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Quantitative Modeling of Human-Environment Interactions in Preindustrial Time

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Quantifying human-environment interactions and anthropogenic influences on the environment prior to the Industrial revolution is essential for understanding the current state of the earth system. This is particularly true for the terrestrial biosphere, but marine ecosystems and even climate were likely modified by human activities centuries to millennia ago. Direct observations are however very sparse in space and time, especially as one considers prehistory. Numerical models are therefore essential to produce a continuous picture of human-environment interactions in the past. Agent-based approaches, while widely applied to quantifying human influence on the environment in localized studies, are unsuitable for global spatial domains and Holocene timescales because of computational demands and large parameter uncertainty. Here we outline a new paradigm for the quantitative modeling of human-environment interactions in preindustrial time that is adapted to the global Holocene. Rather than attempting to simulate agency directly, the model is informed by a suite of characteristics describing those things about society that cannot be predicted on the basis of environment, e.g., diet, presence of agriculture, or range of animals exploited. These categorical data are combined with the properties of the physical environment in coupled human-environment model. The model is, at its core, a dynamic global vegetation model with a module for simulating crop growth that is adapted for preindustrial agriculture. This allows us to simulate yield and calories for feeding both humans and their domesticated animals. We couple this basic caloric availability with a simple demographic model to calculate potential population, and, constrained by labor requirements and land limitations, we create scenarios of land use and land cover on a moderate-resolution grid. We further implement a feedback loop where anthropogenic activities lead to changes in the properties of the physical environment, e.g., through soil erosion.