Climate Change, Agriculture and the West: A Multifaceted Issue

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Introduction

Climate change and associated issues have gained public and scientific prominence in recent years. Policy action is being debated with the past two years revealing US based discussions on cap and trade, policy on renewable fuel standards with greenhouse gas (GHG) emission features, Presidential level agreement to international accords regarding funding of adaptation efforts, the popular spread of the carbon footprint concept, and the release of major US and UN reports among others. Numerous outlets have published materials related to emerging evidence of climate change effects, mitigation of greenhouse gas (GHG) emissions, and adaptation to altered climatic conditions. Virtually every department or research group has a "climate change expert" and there are at least four journals that publish agricultural/resource economic pieces devoted to the subject (*Climatic Change*, *Mitigation and Adaptation Strategies for Global Change*, *Climate Research* and the soon to appear *Climate Change Economics*). The literature available on climate change topics is extensive and exhaustive. So what are the major components of the climate change issue that might stimulate work of an applied economist in the US West? This paper presents a condensed review of the issue, focusing on findings/deductions that are particularly relevant to agriculture in the Western US region. The purpose is to overview where climate change research is today, where it is going, and open questions. It is written from the perspective of an author who published his first climate change piece in the Western Journal of Agricultural Economics in the late 1980's and a group of graduate students just entering the field. It is certainly biased in coverage by the efforts and findings from the research group where they all work. Note, this paper is a companion to a more detailed book chapter[3].

Background

Climate change is already affecting agriculture, forestry, land use, water resources and biodiversity in the Western US and globally. Crops and pests are migrating toward the poles, and livestock grazing land is changing in carrying capacity (IPCC, 2007b; USCCSP, 2008) while water supplies and snowpack are being altered as is the hydrograph. Furthermore, atmospheric greenhouse gas concentrations shall soon attain dangerous levels (Fri et al., 2010). Real global action to manage GHGs seems to be over the horizon if it ever will occur. It is virtually inevitable that climate change will play an even larger role in the coming decades and beyond (Rose and McCarl, 2008) as well as a creating a need for a degree of adaptation. There are also likely to be increasing calls for mitigation efforts plus there is the emergence of state level GHG emissions reduction programs like that in California.

The Western US, being largely semi arid, is at risk to climate change. IPCC (2007a) indicates temperature is expected to increase by 3-4 degrees Fahrenheit by the 2030s and 8-11 degrees by the 2090s. Precipitation is expected to change but at a regionally differential rate. In the Southwest, a decrease is expected with average conditions reaching levels of today's drought of record by the latter part of the 2000's (Seager et al., 2007). Across most parts of the West, there

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[3] Forthcoming book chapter, available at: http://agecon2.tamu.edu/people/faculty/mccarl-bruce/McCarlClimateChange.htm

is an expectation of wetter conditions due to increased evaporation, and increased precipitation in the form of rainfall in the winter. There is also the expectation of earlier runoff of mountain snowpack. Finally, the chance of changes in rainfall intensity, reduced snowpack, more tropical storms, more droughts and increased weather variability loom (IPCC, 2007a). (The precipitation projections are less reliable being substantially more variable across projections than are the temperature ones. For example, the 2001 US National Assessment was based on projections showing a wetter Southwest as opposed to the largely drier ones in the 2007 IPCC. Today the evidence from IPCC depends on the preponderance of the projections.)

A Multi Faceted Issue: Effects, Adaptation and Sequestration

The climate change issue has three major aspects:

- **Effects** of the changed climate;
- **Adaptation** to changed climate; and
- **Mitigation** of GHG emissions on the interest of reducing future climate change.

Each poses unique research challenges and has been the subject of research effort. These will be discussed sequentially.

Effects of climate change

Climate change has its main effects (as covered in IPCC, 2007a) in terms of altered temperature (generally higher), precipitation (generally higher but with sub tropical dryness plus intensity shifts and increased variability), carbon dioxide concentrations, and a mix of potential extreme event effects (possibly stronger El Nino's, more tropical storms, more droughts). Agriculture/forestry and ecosystems are highly vulnerable to changes in such factors due to the following:

- Their level of dependency on the environment.
- Dependency on similarly sensitive resources like water and forage.
- The fundamental relationship between plant photosynthesis and carbon dioxide.
- Vulnerability to pest incidence, forest fire incidence and disease spread plus, in some areas, sea level rise.

