Potential Climate Impacts on Land Use

By **Paul Marx**

Introduction

The Intergovernmental Panel on Climate Change (IPCC) has released its third assessment report on potential regional impacts of climate change in the U.S.[1] This report indicates that the effects of changes in regional weather will not be uniform from place to place. Some regions will receive more moisture than historic averages, others less. Temperatures are projected to shift significantly, resulting in permanent alteration of ecosystems. Will these changes be sudden or gradual, benign or harmful, mild or catastrophic? There is no single or simple answer to these questions. However, we do surmise that the projected changes in the global climate, which in turn will mean changes in national and regional weather patterns, may have substantial effects on our transportation system. How might these effects demonstrate themselves? The effects on transportation depend to a great extent on how we use the land for various purposes.

This paper will look at broad ranges of effects that might result from climatic change with regard to three types of land use activity – agriculture, industry and commerce, and residence. Then, it will describe a range of transportation scenarios that might result from changes in land use that are prompted by a significant climate change. For every scenario and reaction to a scenario described in this paper, there are likely to be many alternatives that could lead to large or small changes in individual or societal behavior. The intent behind this paper is not to forecast or predict specific economic or sociological behavior. Rather, the intention is to present possible alternatives in a way that spurs discussion. Because weather by itself is extremely unlikely to instigate changes in human behavior, we must examine factors that derive from variations in climate and extrapolate these effects on daily behavior. For example, does a gradual evolution from dry plains to desert imply concentration or dispersion of residences? The answer may depend upon whether the vision of a Buckminster Fuller (Geodesic domes) or a Texas rancher leads the particular community. At root, the adaptation to any climatic shift depends upon the sum of individual economic decisions by all of the members of the affected community.

Significant climate changes, in this context, are not the most extreme events that are commonly thought of as emblematic of global climate change - such as dramatic sea-level changes or expansions of deserts. Rather, this paper will focus on fairly subtle changes in regional climates - changes that can easily result from periodic anomalies in weather patterns regardless of their fundamental cause, but that may also be recognized as symptomatic of major changes in underlying weather patterns in coming years. Again, the intention is not to address the best case or worst case – circumstances where opinions are easily formed and defended – but to stay within the range where the future remains the most intractable, or "foggy." The best debates must occur when any participant can reasonably discuss both "pro" and "con" in a single conversation.

Agriculture

The United States faces two broadly-based changes in its weather that would affect agriculture. One is quantity and timing of rainfall (Figure 1). The other is temperature. (Rising CO_2 concentration itself will also affect agriculture, and not necessarily in the same way as related climate effects.)[2] Not only do both factors affect agriculture, but the IPCC report indicates that they will not change uniformly, or in tandem. Some regions of the U.S. will experience greater temperature change than others, and some will experience greater variability in rainfall and snow levels. These factors in turn affect a great range of variables that influence agricultural productivity, including seed germination rates, presence or absence of beneficial and harmful insects, effectiveness of soil treatments (lime, pesticides, fungicides, etc.) and more; together these influences will affect productivity and the type of agriculture that is extant in particular regions. What might be the transportation impacts of a gradual but significant shift in rainfall and temperature over a multi-state part of the country?

One fairly benign scenario has been described (given its more extreme outcome, a desert type scenario is addressed later), in which the Northern Midwest of the U.S. experiences a modest increase in temperature, along with a rise in annual rainfall. Assuming that this is not accompanied by severe weather anomalies (which often damage crops), one might expect a gradual shift in the form of agriculture. More days of sunshine, warmer temperatures, and earlier growing seasons in the states of Missouri, Illinois, Iowa and Kansas might change their agriculture from machine-based (wheat, corn, soybeans) to more labor-intensive crops such as leafy greens, tomatoes, legumes, and fruits.[3] That is, assuming that the change in rainfall does not result in higher erosion levels and a net decrease in agricultural productivity.

Taking this scenario further, changing agriculture to more labor-intensive crops would have far-reaching effects on the region. Rather than a few, highly-paid farm hands driving combines to harvest thousands of acres at a time, many more farm hands would be required to plant, care for, and then harvest the crops. It would require a significant increase in local populations, either on a migratory or permanent basis. Field sizes would be smaller, and crops more diverse, to minimize pest and fungus migration. Field workers would need vehicles to move between their homes and growing areas. The surrounding communities would have to grow to accommodate additional residents, probably in some combination of permanent and transient housing. All of these changes would require additional road and automotive infrastructure. Unless extraordinary measures were taken, the added travel demand would most likely be met through the use of personal automobiles. Would the agricultural shift result in a net increase in automotive and farm-based internal combustion engine use, or would it produce a population shift from one region to the other?

