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Climate change impacts on woodland biomass C density and water-use: a modelling study of the Sudanese gum belt region

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Much of the Sudanese Sahelian zone lies within an area commonly known as the 'gum belt', where bulk of gum producing Acacias grow. The gum belt is located between 10o and 16o N, and the mean annual precipitation (MAP) ranges from 300-800 mm, increasing from north to south. Understanding of water-use (ETc_adj, actual evapotranspiration) and water-use efficiency (WUE) are essential, especially in water-limited environments to evaluate the potential of new crops and effective use of precipitation. The response of the Sahel region to climate change, particularly in relation to biomass production and water-use, remains unclear. We modelled the impact of various climate change and emission scenarios for the 2080s on biomass C densities, water-use and water-use efficiency of woodlands across the Sudanese gum belt region. Eight study grids (1:250,000; 1.0^{o} lat. x 1.5^{o} long.) covering semi-arid grassland and savannah woodland were selected from the gum belt region. Modelled monthly mean scenarios of climate variables (temperature, precipitation and cloud cover) for the selected study grids were derived from the TYN SC 2.0 (0.5^{o} global spatial resolution) under 10 possible scenarios (5 GCMs x A1FI and B1 emission scenarios) for the period of 2070-2099 using TETYN software. Baseline (1961-1990) observed monthly mean values of same climate parameters were extracted from the CRU TS 2.1 having same spatial resolution. The climate data for our study grids were calculated as the average of resulting six TYN/CRU grids per study grid. Sudanese National Forest Inventory data was used to calculate above-ground tree biomass C densities (g C m-2). Using an exponential relationship between biomass C density and rainfall (y = 6.798*EXP(0.0054*x), R2 = 70%), climate change scenario based biomass C densities were estimated. A water balance model, WATBAL, was parameterized for woodland vegetation and two soil types, arenosols (AR) and vertisols (VR) using HWSD soil data, to give monthly water-use (mm) values for the baseline data and each climate change scenario dataset. WUE (g C m-2 mm-1) for each study grid was calculated as grid mean biomass C density divided by ETc_adj (mm). Grid baseline MAP ranged from 12 to 54 mm and mean annual temperature (MAT) from 23.3 to 29.1 oC. MAT increased under all climate change scenarios and for all eight grids (+1.2 to +8.3^{o}C), while MAP either increased (+9 to +18 mm) or decreased (-1 to -16 mm), depending on climate change scenario and study grid. Grid baseline mean biomass C densities varied between 14 and 232 g C m-2. Under climate change scenarios, woodland biomass C densities will either increase (+14 to +241 g C m-2) or decrease (-1 to -148 g C m-2) with relative (scenario/baseline) biomass C densities ranging from 0.36 to 3.30. Grid baseline water-use (ETc_adj) varied from 140 to 595 mm and WUE from 0.103 to 0.500 g C m-2 mm-1. Compared to AR soils, VR soils had equal or greater water-use and equal or less WUE. The relative water-use varied from 0.54 to 1.88 for VR soils and from 0.61 to 1.89 for AR soils while that of WUE varied from 0.48 to 2.56 for VR soils and from 0.45 to 2.32 for AR soils. The largest relative changes in water-use were associated with the drier grids. WUE decreased for the drier grids, but either decreased or increased for the wetter grids, depending on scenarios. Our results indicate that C sequestration and water-use of woodlands in Sudanese gum belt region will strongly depend on the degree and nature of climate change.