ACTIVITIES AND FINDINGS

The main activities of the Climate-Land Interaction Project (CLIP) in the past year were:

1. continued modeling to complete the “loop” of climate impacting vegetative productivity and thus land use, and the resultant land use change impacting climate
2. new sensitivity analyses of the impact of climate change on agricultural productivity
3. policy workshops in Nairobi and Dar es Salaam to present and discuss findings with other researchers, and with Ministry, donor and NGO communities
4. project-wide workshop in Nairobi in June 2008 to discuss research results and to plan final modeling, analyses and writing up of results.
5. preparation of reports and articles, and presentations of the findings at scientific conferences and elsewhere.

This report provides a summary of recent activities and findings. The final project report will include more details and provide an overall project findings summary.

Climate analyses

Statistical analysis of historical trends in climate continued with a focus on changes in frequency or severity of extreme climate events (droughts and floods), and determining the change point of when temperature and precipitation trends began. These results indicate high spatial variability especially in precipitation change, with a trend of increasing precipitation along the East Africa coast and high temporal variability but little clear trend elsewhere. Temperatures, however, have increased in all locations, particularly in highlands and along the coast. Analyses examining changes in the frequency and severity of extreme events (droughts, floods) are now being completed.

Climate simulations continue of the effects of 1) projected green house gases (GHG) with the regional climate model RAMS and with downscaled GCMs for comparison, 2) of the climate effect of projected land use/land cover changes (LULCC) due to socioeconomic drivers, 3) the synergistic effect of GHG and LULCC, and 4) to responses to the changing climate (feedback effect) with RAMS (Figures 1 and 2) (Moore et al. 2007; Olson et al. 2007; Alagarswamy et al. 2008).

As expected from prior GCM simulations, the effects of GHG forcing in East Africa is a general increase in precipitation and a significant rise in temperature. The regional climate model shows, however, high spatial variability in these impacts, and the effects are magnified when considering the impact of climate change on crop productivity. The effect of projected land use change on climate is even more spatially varied with zones near water bodies (ocean, large lakes) receiving higher precipitation and much of the rest of the domain receiving reduced precipitation. The land use change affects local and regional latent heat flux and wind patterns related to the precipitation increase near water (Figure 3). In sum, LULCC may have impacts on the same scale as elevated GHG, but the effects are highly localized. In East Africa, the largest LULCC effect is related to increasing precipitation near large water bodies.

