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Urban green spaces enhance climate change mitigation in cities of the global south: the case of Kumasi, Ghana

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Abstract

Urban green spaces (UGS) contribute to mitigate climate change impacts via carbon sequestration and offer several co-benefits in cities. This contribution, however, is omitted in most national and regional carbon stock estimates, and related literature in the global south is – at best – fragmentary. Therefore, this paper quantifies and maps the distribution of UGS above and below-ground carbon pools in Kumasi, Ghana.
Vegetation carbon stocks were estimated using allometric equations for trees and destructive sampling for crops and other herbaceous plants. Soil organic carbon (SOC) was determined to a depth of 60 cm. Satellite imagery and GIS were used to map and extrapolate carbon stock estimates to a citywide scale.

In the metropolitan area of Kumasi, a total of 3,758 Gg of carbon is stored above (vegetation) and below-ground (roots and soil). On average, 239 Mg C ha^{-1} is stored in trees and 81 Mg C ha^{-1} in the soil. Crops and herbs hold <1% of the total stock. There is no correlation between SOC and tree C stocks ($r=0.1073$, $p=0.2982$). Vegetation carbon stocks differ among UGS ($p=0.0071$). The highest SOC stocks are in cemeteries (111 Mg C ha^{-1}) and home gardens (105 Mg C ha^{-1}) while the lowest (46 Mg C ha^{-1}) occur under natural forest relics. No significant differences were observed in soils under all other UGS types. SOC stock dynamics within and between depths differ among UGS types ($p<0.0001$).

Above and below-ground carbon stocks in Kumasi are quite enormous and sensitive to the UGS type. UGS should be accounted for in urban planning and included in national and regional carbon budgets. These findings complement the global carbon budget datasets and are relevant to urban climate change policy.

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Keywords: Carbon, sequestration, green space types, belowground, abovegrond

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1. Introduction

Urbanization and climate change are coupled contemporary global processes that interact on the earth surface with feedback effects on each other and are predicted to escalate with time [1]. Africa, the most vulnerable and fastest urbanizing continent in the world with urban population growth rate of 1.1 % per annum, is expected to further urbanize by 16 percentage points by 2050 [2]. Nearly 90 % of African cities are exposed to and affected by at least one form of natural disaster, i.e. desertification, cyclones, extreme heat, floods, volcanic eruptions, drought, air pollution, etc. [3]. Climate change is projected to aggravate these disasters and further endanger the lives of urbanites. Moreover, cities globally, account for 70 – 80 % of CO_2 emissions into the atmosphere including other greenhouse gases (GHG) [1], [4]. Carbon dioxide, in conjunction with bare surfaces resulting from urbanization create 'heat islands' and severe air pollution [5]–[8], causing discomfort to the living and sometimes fatalities. Although additional conurbation expansion in the developing world, further convolutes these climate-related challenges, it presents opportunities to innovatively create livable, carbon neutral, and environmentally benign cities.

Multiple alternatives exists that can address climate change and its effects in cities. The choice of a solution, depends on the political, social, economic conditions and resources available to design and implement an intervention. UGS constitute a low-cost local strategy that can easily be adopted and practiced in most human settlements at a limited scale and with limited institutional support. Although often obliterated by human demographic growth as a consequence of poor planning, it is clear from the literature that UGS of various forms remain a major part of the urban landscape of many cities in developing countries [9]. Urban green spaces, in addition to their numerous co-benefits, collapse slowly, are more resource-efficient and more resilient to stress induced by both urbanization and climate change processes [10].

In cities in the Global North, UGS have been documented as important carbon sinks [11]–[20]. Defined as the relics of vegetation (i.e. parks, tree lots, cemeteries, home gardens, lawns, grass and farmlands), bare ground, and waterbodies sandwiched by grey infrastructure (buildings, roads and paved surfaces) in cities [21], [22], UGS can sequester carbon in trees, vegetation, soil, and water. Through photosynthesis, plants absorb CO_2 from the atmosphere, transmit it to the soil in the form of living (roots) and dead organic matter (humus) and release it back to the atmosphere during respiration. Human management of UGS can alter these source/sink processes with the climate and hence the ecosystem services they provide [15], [23]. Because urbanization patterns differ markedly at the global and regional scales governed by varying political, social and economic drivers, it will be a misestimate to extrapolate carbon stocks measurements in cities in other regions to cities in Africa.

Besides influencing local and regional climates, carbon cycle, and energy budgets [24], UGS are preserves of several ecosystem services. These include direct mitigation of urban heat island effect by cooling through evapotranspiration and shading, improving air quality (regulation particulate matter, NOx, SO_2, CO and O_3) [25]–[28], mitigating floods and runoff [29], recreation and cultural services provisioning, erosion control [30], [31], solid waste and sewage disposal, fuel and food provisioning, ground water supply [32], acting as windbreaks, psychological and other health benefits [33] and as sources of food. The capacity of UGS to provide ecosystem services is reinforced by their area extent in the city, composition and biodiversity, and efficiency in their management.

Despite their worth, UGS remain marginalized in many national and regional carbon budgets. In Ghana and indeed throughout Africa, carbon stocks of cities are assumed to be zero [34]. Where cities have been considered, carbon stocks estimates are based on low resolution satellite images [35], which tend to severely underestimate carbon stocks [36], [37]. Furthermore, the variation of carbon stocks among different green space types within the city matrix remains largely nebulous [38]. Besides, carbon storage in both soils and vegetation differ strongly among cities [17], [39] because of varying socioeconomic, geographical, and biophysical peculiarities.