In turn, producers of goods may be impacted directly through increased resource scarcity or productivity changes. Markets, international trade, and technological development will all be shaped by climate change with shifts in comparative advantage and market prices. Sea level rise may also affect marketing facilities. This has been a dominant research topic with literature reviews on approaches and findings in Adams et al. (1998), Reilly et al. (2002, 2004), IPCC (2007b), USCCSP (2008) and Antle (2009).

Adaptation to climate change

A substantial degree of climate change appears to be inevitable (Rose and McCarl, 2008; Antle, 2009). Consequently, society will have to adapt activities to accommodate changes in climate. Agricultural producers have a long history of climate adaptation as seen by the variation in land use and cropping patterns across the globe. Western states producers have adapted by growing high value crops where irrigation water is available and climatic conditions are favorable. They then use those best adapted to local climatic conditions (Oranges in the South and Apples in the North). Livestock, however, predominate in arid regions without irrigation water supplies as well as in mountain alpine regions. A changing climate will stimulate adaptations including changes in varieties, breeds, stocking rates and land use patterns (McCarl, 2007; McCarl, Feng, and Wang, 2009; Antle, 2009).

A changing climate will increase the rate of obsolescence for many long-standing practices. Producers will need to adapt more quickly. Adaptation will also require investment in facilities for processing, handling and transporting crops and livestock commodities in volumes not previously produced in the region. Investments will be needed in research on new varieties better suited to the altered climate. Pest management and the movement of invasive species into new habitats will require practice changes, extension education and investment. This will increase the burden on research and extension units, who will play an important role in disseminating new technology and facilitating adaptation (McCarl, 2007). Adaptation will contribute to survivability of producers and agribusinesses but at the cost of diverting resources that could have been used in other ways. The adaptation investment will be accomplished in part by normal capital stock turnover in equipment and facilities; however, the remainder must be provided from other resources.

Mitigation of Net Emissions

Efforts to limit future climate change involve reducing net GHG emissions and will affect future agriculture and forestry. Agriculture and forestry can play a role in mitigation bylimiting rates of tropical deforestation, increasing rates of afforestation, reducing livestock related emissions, altering rice related emissions, increasing bioenergy feedstock production thereby offsetting fossil fuel use, and increasing sequestration in agricultural soils or forests along with pursuing a number of other strategies (McCarl and Schneider, 2001; IPCC, 2007c). These activities will have impacts on land use competition, water competition and market prices.

Price impacts and their consequences are also a factor. While climate change may lead to altered commodity prices, mitigation efforts divert key resources limiting production and raising prices. Higher market prices will likely lead to reductions in exports or expansions in imports. Environmentally, this will create pressure to bring sensitive lands around the globe into production (including rainforests and CRP) along with increasing agricultural pollution externalities and GHG leakage (Murray, McCarl and Lee, 2004; Searchinger et al., 2008; McCarl and Boadu, 2009). Mitigation activities in energy would also generally increase the cost of fossil fuel related inputs, potentially damaging economic growth and increasing costs of agricultural production (McCarl and Schneider, 2001). Though agriculture is shown to possibly benefit on the output side, the expectation is that the consumer losses will outweigh the benefits but that this would be offset by welfare gains from lessened climate change (Baker et al., 2009; Scheider and McCarl, 2005).

Western Agriculture Sensitivities

Climate change will alter the face of agriculture through longer term effects of the changed climate, shorter term mitigation activities and intermediate to longer term adaptations. A number of climate change related factors that will drive change in Western agriculture, forests and ecological characteristics are briefly discussed. These are presented in the following large groupings: (1) farm/forest productivity and prices; (2) agricultural and industrial water supply/ demand; (3) disturbances; (4) mitigation production and competition; (5) adaptation needs; and (6) ecological services.

Farm/Forest Productivity and Prices

Climate and climate change drivers have been shown to influence crops and livestock in diverse ways. The combination of hotter temperatures, possibly drier conditions, and a carbon dioxide richer atmosphere will have regionally heterogeneous effects on crops. Northern regions generally have larger, positive yield changes, whereas southern regions increase less and decline in some cases (Reilly et al, 2002; McCarl, 2006; Antle, 2009). Elsewhere livestock productivity has been affected directly through climate stress as well as indirectly through

impacts on pasture, forage and grain availability and disease (Seo and Mendelsohn, 2008a; 2008b). Direct anticipated climate effects include reduced cold stress by rising temperatures in winter, but this effect will be offset by the negative effects of hotter summers. Reilly et al. (2002) suggests that productivity losses in the southern US could be in the order of 10 percent or more.Forage yield reductions will mean stocking rates will need to be reduced in drier areas. Furthermore there are likely to be changes as shown:

- *Yield Variability*: Largely projected to increase, as examined in McCarl, Villavicencio and Wu (2008).
- *Shifting Product Mixes and Management*: Crop mixes and management practices will shift to account for direct and indirect climate change impacts (e.g. northward migrations in crop mixes, or altered pest management regimes as discussed in Adams et al. (1998, 1999) or Reilly et al. (2002)).
- *Price Effects*: Market prices are likely to shift and stimulate production mix and other adjustments as shown in McCarl (2006).

