**Literature survey**

Douglas, E., D. Niyogi, S. Frolking, J.B. Yeluripati,R.A. Pielke Sr., N. Niyogi, C.J. Vörösmarty andMohanty, U.C. (2006). Changes in moisture andenergy fluxes due to agricultural land use andirrigation in the Indian monsoon belt. Geophys. Res.Lett., 33, L14403, doi:10.1029/2006GL026550.

Globally, agricultural water use (in the form of crop irrigation) comprises 70% of all human water withdrawals. Irrigation water use can alter the hydrologic cycle in several ways: by reducing base flow to rivers, by increasing physical evaporation (from soils and standing water) and transpiration (from vegetation), by adding to the greenhouse effect (since water vapor is also a greenhouse gas), by changing cloud coverage and depth, through changes in vegetation distributions and surface albedo and roughness, and by subsequent feedbacks to precipitation, and runoff and contributions to the soil moisture and ground water storage. India leads the world in total irrigated land where irrigation withdrawals represent 80 – 90% of all water use in India. Approximately 60% of irrigated food production

Arguez, A. and R.S. Vose (2011). The definition of thestandard WMO climate normal: The key to derivingalternative climate normals. American MeteorologicalSociety, June 2011, pp 699 – 704. (DOI:10.1175/2010BAMS2955.1

 The different drought phases observed during the 1970-2010 period have underlined important weaknesses of West African agricultural systems. The droughts resulted in important decreases in crop production, triggering a significant deficit in food availability. Many studies have identified changes in rain events seasonal patterns as the key drivers of agricultural production failure during these drought phases. In this study, seven agriculturally-relevant intra-seasonal rainfall characteristics (i.e., annual rainfall amount, onset and cessation of the rainy season, dry spells, extreme rain events, hot spells, and strong winds) and associated constraints to crop growth are described for the main cereals (maize, millet, and sorghum) in southwestern Burkina Faso. These characteristics are calculated or determined using daily climate data from a local network of 16 weather stations spanning the 1970-2013 period. A computation of the intensity and the occurrence of these phenomena during the rainy seasons helped to draw the rainy seasons’ nomenclature. Findings suggest that the rainy seasons during the drought phases are characterized by low annual rainfall amount, late onset, early cessation and more frequent long dry spells (>7 days). Furthermore, the long dry spells mostly occurred during the most sensitive phases of crop development: germination at the beginning of the rainy season and flowering at the end of the rainy season. Also, the intensity and the probability of occurrence of the other extreme events (hot spells and strong winds) during rainy seasons are very high in the establishment phase. Thus, adaptation strategies to mitigate these unfavorable climate conditions include a selection of short-cycle crop varieties combined with supplementary irrigation systems during long dry spells.

Douglas, E.M., A. Beltrán-Przekurat, D. Niyogi, R.A.Pielke Sr. and C.J. Vörösmarty (2009). The impact ofagricultural intensification and irrigation on land-atmosphere interactions and Indian monsoonprecipitation - A mesoscale modeling perspective.Global and Planetary Changes, 67, 117-128.

Using Bio-sphere Atmosphere Transfer scheme (BATS) coupled regional climate model (RegCM4) the impact of intensification of irrigation on Indian monsoon atmospheric circulations and surface fluxes is being studied. Land use/land cover change is performed in the model to study the design or sensitivity experiments. This is implemented by changing the vegetation/landuse type in the model. Impact of increase in irrigation activity over Central India and Northwestern region of India is still an open question and hence it is attempted to answer them in this research work. In the first irrigation sensitivity experiment, vegetation/land-use types have been modified to “irrigated crop” type along districts of Central India, Indo-Gangetic plain and northern parts of India, in the RegCM4 model to test the hypothesis that whether-“increase in irrigation decreases monsoon (JJAS) precipitation over certain regions of India and increases pre-monsoon (MAM) precipitation”. Simulations suggest that increase in irrigation over Indian monsoon domain has altered the Indian summer (JJAS) monsoon by weakening it at regional scale over various regions due to probable weakening of the temperature contrast between land and sea. Increase in irrigation over the central India causes a decrease (increase) in sensible heat flux (latent heat flux, surface pressure) in summer monsoon season. To further test the hypothesis that the northwestern region of India is a hotspot for land atmosphere interactions and to test the impact of irrigation intensification over northwestern region of Indian subcontinent, on Indian summer monsoon another sensitivity experiment with irrigation intensification over northwestern regions of India is performed using RegCM4. This experiment suggests that irrigation impact or sensitivity on soil moisture; surface fluxes are limited to northwestern region of Indian subcontinent. Simulations performed at higher (50 km) resolution shows increase in precipitation during pre-monsoon season over northwestern regions of India, too. The Indian monsoon circulations are a part of global general atmospheric circulations periodic in nature and any form of vegetation impact study is a complex process. Thus, from the irrigation sensitivity experiments (using a regional climate model) it can be concluded that due to increase in irrigated land over India, pre-monsoon (MAM) precipitation increase particularly over Central and northwestern regions of India, with the development of anomalous cyclonic circulations.

Feddema, J.J., K.W. Oleson, G.B. Bonan, L.O.Mearns, L.E. Buja, G.A. Meehl and W.M.Washington (2005). The importance of land-coverchange in simulating future climates. Science, 310,1674-1678.