This is not the only effect, however. More damageable crops must be packaged by hand, (rather than being aggregated by conveyor, for example) and are usually shipped in refrigerated containers. What would be the effect on railroads of no longer carrying significant quantities of grain? Could railroads substitute vegetables for unit trains of grain?[4] Would trucking have to increase to service the new agricultural areas? How would that affect carbon emissions, or the distribution of automotive emissions on a regional scale? How would agricultural prices be affected by changes in shipping cost? Who would bear the burden of such costs? How would the relative competitive positions of the U.S. and Canada change with regard to agriculture? How would NAFTA adjust to a large shift in agricultural outputs among its partners? At what point would climate effects be addressed in bilateral or multi-lateral trade talks?

Commerce/Industry

Approximately 70 percent of the U.S. electrical capacity is provided from coal. Another 20 percent or so is provided by nuclear power. The rest is provided by a combination of hydro, wind, solar, biomass, and other sources. However, some areas are particularly dependent on hydropower – particularly in the Northwest and Northeast. In some instances, this has led large users of electricity, such as aluminum manufacturers, to locate near such power sources. Two scenarios analyzed in the IPCC Synthesis Report indicate opposite outcomes for the Pacific Northwest. In one scenario, annual runoff declines by 50 to 150 mm. In the other, annual water runoff increases by more than 150 mm. Either case causes potentially severe disruption.

In the reduced runoff scenario, the cost of hydropower rises, particularly during times of water shortage. As the shortages become more frequent and persistent, the plant must purchase more power than it provides to the grid. Businesses no longer have access to lower-cost electric power. If this lasts more than a year or two, these businesses will have an economic incentive to move to where power is less expensive. This could be to the U.S. Eastern states, or to Canada.

In the increased runoff scenario, there is not much improvement. While there is more water, temperatures are also higher, so less of the water falls as snow – to be melted gradually in the spring. Rather, there are heavier rains causing greater levels of erosion and increasing maintenance and operating costs of hydropower basins. The incidences of excessive rainfall may be followed by extended periods of inadequate rainfall, and higher temperatures, leading to increased evaporation rates and increases in electricity used for air conditioning. This would raise both the cost of producing electric power and the price due to higher demand. What would be the effects of such changes on the transportation system?

One would expect the higher electric power cost to raise the cost of some manufactured products, but would the cost increase be sufficient to alter demand for the final product? We would have to analyze widely differing industries, from canned beverages (soft drinks and beer) to automobile parts. What about the cost of electric power from other sources? Could the higher cost or reduced availability of hydroelectric power provide an opportunity for another fuel type? This would require analysis of the competitive advantages of other fuels such as coal, oil, and natural gas. Unfortunately, in the short term, since coal already provides 70 percent of electric power generation, it would be likely to provide a similar proportion of any increase in demand for electricity, thus contributing to additional quantities of CO_2 emissions.

The effects of the preceding scenarios on the transportation system are difficult to project. They depend on the price sensitivity of consumers with regard to specific goods, as well as the net effects of the manufacturers' cost increase. If the cost can be passed on to consumers, the businesses may remain in place. If the power cost can be mitigated through competitive products produced elsewhere, then businesses that depend on the higher-cost electricity may need to move in order to protect their market shares. This would cause medium-term disruption in the local economies as they adjusted to a new business model.