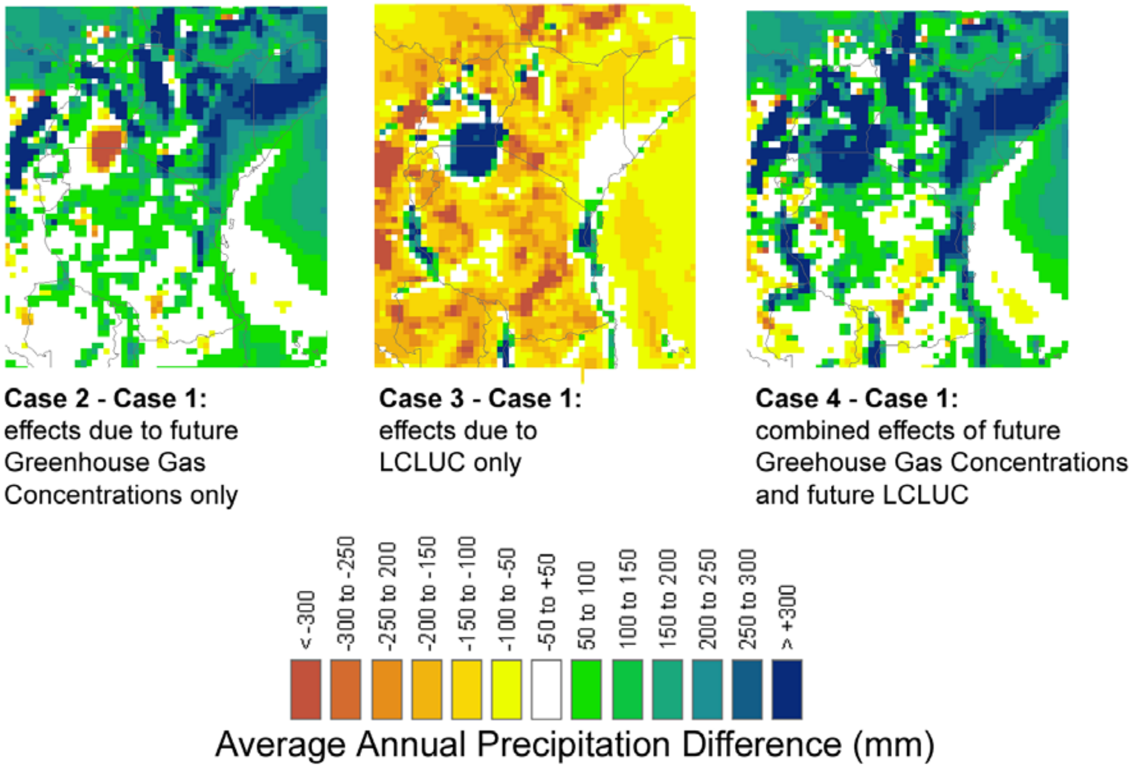


Figure 1. Effects of GHG, LULCC and synergistic forcings on precipitation simulated by the CLIP project's regional climate model, 2000 to 2050.

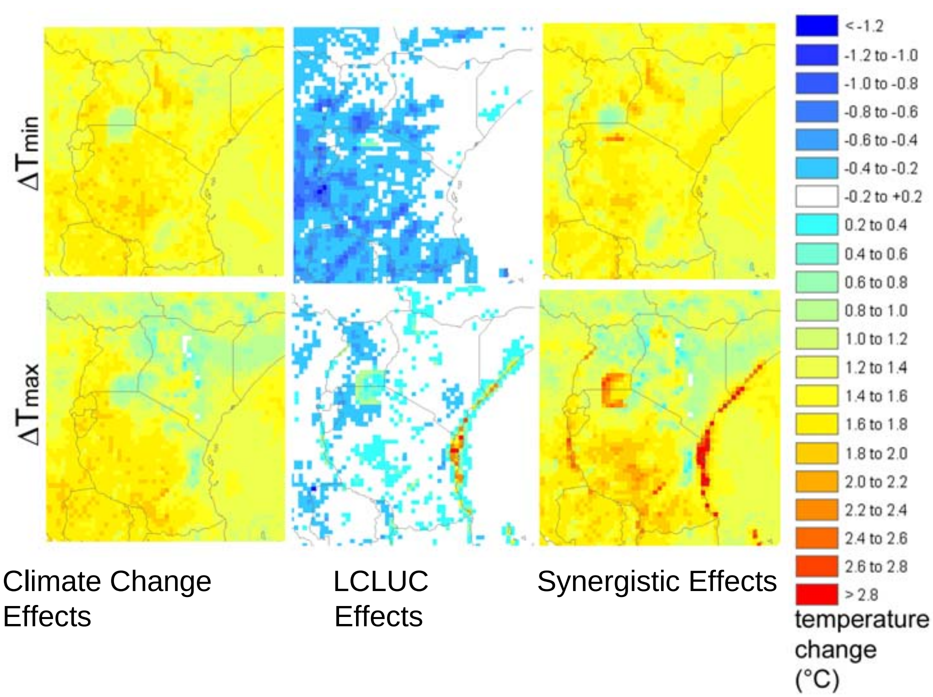
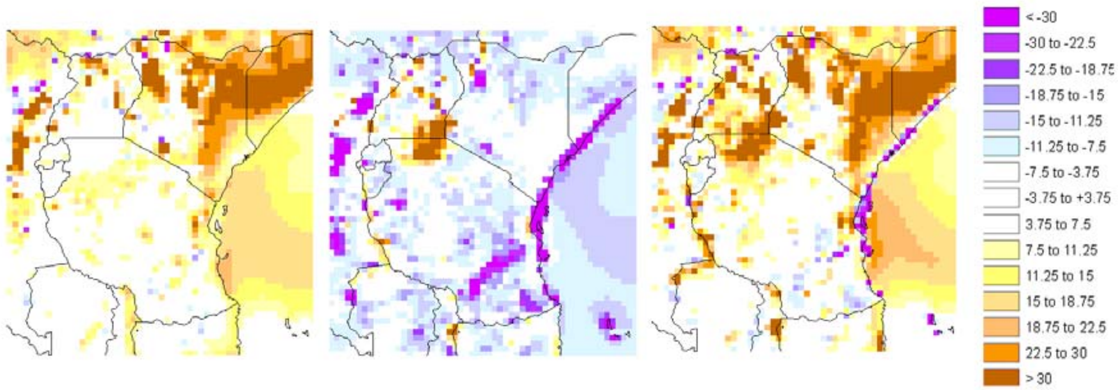


Figure 2. Effects of GHG, LULCC and synergistic forcings on temperature as simulated by the CLIP project's regional climate model, , 2000 to 2050.