Agricultural and Industrial Water Supply/Demand

Climate change is likely to alter water quantity, quality and demand in a variety of ways. Water quantity shortages, inappropriate timing of water availability (precipitation), and impaired water quality caused by drought are expected (Adams and Peck, 2008). Some parts of the western region are projected to have precipitation increases while other regions experience substantial reductions, particularly after adjusting for evapo-transpiration (Antle, 2009; Seager et al., 2007), although there is certainly a wide variance in the regional characteristics of the precipitation projections (IPCC, 2007a). For example, precipitation is expected to decrease up to 10% along the southern coast of Alaska and decline up to 25% in the Oklahoma panhandle, north Texas, eastern Colorado and western Kansas (NAST, 2000).

Water quality will be altered by changing precipitation patterns (Thompson, 2005). Water demand by plants would increase with hotter conditions increasing respiration and evapo-transpiration plus there will be increased demands stimulated by CO_2 effects (Adams et al., 1999) in turn increasing irrigation demands (see the data in McCarl, 2006). Water pricing mechanisms will be stressed, and the allocation of water rights will take on even greater importance (Reilly et al., 2002; Lund et al., 2006). A number of other factors merit discussion including the given changes:

- *Water Seasonality and Storage - Snow Pack:* Snow pack levels are expected to form later in winter, accumulate in smaller quantities, and melt earlier in spring. Rising temperatures increase the proportion of winter precipitation received as rain and decrease the proportion arriving in the form of snow (Adams and Peck, 2008). Earlier, melting of snow pack would shift the hydrograph away from midsummer flows toward spring and winter and perhaps increase storage needs (Gleick et al., 2000). Shifts in the timing of crops to accommodate earlier ends of winter will also alter the seasonal pattern of irrigation water demand.
- *Precipitation Intensity:* IPCC (2007a) summarizes data showing increases in precipitation intensity with larger contributions from the wettest days in a month. This signifies a shift in precipitation shares from gentle frontal rains to more intense storms (a pattern more typical in the sub tropics). The result is less suitable for plant growth and will cause greater erosion and changing runoff patterns, plus challenges for Western reservoir systems (USCCSP, 2008). Intensity increases are likely to become more pronounced as climate change proceeds.
- *Drought Incidence:* Observations show increased summer drought stress in the last 30 years (USCCSP, 2008; IPCC, 2007a). This trend can be expected to continue as

temperatures increase, plus there are projections that the future will contain more and longer lasting heat waves (IPCC, 2007a) as well as perhaps more frequent, stronger El Nino related events (Chen, McCarl, and Adams, 2001; Adams and Peck, 2002; 2008).

- *Non-agricultural Water Demand:* Climate change may increase demand for water resources from environmental, recreational, municipal and industrial uses. For example in a study in the San Antonio region Chen et al (2001) find increased demand from municipal, and ecological sources. (More on aspects of this appears in the Ecological Services section below).
- *Aquifer Depletion:* will likely be greater in many places due to increasing non-agricultural demands (Reilly et al., 2002).
- *Water Distributions Used in Planning:* Milley et al. (2007) argue that water supply distributions and concepts like the 100-year flood and drought are changing, thereby affecting water planning.

Disturbances

Climate change can create more favorable conditions for pests and fires, diminishing productivity as the following offers:

- *Fire Risk:* Increased spring and summer temperatures, earlier spring snowmelt and woodland growth have been associated with increased fire risk (Westerling et al., 2006; PNRS, 2004) and thus climate change will exacerbate this. New fire and fuels management strategies may be needed to manage such risks (Brown et al., 2004).
- *Crop Pest Incidence:* Empirical evidence shows climate conditions are expanding pest ranges and management costs (Chen and McCarl, 2001; Gan, 2004). Plant disease pressure may also increase (USCCSP, 2008).
- *Livestock Disease:* Diseases previously rarely observed may become more prevalent. For example, spread of vector borne diseases like Avian Influenza show positive correlation with increased temperatures (Mu, 2009).