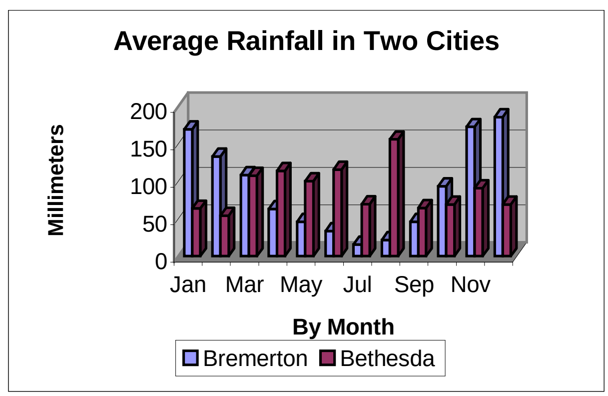

Figure 1. *This chart shows average monthly rainfall in two areas on opposite coasts of the U.S. with nearly identical annual rainfall. Yet, their monthly rainfall patterns are significantly different. Bremerton receives very little rainfall in summer, while Bethesda's is spread more evenly throughout the year. Source: NCDC Cooperative Stations, 1919 – 1995.*

Residence

This is the most difficult area of human activity to assess in terms of climate change. Our society is in flux, gradually urbanizing as more of our agriculture becomes either machine-oriented or dependent on migrant labor. Even where our population is gravitating to cities in search of employment, this often means "suburbanization" rather than urbanization. That is, new urban immigrants will often reside where housing prices are lower – in the suburbs – rather than in towns where the cost of housing is significantly higher. At what point is it more expensive to live outside of town than in town? At the same time, our society is aging. "Empty nesters" who have raised their children and are now approaching retirement age have sufficient wealth and income to afford an urban lifestyle. Thus, many American towns are seeing a resurgence in their downtown cores. Houston, long known as a center of auto-oriented culture, is building a light rail system through its downtown, to accommodate the highest rate of resident in-migration in the U.S. for the last two years.

So what does climate change mean to residential land uses? Taking the two basic scenarios of excessive rainfall and insufficient rainfall as points of departure, the effects depend on location. In Central and North Texas, temperatures are likely to rise and rainfall decline. This may result in the elimination of forest habitat and evolution of a desert habitat. The transportation effects of such a change could be significant, and may be disruptive unless the infrastructure is modified to accommodate the necessary uses. With a significant decline in rainfall would come reduced water levels in the aquifers needed to support continued habitation. The two alternatives cited previously would come into play. Residences might coalesce around a center, at the extreme reaching a futuristic Geodesic Dome form to minimize per capita consumption of water and other essentials for life. Or, residences might spread out, following the traditional pattern that has evolved since the initial European settlement of the Southwest.

In the near to medium term it is hard to imagine entire communities of Geodesic Domes springing up in the desert. Thus, this scenario would most likely result in low-density communities, heavily dependent upon individual automobiles for transportation. Local shops and businesses would depend upon trucking more than trains for their freight needs. Vehicle miles

***Figure 2**. Photo of the Colorado River in Mexico. The extensive use of its waters for agriculture and urban water supplies throughout the Southwest reduce it to a trickling stream by the time it reaches the sea. Photo source: Los Alamos National Laboratory.*

of travel would increase on a per capita basis. At what point would a sustainable, ecological equilibrium be reached?

Let us take a more problematic scenario. Rainfall and snowfall feeding the Colorado River are projected to decline in an erratic pattern. The river already provides a limited but vital resource to California and northern Mexico. Some argue that the Colorado River is not adequately priced even now to reflect its essentiality to the Southern California economy, and that Mexico is being short-changed as a result. What happens if the flow is reduced, or severely disrupted, by weather anomalies? The cost of living rises, States are forced to renegotiate long-standing agreements, and farm products that depend upon irrigation rise in cost.[5] Not only do costs rise for California, but for the rest of the nation as well. For how long are people willing to pay the higher price to live in Los Angeles or Orange County? Part of these cost increases will come from higher repair costs for the infrastructure, as roads, railroads and bridges are damaged by more frequent (and more severe) floods.

One potential effect would be to depress real estate prices as the cost of living increased. Rates of in-migration would fall, lowering demand for housing, and rates of out-migration might increase, as people sought new situations with a better mix of wages and cost of living. If this process continued long enough, businesses would follow the workforce to areas with greater stability of resources, particularly water, such as the Pacific Northwest and Western Canada.

If the water supply disruption in the Pacific Southwest continued long enough, the region would be forced to adjust to a new environment. Water rationing would be common. New investments would be reviewed on the basis of their probable demand for water. If conditions became severe enough, entire communities would be re-designed in a more compact form. More space and resource-efficient designs for residences and businesses would proliferate, and the levels of resource use per person might decline. In such a scenario, personal trips by automobile would be viewed as excessively resource-intensive. Living near where one worked, or near public transportation, would confer significant economic benefits.[6]

These changes in personal behavior would be encouraged by the municipality, within a sustainability strategy. Such a strategy might include the design of special transportation infrastructure, engineered to withstand both excesses of heat and flash flooding, which might occur with increasing frequency.

