climate will be staying ahead of the curve and maintaining the delicate balance between acquiring supply and building infrastructure and the likelihood of declaring shortages and use restrictions. This is difficult enough in a supposedly stable climate. Land use planners will be asked to play significant roles in the realm of demand and supply forecasting, zoning, concurrency, and permitting. Even those innovative jurisdictions that have begun to require water supply adequacy for plan approval, will find themselves deciding when to start requiring permittees to including climate change in their certifications of water adequacy.

Most climate models project more intense precipitation events (even if average precipitation changes little or declines; see Table 1)—so that rain comes in shorter, more intense episodes. This scenario complicates urban flood control and drainage planning, especially in desert cities like Las Vegas where monsoonal thunderstorms already cause significant problems (especially in alluvial fan settings). In response, planners will need to re-assess the deployment and management of floodways, storage basins, and natural streams and wetlands, as well as up-date risk assessments and emergency response plans.

Other Effects

Besides those already mentioned, changes in temperature and precipitation will have other knock-on effects. Moreover, the climate of a region includes other factors that could affect

[4] *Atlas of the New West*, pp. 83-93, especially the map on page. 83; *New Geographies*, chapter 2, and "Water to Grow On" *Rocky Mountain News*, 2002; see: http://spot.colorado.edu/~wtravis/

land use, like cloudiness, circulation, and winds, which can affect, for example, air pollution and alternative energy systems. Indeed, if

Wildfires: A More Flammable (or is it inflammable?) West

One theme not well explored in climate impacts research is the potential for very extreme outcomes, either from climate flips (like melting of the Greenland ice cap) or from the interaction of multiple factors in the earth system. It is simply not clear how we should assess the potential effects of a major climate flip, and unclear what the impacts would be in the American West (so far scientists have focused on sea level and hurricanes in this regard).

Still, some regional processes are naturally step-functional and "catastrophic" in the sense that conditions building up over time pass some threshold in which a concentrated (short duration, high intensity) episode ensures and alters the fundamental state of the system. This is true for wildfires, in which long-term (century-scale) forest dynamics can combine with meso-term (inter-annual) climate dynamics (drought), and, finally, short-term (weekly and daily) weather dynamics (hot, windy weather), to create large, intense wildfires that consume mature forests in just a few days and leave a landscape legacy that lasts for decades. Each condition is necessary but not sufficient to create large wildfires. A few days of hot, dry, windy weather in the middle of an otherwise relatively wet summer, will not yield regional-scale, crowning wildfires. Longer periods of dry, windy weather will not necessarily yield catastrophic fires if the forests are not mature and ready to burn.

Add climate change on top of this and it makes sense that regional warming will increase the potential, at least for some window of time, for an intensified wildfire regime, and we may already be witnessing the start of this pattern.[5] Wildfires, especially large, stand-replacing fires, are inherently discreet, step-functional events that are driven by accumulating pressures. Forest fires might, under pressure of warming and drying summers (plus less extensive snowpack), and over a multi-decadal period (say, for kicks, 2030-2040), become pandemic in the American West, raging like a plague until so much of the region's forest cover has been consumed in stand-replacing fires that fire frequency and intensity must, perforce, decline sharply for at least several subsequent decades. The climate and forest ecology conditions setting up this catastrophe are nothing but non-linear, and episodes like this are actually found in the tree-ring record.[6]

The implications for land use planning and development are obvious. First, of course, this means that the inevitable head-on collision between fires and spreading exurban development will come sooner and more painfully. My sense is that most of the so-called wildland-urban interface is under county rather than municipal jurisdiction, so county master plans, which traditionally lack classical zoning, will be affected most. But Oakland Hills, Los Alamos, and fires burning on the suburban edge of Reno last summer (2007), bring fire into the realm of suburban land use planning. Increased fire risk will also affect the resorts and many small towns around the West.

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[5] A. L. Westerling, H. G. Hidalgo, D. R. Cayan, T. W. Swetnam (2006) "Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity." *Science* 313 (18 August): 940 – 943.

[6] W.H. Romme, et al. *Recent Forest Insect Outbreaks and Fire Risk in Colorado Forests: A Brief Synthesis of Relevant Research*. Colorado Forest Restoration Institute, Colorado State University. 2006.

One land use planning implication of wildfire showed up in Lake Tahoe during the 2007 fires: some residents blamed Tahoe Regional Planning Agency land use and forestry restrictions for the fires.[7]

Shifting Ecologies

I see one of the largest potential effects of global warming on Western land use in land and habitat conservation. Conservation is both a goal and use of land, and climate change could undermine achieving the goal, even with a well-demarcated set of uses.

