Impact of Climate Change on Irrigation Water Availability, Crop Water Requirements and Soil Salinity in the San Joaquin Valley

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An assessment of potential climate change scenarios projected to the year 2100 concluded that irrigated agriculture in the western San Joaquin Valley may adapt for a wide range of climate change scenarios. Projected reductions in surface water supply are expected to be offset in part by reduced crop water requirements due to faster crop development, and by increased groundwater pumping. The model predictions indicated that groundwater pumping will likely reduce soil salinity and will not further increase land subsidence, though will increase groundwater salinity.

The objective of the project is to assess the impact of potential climate change scenarios on the sustainability of irrigated agriculture in California; particularly, potential changes in irrigation water availability, crop water requirements, groundwater pumping, groundwater levels, and soil salinity. We consider three increased greenhouse gas (GHG) emission scenarios and study the potential impacts on the agro-hydro-climatological conditions in the region up to 2100. In particular, the analysis is broken down into four main impact areas: (i) climate responses, (ii) crop responses, (iii) agricultural water and crop management responses, and (iv) hydrologic responses.

<u>Climate responses:</u> For each of the three GHG emission scenarios we calculated the effect of increased atmospheric CO_2 levels on future climatic variables, i.e. daily precipitation, air temperature, and reference evapotranspiration (ET), at the regional-scale of the San Joaquin Valley (SJV) using projected output from two General Circulation Models (GCM's) until the year 2100. Relative to the no-climate change scenario, we predicted for the period 2070-2099 an annual average air temperature increase of 1.5 – 5 ^{o}C, causing an increase of annual reference ET of 0 to 12%, while annual precipitation projections are not clear. Water supply projections were based on historical water supply numbers as a function of annual precipitation. Future water supply scenarios account for long-term trends in surface water supply as a function of long-term precipitation shifts, and preserve short-term statistical properties. Predicted changes in surface water supply to the entire study area for the period 2070-2099 relative to the no-climate-change scenario ranged from -25 to +12%.

<u>Crop responses:</u> We considered future changes in potential crop ET rates caused by (i) increased atmospheric CO_2 levels, (ii) increased reference ET, and (iii) increased air temperatures. For direct CO_2 effects on ET, we assumed that its increase by larger leaf biomass would be offset by a decrease through stomatal closure. We also accounted for the effects of projected temperature increases on crop development through the use of degree-days. Crop ET is estimated for all climate change scenarios and for various crops in the study area. Overall changes in crop ET ranged between -13 and +7%, for the period 2070-2099 relative to the no-climate-change scenario.

<u>Management responses:</u> We considered the following possible management responses to changes in surface water supplies and crop ET: (i) land fallowing and retirement, (ii) changes in cropping patterns, (iii) groundwater pumping, and (iv) technological adaptation. We predicted temporary land fallowing assuming it is inversely related to surface water supply, as indicated by historical fal-

lowing during droughts in the study area. Predicted changes in land fallowing for the 2070-2099 period, relative to the no-climate-change scenario ranged from -20 to +40%. Aside from temporary fallowing we also included recent permanent retirement of agricultural land in all our predictive simulations. Predicted changes in total irrigation water requirements for the period 2070-2099 relative to the no-climate-change scenario ranged from -9 to -1%. The general decrease in crop water requirement is caused by a combination of (i) increased fallowing due to permanent reductions in surface water supply, and (ii) a decrease in crop ET by faster crop development. A comparison to changes in surface water supplies (from -25 to +12%) indicated that in some scenarios groundwater pumping will need to increase to compensate for the loss in surface water supply, despite the decrease in irrigation water requirements. Predicted changes in groundwater pumping for the period 2070-2099 relative to the no-climate-change scenario ranged from -59 to +110%. For the worst case scenario we concluded that a region-wide improvement in irrigation efficiency to 90% through improved irrigation technologies resulted in a 50% decrease in groundwater pumping.

<u>Hydrologic responses:</u> As a final step, the climate-change induced changes in crop ET, surface water supply, and groundwater pumping were used as input into a hydro-salinity model of the study area to assess resulting impacts on groundwater levels, land subsidence, soil salinity, and crop yields. This was done for 8 climate change scenarios, including a no-climate-change scenario and one that assumes a uniform irrigation efficiency of 90% by technological adaptations. Groundwater levels are largely determined by pumping rates. Predicted changes in shallow water table extent in the study area for the period 2070-2099 relative to the no-climate-change scenario ranged from -30 to +30%. These numbers indicate that there is significant uncertainty regarding effects of climate change on shallow water tables. In none of the scenarios did the computed confined groundwater levels fall below the historical maximum drawdown in the confined aquifer of 1965. Therefore, it can be concluded that climate-change induced increases in groundwater pumping (up to 110%) will not lead to significant land subsidence in the study area. Simulated soil salinity changes as a function of (i) salinity of applied irrigation water, with groundwater containing more salts than surface water, and (ii) drainage or leaching restrictions due to shallow water tables. Although scenarios differed significantly in the amount of groundwater applied, and the simulated extent of shallow water tables, soil salinity predictions do not vary greatly between scenarios, with a gradual decrease in the simulated extent of salt-affected soils. Wet scenarios resulted in less groundwater use, counteracted by a larger simulated extent of the shallow water table area. Dry scenarios used more groundwater, but caused a lowering of shallow water tables.

Overall, our results indicate that irrigated agriculture in the western SJV may adapt for a range of climate change scenarios. Possible reductions in surface water supply are partly offset by reductions in crop water demand and increased groundwater pumping. However, no significant negative effects are anticipated due to this increase in groundwater pumping, as our simulations predicted no land subsidence or soil salinity increase.

Selected Professional Presentations

Hopmans, Jan W. Sustainability of Irrigated Agriculture, Pedofract, Madrid, Spain, June 2007.

Hopmans, Jan W. Sustainability of Irrigated Agriculture in the SJV: A historical and future perspective with climate change. University of Madison, WI, September 2007.

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