Climate Change Effects (7.8 W/m²) — LCLUC Effects (-2.8 W/m²) — Synergistic Effects (8.6 W/m²)

Figure 3. Effects of GHG, LULCC and synergistic forcings on latent heat flux as simulated by the CLIP project's regional climate model, 2000 to 2050.

Impact of climate change on crop productivity

The regional climate model simulation results presented above point towards high levels of spatial variability in climate change. Modeling their impact on crop productivity reveals how this spatial variability in combination with other factors—especially changes in seasonality of precipitation and the effects of soil—leads to results that markedly differ from analyses using GCMs and without considering LULCC. The project is using maize as a proxy for agricultural productivity, modeled with CERES-Maize. .

The results show that different local factors influence how maize is affected by climate change (Figure 4). In cool, high elevation areas (the highest agricultural producing areas in the region), the rise in temperature leads to significant rises in maize yields since cool temperature were the limiting factor (but cool temperature crops such as coffee would suffer). In lowlands, however, maize yields generally decline even where not water stressed because the rise in temperature reduces the growing season length due to more rapid plant metabolism. The combination of warmer temperatures and little change in rainfall, the most common situation in the region, leads to declining yields because of both reduced growing season length and water stress. LULCC impacts of a rise in precipitation near water bodies leads in some dryer areas to an increase in yields. And, unexpectedly, yields decline in some high rainfall areas with sandy soils that will receive increased precipitation because of significant leaching of soil nutrients.

The results show that: 1) GHG-influenced yields and LULCC-influenced yields are highly heterogeneous and not generalizable for the region, and 2) LCLUC effects can be alternately counteract or exacerbate GHG influences, particularly in highly populated areas. Furthermore, high spatial variability in yield is indicated for several key agricultural sub-regions of East Africa. This variability is masked in coarse-scale studies, effectively leading to under-identification of areas with elevated food production risk. The broad range of projected yields reflects enormous variability in key parameters that underlie regional food security; hence, donor institutions' investments cannot be guided effectively with only coarse, global-scale investigations.

Ultimately, global assessments of food security risk must include regional and local characteristics of GHG, and should consider LCLUC influences as well.

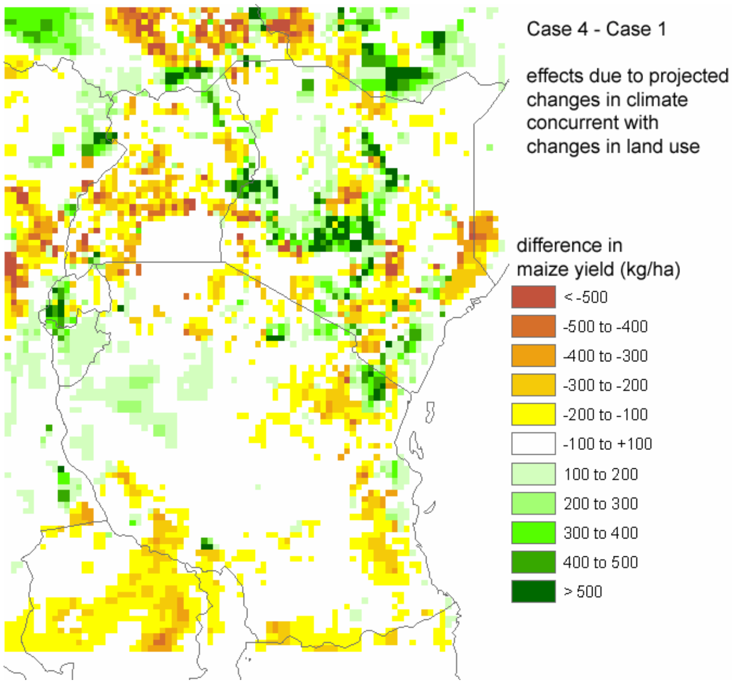


Figure 4. Average difference in maize yields due to both GHG and LULCC combined, 2000 to 2050, as simulated by the CLIP project's regional climate model.

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In addition to the regional climate model, maize and bean yields were compared in different climate change scenarios (Thornton et al. 2008). We used high-resolution methods to generate characteristic daily weather data for a combination of different future emission scenarios and climate models to drive detailed simulation models of the maize and bean crops. The dataset TYN SC 2.0 was used; it includes 20 climate change scenarios for 1901 to 2100. The climate change scenarios are made up of all permutations of five Atmosphere-Ocean General Circulation Models (AOGCMs) and four emission scenarios, A1FI, A2, B1, B2 (SRES, Special Report on Emissions Scenarios, IPCC, 2000).