 Through the monthly data of 71 meteorological stations of the North Pacific Watershed in northwest Mexico, the annual trends of nine temperature variables were estimated using the non-parametric Mann-Kendall test and the Q Sen’s slope estimator. Annual Q Sen’s slopes were analyzed in spatial terms using geographic variables as independent factors and likewise with Moran’s I index. Three major physiographic zones were used to perform a regional analysis using pooled data. The monthly trends were also analyzed. Divergent annual trends were found for the nine proposed variables and warming trends were predominant in almost all of them. Latitude is the most relevant factor in the spatial distribution of the Q Sen’s slopes. Four temperature variables were found statistically clustered, as depicted by the Moran’s I index. The largest regional Q Sen’s slopes values were found in the Coastal Plains. In this area a larger increase in minimum temperatures was observed, in contrast with the Sierra Madre regions, where the largest rate of increasing change was found in maximum temperatures. The monthly analysis indicates warming trends in the first six months of the year with a sudden decrease in July and also a noticeable decrease in the slope values in December.

Pielke, R. A., Sr., J. O. Adegoke, T. N. Chase, C. H. Marshall, T. Matsui, and D. Niyogi (2006), A new paradigm for assessing the role of agriculture in the climate system and in climate change, Agric. For. Meteorol., in press

It is hypothesized that land cover change (LCC), driven by mountain top removal (MTR), in the Appalachian region of eastern Kentucky would change biogeophysical properties of land surface and subsequently various atmospheric boundary layer parameters and precipitation. In this research, we have conducted model-based sensitivity experiments of atmospheric response of a significant flash flood–producing rainfall event by modifying land cover and topography. These reflect recent LCC, including MTR. We have used the Weather Research and Forecasting (WRF) model for this purpose. The study found changes in amount, location, and timing of precipitation. LCC also modified various surface fluxes, moist static energy, planetary boundary layer height, and local-scale wind circulation. This study reports that there was an increase in sensible heat flux (H) for bare soil simulation (post-MTR) compared to pre-MTR conditions (increased elevation with no altered land cover). Allowing for growth of vegetation, the grass simulation resulted in a decrease in H. With regard to latent heat flux (LE), there was a notable decrease from pre-MTR to post-MTR simulations. For the grass and forest simulations, LE increased and were comparable to the pre-MTR simulation. Under the pre-MTR condition, the total precipitation was at its highest level. For the simulated loss of vegetation (bare soil) and elevation (post-MTR), there was a decrease in precipitation. With grass land cover, precipitation increased in all areas of interest. Forest land cover resulted in slightly higher simulated precipitation than grass.

Frolking, S., J. B. Yeluripati, and E. Douglas (2006), New district-level maps of rice cropping in India: A foundation for scientific input into policy assessment, Field Crops Res., 98(2 – 3), 164 – 177.

The goal of this study was to map rainfed and irrigated rice-fallow cropland areas across South Asia, using MODIS 250 m time-series data and identify where the farming system may be intensified by the inclusion of a short-season crop during the fallow period. Rice-fallow cropland areas are those areas where rice is grown during the kharif growing season (June–October), followed by a fallow during the rabi season (November–February). These cropland areas are not suitable for growing rabi-season rice due to their high water needs, but are suitable for a short -season (≤3 months), low water-consuming grain legumes such as chickpea (Cicer arietinum L.), black gram, green gram, and lentils. Intensification (double-cropping) in this manner can improve smallholder farmer’s incomes and soil health via rich nitrogen-fixation legume crops as well as address food security challenges of ballooning populations without having to expand croplands. Several grain legumes, primarily chickpea, are increasingly grown across Asia as a source of income for smallholder farmers and at the same time providing rich and cheap source of protein that can improve the nutritional quality of diets in the region. The suitability of rainfed and irrigated rice-fallow croplands for grain legume cultivation across South Asia were defined by these identifiers: (a) rice crop is grown during the primary (kharif) crop growing season or during the north-west monsoon season (June–October); (b) same croplands are left fallow during the second (rabi) season or during the south-east monsoon season (November–February); and (c) ability to support low water-consuming, short-growing season (≤3 months) grain legumes (chickpea, black gram, green gram, and lentils) during rabi season. Existing irrigated or rainfed crops such as rice or wheat that were grown during kharif were not considered suitable for growing during the rabi season, because the moisture/water demand of these crops is too high. The study established cropland classes based on the every 16-day 250 m normalized difference vegetation index (NDVI) time series for one year (June 2010–May 2011) of Moderate Resolution Imaging Spectroradiometer (MODIS) data, using spectral matching techniques (SMTs), and extensive field knowledge. Map accuracy was evaluated based on independent ground survey data as well as compared with available sub-national level statistics. The producers’ and users’ accuracies of the cropland fallow classes were between 75% and 82%. The overall accuracy and the kappa coefficient estimated for rice classes were 82% and 0.79, respectively. The analysis estimated approximately 22.3 Mha of suitable rice-fallow areas in South Asia, with 88.3% in India, 0.5% in Pakistan, 1.1% in Sri Lanka, 8.7% in Bangladesh, 1.4% in Nepal, and 0.02% in Bhutan. Decision-makers can target these areas for sustainable intensification of short-duration grain legumes.

de Rosnay, P., J. Polcher, K. Laval, and M. Sabre (2003), Integrated parameterization of irrigation in the land surface model ORCHIDEE: Validation over Indian Peninsula, Geophys. Res. Lett., 30(19), 1986, doi:10.1029/2003GL018024.

The work presented here describes a new modeling infrastructure of irrigation which is integrated in a land surface model and which will make this model a suitable tool for studies of interactions between irrigation water use and climate change. The model is presented and validated off‐line over the Indian Peninsula. Numerical experiments are conducted with a 1 degree spatial resolution land surface model. Two 2‐year simulations, forced by the ISLSCP (1987–88) data sets, are conducted with and without irrigation. The analysis focuses on irrigation modeling validation and briefly presents first results on irrigation's impact on the surface fluxes.