SYNERGIES BETWEEN CHANGES IN CLIMATE, LAND USE, AND STREAMFLOW REGULATION IN THE MEKONG RIVER BASIN

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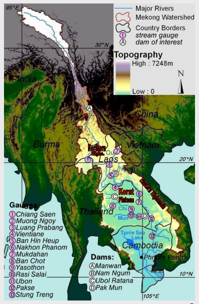
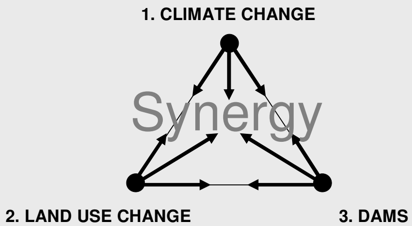
INTRODUCTION



The Mekong River basin (~800,000km^2) showing the major existing dams.

Three major pressures are transforming Southeast Asia's Mekong River basin:

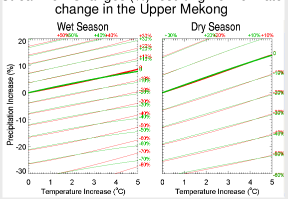


LAND USE CHANGE: Over the second half of the 20th century, vast regions of forest were replaced with cropland, including irrigated and rainfed crops. The most dramatic deforestation took place in Northeast Thailand. The hydrologic cycle in this region was greatly modified, with reduction of direct runoff due to retention in bunded fields, increased infiltration, and wet season evapo-transpiration volumes comparable to those of forest.

CLIMATE CHANGE: We downscaled the IPCC (2007) results of 14 Global Climate Models to the Mekong River basin. The average predicted time evolution for each season is shown in **Box 1**, together with the upper and lower quartile predictions. Precipitation changes are predicted to accentuate the already marked seasonality, making the wet season wetter and the dry season drier, while temperature is expected to rise year-round.

The response of simulated streamflow to these changes in climate was simulated with the Variable Infiltration Capacity (VIC) macro-scale hydrologic model. This response varies regionally within the basin. Compare for example the streamflow response in the Upper Mekong (below) to that in NE Thailand (**Box 1+2** on the right).

Streamflow Changes (%) resulting from climate change in the Upper Mekong

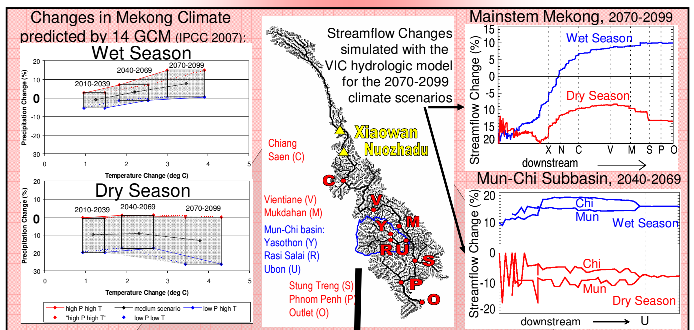


In Northeast Thailand, where land use change has been greatest, the difference in simulated response between the current (cropland) and historical (forest) land use scenarios is large (see **Box 1+2**). Depending on the specific changes in temperature and precipitation, the streamflow response may be more accentuated or less accentuated for cropland than for forest.

DAMS: The Mekong, which is the world's 10th largest river basin in terms of annual streamflow but is one of the least regulated, may be about to be dramatically changed by proposed large scale dams:

- A cascade of hydropower dams in China with a combined 23 km^3 of reservoir storage (the "Chinese Cascade")
- Several dams along the mainstem Mekong river.
- Large dams in major tributaries in Laos.
- Streamflow diversion from the mainstem Mekong to the Northeast Thailand region.
- Irrigation expansion, especially in Cambodia.

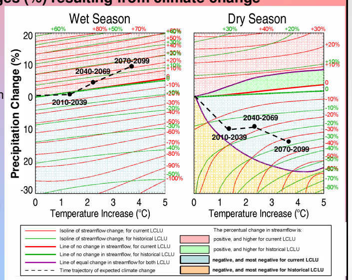
PRESSURE 1: CLIMATE CHANGE



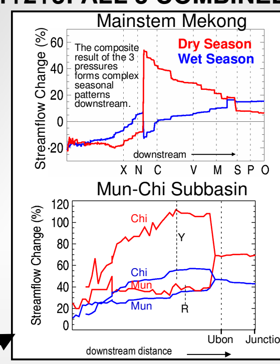
1+2: CLIMATE + LAND USE CHANGE

Streamflow Changes (%) resulting from climate change in NE Thailand

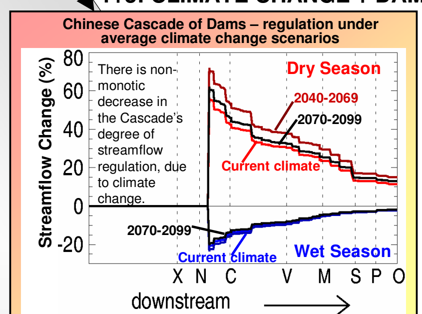
The dramatic land cover and use changes in NE Thailand, where lush tropical forest was replaced by cropland and wet-season irrigation expanded, as well as rainfed bunded crops, has resulted in an enormously altered hydrologic cycle. The simulated response of the current land use to climate change differs from that of the historical forest, as shown. Wet-season rise in streamflow and dry-season decline will both be accentuated by the current land use.