Mitigation Production and Competition

Today one commonly hears words like carbon market, cap and trade, and climate bill. All involve limiting or mitigating GHG net emissions. McCarl and Schneider (2001) discuss four roles agriculture and forestry could play under such programs. They may(1) live with higher energy prices (note approximately 84% of emissions come from energy so an increased cost of using energy is an inevitable outcome of limiting GHGs); (2) reduce emissions from energy use, fertilizer, livestock and other sources; (3) increase sequestration or retention of sequestration through soil management, afforestation, forest management or reduced deforestation; and/or (4) replace of emission intensive products (though production of bioenergy feedstocks or building materials). When such actions are followed they tend to replace traditional production practices and generally reduce production. This implies higher prices. Two principal implications arise in the west:

- *Production Alterations:* Production practices could be altered, although the possible alternatives may be limited by moisture. Regionally manipulating feedlot diets and managing manure, are possibilities as well as forest management, afforestation and avoided deforestation. Bioenergy possibilities may play a role perhaps with the largest possibility involving fuels for electricity (see Murray et al. (2004)). However moisture and other factors may limit the possibilities as discussed by Young (2009).
- *Market Consequences:* Market prices would be impacted, not only for items directly used in mitigation (switchgrass, corn, soybeans etc.) but also for other commodities, due to substitution in consumption and competition for land (Baker et al., 2009). Evidence of this has been seen in commodity prices during the ethanol expansion, which does from

some viewpoints reduce GHG emissions (McCarl and Boadu, 2009) although this issue is complex involving many drivers (Abbott et al., 2009; Searchinger et al., 2008).

Adaptation Investment

Adaptation actions in the face of climate change will affect the West. There will be alterations in crop and livestock mixes, tree species, livestock breeds and land management practices plus a need for investments in infrastructure (McCarl, 2006; Antle, 2009; 2010). This will require additional research and extension efforts to adapt existing crops and livestock, move varieties of heat tolerant crops and livestock breeds into the region, and adapt management. Expanded investment may be needed for a sufficient food supply given the factor productivity implications of climate change as found by McCarl, Villavicencio and Wu (2009). Investment will be needed to facilitate new fire and pest management strategies.

Ecological Services

Large changes in climate and land use typically impact ecosystems, thereby altering the quantity and quality of the services that they provide. Economic value is generated through ecological service provision, biodiversity, and recreational benefits among others (Loomis and Richardson,2001). The items discussed in prior sections are agricultural, such as crop/pasture land use and water issues. Some other issues are relevant:

- *Water Usage:* climate change can create environmental conflicts between stream flows and consumptive usages (Chen, Gillig and McCarl, 2001). As populations increase competition increases for what may be a smaller available amount of water.
- *Biodiversity and Habitat Conservation:* Changes in regions suitable for pests can lead to large changes as evolving with the mountain pine bark beetle. Fisheries may also be affected, with an example being Salmon. Hibernating and migratory species, like marmots, are emerging a few weeks earlier, which may be due to the ongoing climate changes (USCCSP, 2008). Increased amounts of mitigation activity may lead to changes in land use with possible reductions in programs like CRP, but also the possibility of increased inventories of forest land.
- *Recreational Value:* the West has a wide range of ecosystems accommodating various recreation activities. Climate change adaptation and mitigation may involve change in the quantities and qualities of natural resources and thereby the recreational value of these resources. Whether the change is positive or negative depends on the type of the activities. Loomis and Crespi (1999) estimate that the effect of climate change on forest-based recreation is negative while that on stream recreation is positive. A recent more comprehensive review can be found in Shaw and Loomis (2008).

Concluding Comments

Climate change poses a substantial risk to the Western US. Issues arise as to the effects, how might we cope with them (Adaptation) and how can we limit the climate change effect (Mitigation). Climate change research is investigating these issues but it is a large and daunting task with a number of unresolved lines of inquiry. A few unresolved issues in this context are as follows:

- Climate change effects have, and will continue to, impact traditional production, water availability and ecological services with a number of these investigated. However, not much work has addressed the interaction of these areas.
- While extensive work has been done on the effects of climate change on crop yields and productivity, less work has been done on livestock productivity plus the implications of altered pests, and extreme events.

- Adaptation activities will be necessary and work on the economic alternatives and implications is only at its infancy.
- Mitigation is being widely discussed but program implementation and implications are in need of substantial work.
- Adaptation will alter the ability to mitigate GHG emissions, and vice versa plus will compete for resources that would otherwise be used in various ways such as promoting economy growth and combating hunger.

Overall, agricultural and resource economists will find much opportunity for research and outreach as society wrestles with these issues.

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