There are considerable differences between SRES scenarios and between the different GCMs, in terms of projected changes in temperatures, rainfall and length of growing periods. For the East African region, there is considerable spatial and temporal variation in this crop response. We evaluated the response of maize and beans to a changing climate, as a prelude to detailed targeting of options that can help smallholder households adapt. The results argue strongly against the idea of large, spatially contiguous development domains for identifying and implementing adaptation options, particularly in regions with large variations in topography and current average temperatures. Rather, they underline the importance of localised, community-based efforts to increase local adaptive capacity, take advantage of changes that may lead to increased crop and livestock productivity where this is possible, and to buffer the situations where increased stresses are likely.

Results indicate that under the four GCM–scenario combinations considered, the aggregate production decreases are projected to be modest to 2050. These aggregate production changes, however, hide a large amount of variability, and under the higher emission scenario (A1FI), substantial maize and bean yield reductions can be expected in 50–70% of cropped pixels. At the same time, the highland areas in many parts will see increases in yield potential, although there may well be concomitant changes in the type, distribution and severity of crop diseases (which are not taken into account in these model runs). A substantial part of this heterogeneity in yield response can be explained by temperature effects. In maize, at high altitudes, yields may increase as temperatures increase, but at most lower elevations, yield changes also depend on water balances, and many places will see increasing water stress in the maize crop, all other things being equal. For secondary-season beans, temperature-driven yield increases will occur at higher elevations or up to average temperatures of about 20–22 8C. Beyond these temperatures, yields will tend to decline.

In terms of adaptation options, this characterization suggests the need for more drought tolerant maize varieties, coupled with management practices that can make the most of available rainfall (such as water harvesting, for example). For bean production, the results suggest that a shift in bean cropping to higher elevations may be appropriate. It is likely that the extent of climate-related hazards is underestimated because important extreme events such as droughts and flooding are not being directly taken into account. In addition, the analysis does not fully account for the fact that the variability of weather patterns in many places is increasing and with it the probability of extreme events and natural disasters. These issues and other adaptation issues were written in policy-oriented climate adaptation reports in Kenya, Tanzania and Uganda. Policy briefs were also prepared and disseminated, and.discussed during policy workshops in Nairobi and Dar es Salaam in June and July 2008 (see outreach section).

In addition to the analysis of the impact of climate change on maize and beans, specific analyses of the climate / vegetation relationship in Kenya's rangelands was conducted including developing a detailed database of over 200 grass species (Maitima et al 2008). The analysis provides information on how different grassland systems—for example those dominated by C3 versus C4 photosynthetic pathway (or short/tall grass) plants—will be affected by climate change. The tall / short grass distribution is generally heterogeneous due to spatial gradients of climate, soils, landscape and disturbance. The ratio between these grasses is strongly dependent on rainfall and temperature variability, with dramatic compositional shift being induced by droughts. Among climatic variables, those related to water balance are most influential in controlling geographic distribution of grasses. Typically 90% of the variance in primary production is accounted for by annual precipitation. Where tall grass dominates the rangeland, the pastoral communities are not very vulnerable to climate variability. In areas where short annual grasses dominate the rangeland, pastoralists exploit spatially distinct areas of vegetation type and productivity by moving species-specific livestock across the landscape. Under continuous climate change, the resilience is likely to decline.

Five summary points include:

1. Significantly higher temperatures are expected. Temperatures are already rising, and are expected to continue to increase an additional 2 to 2.5 degrees C by 2050. The temperatures will lead to increased evaporation and to increased water stress on vegetation, affecting especially the arid and semi-arid areas. Higher evaporation will also worsen surface water scarcity..
2. Increased rainfall variability within seasons, and inter-annually are expected.
    a. Fewer but heavier rainfall events even in "normal" rainfall years.

   b. Rainy seasons appear to be less reliable with more inter-annual variability, and this is expected to continue to intensify.
   c. An increase in the impact of extreme events of droughts and floods.
   d. This annual and inter-annual variability will require adaptations to severe extreme events, and even in normal years to plan for less reliable rainfall.
3. Change in rainfall patterns. Africa will experience in general declining rainfall, but the degree of decline varies across the continent and even within regions such as East Africa. The worst hit zones are those that are already arid or semi-arid. The impact will be severe on people's crops reducing yields and shrinking the area suitable for crops, and reduce forage productivity.
4. In most other locations, rainfall will decline, in a few places it may increase somewhat. Even where the rainfall is not expected to decline or to increase somewhat, in most places the effect of the higher temperatures on vegetation will dominate and lead to declining vegetative productivity.
5. The effects of climate change are extremely spatially variable. Macro analyses hide significant local impacts. Regional climate models reveal that the combined effects of enhanced greenhouse gases and land use change are highly location-specific, with lake and ocean coasts, and highlands, for example differently affected from other areas.