Contents Lists Available At sddubidsjplm.com
Journal of Planning and Land Management
Journal homepage: www.sddubidsjplm.com
DOI:10.36005/jplm.v4i2.113

Towards a nexus between land tenure and urban ecology: Value and health benefits of trees in 'large urban land acquisitions' in Wa, Ghana

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A R T I C L E I N F O

Article history:
Received: December 27, 2024
Received in revised form: March 16, 2025
Accepted: April 11, 2025

Keywords:
Large land acquisition, ecosystem services, secondary African cities, Urban Trees, urban land tenure, urban management

A B S T R A C T

Persistent reduction in urban green spaces in rapidly growing African cities compromises ecosystem services critical to urban resilience and health. Anchored with urban resilience and *salutogenesis*, this research examined the role of trees preserved in large urban parcels in promoting urban ecology in Wa Township. The study adopted a mixed-methods approach, with quantitative analysis on the values of the preserved trees and qualitative analysis based on interviews conducted with property managers (n=3), resident-students (n=10), and resident-workers (n=6) of the sites and other urban dwellers (n=4), to understand their perspectives. The quantitative data processing was carried out within the I-tree canopy interface, whereas the qualitative data was transcribed from voice recordings and analysed thematically. The findings illustrate that the preserved trees contribute to substantially reduced carbon and air pollution and produce hydrological benefits. The total carbon benefits alone from both sites amounted to 4427.37kT. Overall monetary value from carbon, air pollution, and hydrological benefits for site B was $874,400 (≈GhȻ14,864,800). This is more than twice the value for site A, with the two summing up to $1,307,578 (≈ GhȻ22,228,826) relative to the $18,659,944 (≈GhȻ317,219,048) for the entire Wa Township. The trees preserved within the study sites enhance biodiversity, provide habitats for fauna, and preserve indigenous plant species while offering several economic, socio-cultural, and health benefits, albeit with certain challenges. The research contributes to a nexus between neo-customary land holding and urban ecology.

1. Introduction

Secondary cities play an important role in the urbanisation of sub-Saharan African countries. Abdulai et al (2022) recently recognised Wa as epitomising a typical secondary city in the global south and that it has long been offered such recognition by the country's secondary cities support programme that was began by the Ministry of Local Government, Decentralisation and Rural Development in 2019, with funding from the World Bank. Secondary cities are characterised by a population of at most 500,000 (Rahayu & Mardiansjar, 2018). Estimates in the year 2014 show that 2.26 billion of the world's urban population will live in cities with populations of less than half a million (United Nations, 2015). Due to these growth prospects, secondary cities are projected to experience an increased role in global urbanisation dynamics. Ghana's rapid urban population growth moved from 50.9 per cent in 2010 to 56.7 per cent in 2021. The urban population of Ghana is projected to increase to 60.7 per cent in 2030 and 66.2 per cent in 2050 (Ghana Statistical Service (GSS), 2021). The population of cities in Ghana has seen a significant change in the reclassified city populations by administrative boundaries in the 2021 population and housing census. Consequently, all cities, including metropolises and municipalities in Ghana, fall under the secondary city class. This led to dramatic shifts in the population of the cities in Ghana. For instance, over 50 years ago, Kumasi (346, 336) and Accra (624,091), which were the only cities in 1970 with populations higher than 100, 000 now have populations of 443,981 (Kumasi) and 284,124 (Accra) in 2021 (GSS, 2021). From the 2010 Population and Housing Census, Kumasi had a population of 2,035,064, while Accra's population was 2,070,463. All other cities had populations less than 500,000, with Tamale (202,317) being the closest to that figure (GSS, 2013). Despite this, it is clear that the role of secondary cities in the urbanisation of Ghana cannot be overemphasised.

The pressures of urbanisation lead to depletion of urban green infrastructure in general, thereby compromising the ecosystem services critical to urban resilience. Simultaneously, the evidence shows that the entire globe is becoming urban. It is no longer feasible to preserve ecosystem services using large-scale nature reserves that run into 1000s of hectares (Green et al., 2015). The ecological benefits, often termed as ecosystem services, of patches of urban green spaces help to address several negative consequences of urbanisation, such as urban heat island, noise, and air pollution, among others. Ecosystem services are classified into provisioning (food and water), regulating services (climate, water quality, and air quality), support services for environmental processes such as soil condition, cultural services such as spiritual and aesthetics, and finally economic services including impact on property values among others (Millennium Ecosystem Assessment, 2005; Green et al., 2015). As Tate et al. (2024) have observed, urban green spaces in general have the potential to contribute to achieving the SDGs, i.e., they mitigate environmental impacts of urbanisation and reduce social and health inequalities.