An Excessive Rainfall Scenario

The Pacific Northwest has been mentioned as a possible haven from the disruptions in water supply that may affect the Southwest. Already, places such as Portland, Oregon and Seattle, Washington have seen dramatic increases in

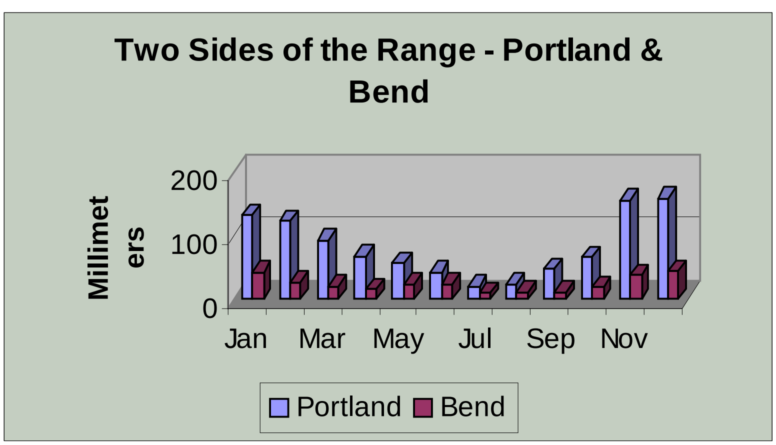

Figure 3. *Average monthly rainfall in Portland and Bend, Oregon. Bend, on the east side of the Cascades, is significantly dryer than Portland, so that even a 50 mm change in rainfall is an extreme change for Bend, while Portland might absorb it with only moderate disruption. Source: NCDC Cooperative Stations – 1919 to 1995.*

in housing cost from the increased demand. This has occurred through an entire cycle of boom and bust in the raw materials processing and transportation sectors. But even this region of the United States is not immune from climate variation.

A likely weather scenario that may result from global climate change is a modest increase in temperature and concurrent increase in rainfall in the Pacific Northwest. How could this be bad? The region is already famous for its persistent rainfall, particularly along the coast. However, the rainfall is fairly light. Many communities depend upon fresh water runoff for municipal water supplies. Aquifer recharge occurs through a combination of spring runoff of winter snows and very gradual seepage from rainfall. Even a modest increase in average temperature could shorten the accumulation time of winter snows, or disrupt the pattern or frequency of snowfall. The same circumstances that are cited above with regard to the water-dependent industries of the Pacific Northwest would also affect residential land uses.

The gentle rainfall of the Northwest has ample time to filter through the ground. Current temperatures allow significant snowfall to remain high in the mountains, to melt gradually as spring approaches. One-time disruptions in these patterns have proven highly disruptive on both sides of the mountains. On the densely populated coastal region, streams have flooded and fish spawning areas have been disrupted. Water quality has been reduced by flooding, which introduces pollutants from the soil surface, requiring more complex (expensive) filtration and treatment. On the agricultural side of the mountains, a boom and bust cycle is initiated, where disruptive floods are followed by periods of inadequate moisture, and thus lower crop yields (Figure 2).

Communities in the Pacific Northwest are beginning to adapt their infrastructure to these circumstances, however, and this may point the way toward a more broadly-based approach to infrastructure nationwide. Through "Green Building Standards" the town of Portland rewards businesses for innovative design and construction of their facilities. For example, tax credits are offered for businesses that grow grass on their roofs, or that design parking facilities with water-filtering swales rather than hard concrete channels. How do these modifications in infrastructure design make any difference?

The surface of the Northwest coast is not very permeable - it requires gentle and persistent rain to function as a water collector. Most transportation infrastructure is even less permeable. Thus, any pollutant that can be transported by air will eventually fall to the ground or on a building or parking lot and be carried to storm drains. From there these pollutants make their way into the municipal water supply, where they have to be filtered and processed before the water can be used. But, if the buildings have permeable earth roofs, with grass or other vegetation growing on them, then pollutants are filtered out from rainfall before it reaches the ground, mitigating the pollutants' effects on the water supply. Such a technology could be applied to transportation infrastructure generally.

