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Impact of environmental change and land management practices on major crops in India: land-atmosphere interactions in agricultural ecosystems

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Changing environmental conditions impact the dynamics of all terrestrial ecosystems through land-atmosphere interaction processes. Agricultural ecosystems are unique in their interactions with the environment and any change in these ecosystems directly impacts food production. In this study, we aim to understand how environmental factors like elevated atmospheric CO_2, changing climate, and land management factors like irrigation and application of nitrogen fertilizers affect the growth of rice and wheat, which are the 2 most important food crops grown in India. For this purpose, we have developed and implemented dynamic crop-specific modules in the Integrated Science Assessment Model (ISAM), a state-of-the-art modeling framework. This module can simulate crop growth dynamics at half-hourly timestep for rice and wheat including how water, temperature and nutrient stresses affect crop growth. We have placed particular emphasis on representing the impact of temperature extremes in the form of frost damage and heat stress on crops. First, we validated the model by comparing against observations at site scale and regional scale. Simulated values of LAI matched the observations at several field sites. Simulated crop yield and production values have been validated with M3-Crops dataset on a regional scale. Next, we conducted numerical experiments to study the role of environmental change and land management practices on wheat and rice growth in the recent past (1901-2012). Results showed that carbon assimilation and crop growth has increased because of CO_2 fertilization as a result of the increase in atmospheric CO_2 levels. Some of this increase is offset by the increase in respiratory losses due to increase in temperature. Decrease in net precipitation over the years has also led to increasing demand of irrigation to meet water stress in agricultural ecosystems. Because, double cropping is widely practiced in India, nitrogen fertilizers are playing an increasingly important role to meet the nitrogen requirements of 2 food crops grown on the same piece of land in one year. This study advances our understanding of the role of environmental and anthropogenic factors in crop growth and thus can play a crucial role in developing appropriate policy measures to meet the growing demands of food and to ensure food security.