Urban trees play a key role in carbon offsetting by absorbing CO_2 through photosynthesis and storing it in their leaves, trunks, branches, and roots for a long period. This reduces the concentration of the CO_2 atmosphere, which is a major driver of climate change. Carbon offsetting is, therefore, compensating for carbon dioxide (CO_2) uptake by reducing or capturing its emissions, usually implemented by such means as issuing carbon credits (Kaarakka et al., 2023). The second contribution is microclimate regulation, which represents trees' ability to modify the local climate in urban areas through the urban cooling effect (Erlwein et al., 2021). Other contributions include shading and transpiration that help cool the urban environment. Erlwein et al. (2021) highlight that green infrastructure does promote daytime thermal comfort by compensating for the warming effects of building densification. This is especially important in cities, where human-made structures such as concrete and asphalt absorb and retain heat, creating what is known as the urban heat island effect. For these benefits, urban trees have become very essential.

Indeed, these ecosystem services provided by urban green and blue infrastructure are attracting increasing importance in economic, social, and health aspects. Tate et al. (2024) revealed that most of the eligible studies on urban green and blue spaces related to their contribution to health and wellbeing and pollution, and urban heat island reduction. Tate et al. (2024), having uncovered several gaps, called for more research that particularly links the urban green spaces to the achievement of the SDGs. Richards & Thompson (2019) assessed public perceptions of and willingness to pay for ecosystem services as a solution to the declining urban ecosystem services. One of the challenges of managing urban ecosystem services is seen to be the poor recognition and non-valuation of the economic benefits of these services. Therefore, Richard & Thompson (2019) viewed the valuation and payment for ecosystem services to be an innovative way of funding and incentivising it. Kremer et al. (2016), in highlighting the state-of-the-art in urban ecosystem services research, reveal that land use and land cover indicators of urban ecosystem services are convenient but not always appropriate proxies for urban ecosystem services, thus calling for new techniques as adopted in the current study in Wa, Ghana. Studies that have examined land use changes in Wa have expressed concerns about the consequences on ecosystem functioning (Dambeebo & Jalloh, 2018; Osumanu et al., 2018).

Urban or neo-customary land tenure is dynamic, and urban landholding is often fragmented among numerous owners. However, 'large-scale urban land acquisition' is an emerging term that represents urban landholdings that deviate from this fragmentation of urban land (Sennett et al., 2018). Unlike typical definitions of large-scale land acquisitions such acquisitions exceeding 200 hectares (Anseeuw et al. 2012), in this study 'large urban land acquisition' is any consolidated parcel of land composing of several plots either belonging to one or several owners but with relatively little or no built structures as a result of which there is significant urban tree preservation. As a result of this modification in definition, this study adopts the term 'large urban land acquisition'. Concerns have been raised about the tendency of large urban land acquisitions by corporate entities to de-urbanise cities in the sense of reduction in diverse ownership, undermine public control, and promote social segregation (Sennett et al., 2018). One benefit observed in ecological terms is that such large urban acquisitions have the potential of preserving ecosystem services in secondary cities by conserving flora and fauna, since in these cities, the large land acquisitions are often yet to be developed. In this regard, the nature of urban land holding or tenure in terms of size and, by extension, the nature of ownership, determines the opportunity to preserve trees. This suggests a relationship between, on one hand, the nature of land holding or land tenure in terms of size and nature of ownership, and on the other hand, the opportunity to preserve trees. This study examined the preserved urban trees in large urban acquisitions in Wa Township towards a nexus between urban land tenure and urban ecology, and contributing to the emergent discourse on carbon frameworks. The study's conceptualisation is quite a novelty as there is hardly any study on the value of trees in large urban land acquisitions in Wa, Ghana, and globally. In Ghana, Nero et al. (2018) assessed carbon stocks of trees in Kumasi, not targeting large urban acquisitions and using a different approach. With regards to the approach, Qaro & Akrawee (2020) utilised the i-tree approach to examine carbon storage and sequestration in an urban forest (not necessarily 'large urban acquisitions') in Iraq. The study was guided by the question "How do large urban land acquisitions contribute to ecosystem regulating services in a secondary city in Ghana? Focusing on the monetary value and health benefits of two target large parcels within the township of Wa. The Wa Municipality has a population of 200672, 71.4 per cent urban, and has a land area of approximately 580 square kilometres (GSS, 2010; 2021).

The next section of the article discusses the commodification and emerging value of ecosystem services, followed by the theoretical framework. The study settings and the research methods are then discussed before the study results are presented and discussed. The final section presents conclusions and policy recommendations.

2. The value of urban ecosystem services – literature synthesis

The Millennium Ecosystem Assessment (2005: 3) defined an ecosystem as "a dynamic complex of plants, animals, microbes, and physical environmental features that interact with one another". Ecosystem services are the benefits that humans obtain from interactions with and within the ecosystem. Ecosystems like forests, grasslands, mangroves, and urban areas provide different services to society. As mentioned previously, these services provided by ecosystems are classified into provisioning services, regulating services, supporting services, cultural services, and economic services, which overlap with the first four (Millennium Ecosystem Assessment, 2005; Green et al., 2015). The Millennium Ecosystem Assessment (2005) links all these services to human wellbeing, categorised as security, entailing personal safety, resource access and protection from disaster, materials for a good life, namely livelihoods, nutrition, and shelter. The health category comprises benefits such as strength, wellness, access to clean air and water, whereas the category of good social relations concerns social cohesion, mutual respect, and support for others.

