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Assessment of anthropogenic vegetation productivity decline in the Volta basin from 1982 to 2003

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Primary productivity decline is causing loss of ecosystem services which in turn influences not only the water cycle, but also the livelihoods of millions of inhabitants worldwide. Climate change or other natural events may be responsible for land degradation, but the phenomenon is mainly due to human actions. Therefore, it would be important to identify those areas in which the pressure on land needs to be alleviated. In this study, we conducted a step-wise analysis using a series of databases to identify the extent of land under anthropogenic threats. We processed time-series NDVI (Normalized Difference Vegetation Index) products for the period 1982 - 2003 to analyse long-term trends in biomass productivity changes over the Volta basin. To distinguish human-induced biomass trends from climate-driven vegetation dynamics, we excluded those areas that had shown a strong biomass response to inter-annual rainfall variation. Pixels with NDVI changes in accordance with rainfall (positive correlation) were considered due to climate change or variation. Pixels not affected by rainfall (no or negative correlation) are those where green biomass change could be interpreted to reflect areas with strictly human induced land degradation. Spatial data of soil constraints, land-use/cover and population density within the study period were used to interpret possible underlying factors of land productivity decline. The results of the study show that about 31 thousands km2 (8% of the basin land mass), which is the living space of over 1.3 million people, was land that is losing its ability to produce green biomass due to human actions. The degradation areas for the various land cover types are 12.2 thousands km2 for woodland, 8.3 thousands km2 for agriculture, 7.3 thousands km2 for shrubland, and 1.6 thousands km2 for evergreen forest. The relatively low population density in the degraded areas (averagely 43 pers.km-2) would suggest that these are marginal areas with limited carrying capacity to start with. As population pressure increases, more fragile lands will be taken into cultivation leading degradation with below average population densities.

The fraction of degraded areas is modest in relation to the land showing significant improvement in green biomass, which covers 87.4 thousands km2 (22% of the basin's land mass). Moreover, about 81% of the greening areas experienced no significant correlation to annual rainfall, showing that this profound greening cannot be explained by rainfall dynamics. Given worldwide evidences on the effect of atmospheric fertilization (e.g. the elevated atmospheric levels CO2 and NOx) on vegetation productivity, the observed productivity improvements in Africa is likely explained by the shift in atmospheric chemistry. Assuming that atmospheric fertilization is ubiquitous, the process would mask degradation of land due to direct human activities. After correction for atmospheric fertilization effect by considering pristine regions with no human disturbance and lacking significant NDVI-rainfall correlation in sub-Saharan Africa, the area of human-induced productivity decline increased from 8 to 65%. The masked degradation areas for the various land-cover types are 106 thousands km2 for agriculture, 55.5 thousands km2 for shrubland, 52.5 thousands km2 for woodland and 10.4 thousands km2 for arid grassland. At this rate of decline in land productivity, the basin may soon lack the land resources necessary for economic development.