1+2+3: ALL 3 COMBINED

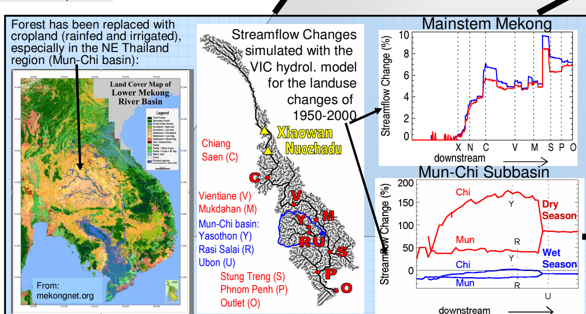


1+3: CLIMATE CHANGE + DAMS

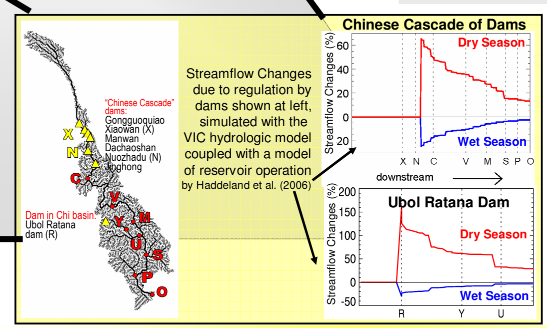


2+3: LAND USE CHANGE + DAMS

With the exception of the Chinese Cascade, all current and most planned dams in the Mekong are intended for irrigation as well as power production. Thus, the change in land use is closely tied to streamflow regulation.



PRESSURE 2: LANDUSE CHANGE



PRESSURE 3: DAMS

CONCLUSIONS

THE DOMINANT PRESSURE AMONG THE THREE IS THE DAMS. The dams composing the planned Chinese Cascade in the Upper Mekong river are predicted to profoundly alter streamflows in the dry season. A similarly dominant but more localized impact is exerted by the Ubol Ratana dam in Northeast Thailand, and the large planned Nam Theun II dam in Laos (not shown). This conclusion has important implications for the potential impacts of current plans for construction of large new dams along the mainstem Mekong, Laos tributaries, and the Mun river. Resulting seasonal streamflow changes are expected to largely surpass those due to either climate or land use change.

IMPACTS OF DAMS (see Box 3) composing the planned "Chinese Cascade" in the Upper Mekong have a profound influence on streamflows along the entire Lower Mekong mainstem, especially in the dry season. With a simulated degree of regulation above 20% (i.e., over 20% of wet season streamflow is released in the dry season), the dry season flow is expected to rise by more than 60% at the cascade's outlet. While the cascade's signal fades with distance downstream, the rise in dry season streamflow is as large as 14% all the way down at the basin's outlet. The Ubol Ratana dam in the Chi River basin also has a dramatic effect on streamflows, with an observed degree of regulation of nearly 30%. Dry season flows as far down as Ubon are heightened by over 30%.

IMPACTS OF CLIMATE CHANGE (see Box 1): Climate change over the 21st century is expected to accentuate the already marked seasonality in precipitation (wetter wet season, drier dry season), with rising temperatures on both seasons. As a result, by 2070-2099 climate change is expected to lower dry-season streamflows by 10-20% along the entire length of the Mekong River mainstem. Wet season streamflows are expected to drop by up to 20% in the Upper Mekong but rise by up to 10% in the Lower Mekong. The reasons for this difference between the Upper and Lower Mekong were previously addressed.

IMPACTS OF LAND USE CHANGE (see Box 2) from forest to cropland increases year-round streamflows along the Mekong mainstem.

SYNERGY BETWEEN CLIMATE AND LAND USE CHANGE (see Box 1+2): In Northeast Thailand, where land use change has been greatest, the difference in simulated response between the current (cropland) and historical (forest) land use scenarios is large. Depending on the specific changes in temperature and precipitation, the streamflow response may be more accentuated or less accentuated for cropland than for forest. For the predicted climate change time sequence (shown in figure in Box 1+2), simulated streamflow may increase by about 20% in the wet season and decrease by over 30% in the dry season.

SYNERGY BETWEEN CLIMATE AND DAMS (see Box 1+3): Simulations of dam operation for future climate scenarios predict a non-monotonic evolution of the degree of regulation of the Chinese Cascade, first increasing from 21% 26%, then decreasing to 20% by 2070-2099. The decline in simulated degree of regulation results from the decline in wet season streamflow in the Upper Mekong, under the assumption that the cascade will aim at maximizing annual power production.

SYNERGY BETWEEN LAND USE CHANGE AND DAMS (see Box 2+3): With the exception of the Chinese Cascade, all current and most planned dams in the Mekong are intended for irrigation as well as power production. Thus, the change in land use is closely tied to streamflow regulation.

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