Quite large geographical shifts of habitats appear to be an inevitable outcome of any significant climate change, though the links between climate and habitat are complex, and the outcomes hard to predict (say perhaps more difficult than water impacts). The simplest projections force habitats to shift along with their "limiting factors" (temperature, precip, growing seasons, etc.) though this glosses over two key complexities: First, that habitats or ecosystems are not "wholes" but complexes of species each of which might respond in a different manner, thus disaggregating what today looks like an integrated natural community. Second, even in the simple model the shifts would take time and must overcome various frictions and obstacles (will the target niche be available?). In short, the flora and fauna of, say, northern Florida (where I was raised) may not surround Washington, DC in 2100 just because DC's climate becomes that of today's Daytona. Finally, some ecologists argue that ecosystems will become chaotic under climate change pressures, almost certainly *degrading in place* rather than simply changing "seats in a cakewalk."

Germane to our concerns in this same series of studies, Galbraith et al.[8] conducted an innovative analysis of a critical habitat (coastal sage, the subject of conservation goals) as it is simultaneously affected by climate change and urbanization. It works out that coastal sage gets hit by most of the scenarios and by urbanization such that there remain very few *refugia* by the time of greenhouse doubling and a state population of 94 million. This innovative study is the only one I've seen that explicitly links land use change (urbanization; at a very coarse scale in this case) and climate change, and more work along these lines seems in order.

The implications for land conservation are obvious: climate change can undermine land conservation goals, especially those arrayed around a particular habitat or species (which may simply vanish from the land thus conserved over the next several decades), especially if the land lies near natural ecotones likely to shift with climate change.[9]

Planning to Adapt

Planners, especially in jurisdictions preparing climate action plans, should conduct a rapid assessment of climate vulnerabilities, and potential adaptations, both short- and long-term. If the U.S. mitigation policy regime emulates the international framework (The UN Framework Convention on Climate Change—UNFCCC, and its Kyoto Protocol), then it becomes likely that some resources will be made available for assessing vulnerabilities and adaptations. In the

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[7] Aaron C. Davis and Amanda Fehd (2007) "Blaze weakens; need to blame intensifies." Associated Press (*Daily Camera*, June 29, p. 4B).

[8] Hector Galbraith, Joel B. Smith and Russell Jones: "Climate Change and Urbanization in California: Potential Effects on the Extent and Distribution of Major Vegetation Community Types", accessed at: http://www.energy.ca.gov/pier/final_project_reports/500-03-058cf.html, with a final version available in: Joel B. Smith and Robert Mendelshon (eds.) *The Impact of Climate Change on Regional Systems: A Comprehensive Analysis of California*. (Elgar, 2007).

[9] Root T., Liverman D. and Newman C. 2006. Managing Biodiversity in the Light of Climate Change: Current Biological Effects and Future Impacts. Key Topics in Conservation Biology. D. Macdonald and K. Service. Eds. Oxford, Blackwells: Chapter 6.

UNFCCC some of the moneys gathered under carbon trading are assigned to an Adaptation Fund aimed at helping poorer countries prepare for climate change. It makes sense for planners involved in local CAP's to insert similar provisions, say if the city enacts a carbon tax. Urban planners should also:

- Obtain and secure long-term local records climate and hydrology records, being especially careful to archive data that the state and feds may neglect.

- Identify sources of scientific advice on climate change, hydrology, ecology, etc.

- Examine current plans and ordinances for climate-sensitivities in three categories:

  (a) Plans with climate sensitivities but for which a wait and see approach makes sense;
  (b) Plans that are undermined by the mere existence of growing climate uncertainty, and need to be reformed to deal with uncertainty;
  (c) Plans that can be altered in light of what we know now.

- Explore plans for sensitivities to surprises and worst-case scenarios.

Planners also need to think about potential surprises in the development of the West. Changing fire regimes might occasion such a surprise, or perhaps a set of regional environmental changes could actually retard urban growth. Wildfires, floods, and coastal storms worsened by sea level rise (to include the Pacific Coast in this look at the West) might also evoke an investment downturn. Or, perhaps an insurance crisis. Economist and insurance theorist Howard Kunreuther's research group at the Wharton School has shown that people persistently under-insure (among other reasons, they reckon insurance as an investment rather than as a hedging of risk, and every premium that does not "pay off" is seen as wasted.). Any significant earthquake along the US Pacific Rim or even on the Wasatch Front will already probably cause an insurance liquidity crisis, and a period of widespread wildfires would at least further stress the property casualty system.

It only makes sense that planners become a bigger part of the effort to mitigate and adapt to climate change. Land use planning is ready to contribute to mitigation, but what aspects of land use planning and development play into how society adapts with actual climate change?