The Dutch government, recognizing that one of Holland's primary agricultural activities, greenhouses, presents an even less permeable surface than roads, has mandated that greenhouses be surrounded by filtration canals. This prevents any airborne pollutants from reaching nearby streams or rivers. In Germany, bicycle and pedestrian trails are being built from interlocking, permeable construction blocks. These are angled away from storm drain systems, to ensure that rainfall is filtered and channeled toward parkland and other surfaces that help to recharge aquifers. In the U.S., roadway materials have been developed for safety reasons, to wick away rainwater and assure cars and trucks of continued traction even in heavy rainfall. Now these materials are also being used for environmental reasons, to prevent the intrusion of particulates and other airborne pollutants from invading streams and rivers. How would a national plan be developed to identify the locations where this technology is most necessary today? Would initiating such adaptive mechanisms actually allow a community to mitigate the negative effects of climate change sufficiently to remain viable over time?

Conclusion

This paper was written to provide a broad overview of potential effects of climate variation on basic human activities, remaining silent on the possibility that those very activities may be contributing to the self-same climate variations through greenhouse gas emissions. The scenarios presented should be viewed as notional, rather than predictive. The reader is encouraged to view the potential adaptations presented as a limited subset of options, developed to force a transportation infrastructure impact if possible. However, while transportation is involved in most human activities, it is not the only issue in most instances. The intent behind this paper was to address that subset of possible impacts that would relate to transportation and its infrastructure, in an effort to identify whether, and how, the infrastructure might have to be modified.

All of the modifications to infrastructure mentioned in this paper have a cost. However, that cost has to be balanced against the benefit provided by the modification. In the case of changing land uses, the benefit may be significant. The modifications being made to buildings in downtown Portland may help to mitigate long-term effects of a changing climate *at the same time as they help to mitigate pollution that results from human activities*. By having a robust infrastructure, able to help recharge the local aquifer and preserve the purity of runoff water supplies, Portland preserves its ability to cope with excessive rainfall and to mitigate some negative effects on its local ecology. By reducing the human infrastructure impact on otherwise disruptive weather effects, Portland is actually helping to mitigate some of the most severe effects of modified rainfall or snowfall patterns that may be caused by global climate changes.

The question is whether such measures are sufficient as an adaptation strategy. Individual techniques will not work everywhere, but their root philosophy - working with the local environment - may help to formulate similar strategies for a wide variety of environments, from Arctic to Desert. In the end, it may be that the solutions developed to mitigate the effects of severe weather events on our Nation's transportation infrastructure are also those that reduce the climate effects of our patterns of land use and life activities. Solutions developed to adapt to climate change may help us to mitigate our effects on our climate. The final question is, "will it be enough, soon enough?"

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[1] "Climate Change 2001: Synthesis Report" Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2001

[2] Higher CO_2 concentrations are linked to global climate effects, but the relative effect on specific crops depends on other supporting circumstances. While higher CO_2 levels may result in higher-yielding crops, ceteris paribus, concurrent high heat and low moisture rates may interfere with germination or fruiting in unpredictable ways, thus supporting rapid growth, for example, with little or no fruit.

[3] Actually, the soil there is probably much too heavy to allow such a transition. The scenario is proposed in order to arrive at a structural shift in type of agriculture, to see its potential effect on transportation.

[4] In fact, recent advertisements by the Freight Railroad Association indicate that trucking is the railroads' fastest growing market segment. Trains are carrying an increasing share of trailers on long distances, for distribution near their points of destination. At what point does this market repositioning require additions of rail track to serve the new markets, and at what cost?

[5] Recent news commentary (MSNBC, Dan McFadden, October 10, 1999) implies that the positions of the States regarding Colorado River agreements are so intractable that the U.S. Government may have to initiate some change in these relationships via negotiations with Mexico.

[6] In the soon to be published TCRP H-21 study "Combating Global Warming Through Sustainable Surface Transportation Policy" the Center for Neighborhood Policy indicates that the more dense urban environment uses far less energy per transportation use than surrounding suburban and rural areas. The lower energy use (and resulting carbon emissions) is directly linked to the presence of public transportation. GIS analysis shows that the higher-efficiency pattern of land use follows commuter rail lines to the suburbs.

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