More recently, the importance and value of ecosystem services have seen much more international attention. This is evident in the formation of intergovernmental platforms on Ecosystem Services (Blahna et al., 2017). With regards to the current global agenda, Tate et al. (2024) reviewed the contribution of urban ecosystems, specifically, green and blue spaces, to the SDGs and found that they have the potential to contribute to 15 out of the 17 SDGs. This highlights the importance of urban ecosystems to development. One of the challenges of preserving urban ecosystems is the lack of incentives for owners and managers of the same (Richard & Thompson, 2019). However, economic incentives for conservation of ecosystem services have been reported in rural settings as encouragement to landowners to retain, protect, and enhance these services (Naeem et al., 2015; Wunder, 2015). Under the current global urban development agenda of sustainable cities, Richard & Thompson (2019) argue that new approaches need to be developed to encourage the creation, maintenance, and improvement of the counterpart urban ecosystems. For instance, land values, land tenure, and land management practices tend to influence the availability and conditions of urban ecosystems and the provision of their services, thereby requiring land tenure innovations. Richard & Thompson (2019) have identified several beneficiaries that, if these urban ecosystem services are prioritised, can make payments to owners and managers of urban ecosystems. These include park users paying user fees for recreation, private companies with premises near city green spaces paying for decreased ambient air temperature, and private companies paying for emitting CO_2, among others (Richard & Thompson, 2019). Cao et al. (2021) recently examined the balance between economic prosperity and ecosystem service value of urbanisation in China. Cao et al. (2021) found that wetland land ecosystems were the worst affected by urbanisation, and call for protection for ecosystems and or the restraining of urbanisation in areas with higher ecosystem opportunity costs due to land urbanisation. Kovacs et al. (2013), on the other assessed the return on investment of public land acquisitions for conservation relative to the value of ecosystem services and found that conservation of urban ecosystems, such as urban forests, is a good investment provided the cost of conservation is not too high.

Therefore, the discussion of this related literature shows that the value of urban ecosystem services is gaining economic relevance in recent times, thereby necessitating more understanding of the economic benefits of urban ecosystem service provision. In this study, the economic value of the ecological services of trees preserved in large urban land acquisitions is termed as *econlogic* value. This value was measured with the use of the i-Tree canopy application (US Department of Agriculture (USDA) Forest Service, 2024). Notably, the *econlogic* value differs from the economic value of the tree in several regards. For instance, while the tree may be felled and its parts used to produce charcoal for economic benefits, econlogic value is limited to the benefits the tree offers in the urban area while it is alive.

3. Theoretical framework

The study is anchored on land tenure theory, urban resilience theory (Holling, 1973), the Salutogenic model of health (Antonovsky, 1979), and the analysis was supported by the ecosystem services framework as discussed from the Millennium Ecosystem Assessment (2005) and Green et al. (2015). Land tenure is essentially legal and customary relationships between people and land (Payne et al., 2009). The legal approach is rooted in statute, while the customary theory deals with informal rules (Hull et al., 2019). Similarly, the Food and Agriculture Organisation (FAO) (2002: 3) defines land tenure as 'the relationship, whether legally or customarily defined, among people, as individuals or groups, concerning land'. Hence, a popular view of sub-Saharan Africa's land tenure is a duality of formal and customary land tenure. However, one new approach, which is framed in the context of changes to customary land tenure, theorises land tenure as either customary or neo-customary, which is mostly in peri-urban areas (Wamukaya & Mbathi, 2019). Neo-customary land tenure is observed to operate through 'a mixture of reinterpreted customary practices with other informal and formal practices' (Wamukaya & Mbathi, 2019: 80). For Cleaver (2002: 11), neo-customary systems possess a newly arranged 'institutional bricolage', different from the institutional setup in a typical customary land tenure system. One common feature of this is that neo-customary land tenure often concerns fragmented parcels of land (Bertram et al., 2022) as opposed to the consolidated customary land tenure. This study argues that the large urban land acquisitions, which are exceptional land holdings under the neo-customary, provide the opportunity to preserve urban trees for ecosystem services.

Systems, including urban systems, which are viewed as complex and adaptive, are understood to be in constant change (Batty, 2008; Rodin, 2014); thus, they require persistence in function amid the rapid change. Resilience theory itself has a long history (Matyas & Pelling, 2014), whereby Holling (1973) is often cited as the origin of more recent resilience theory that is related to ecological systems and urban resilience (Meerow et al., 2016). While the definition of resilience is viewed as fuzzy, Meerow et al. (2016) offer a flexible and workable definition of urban resilience as “the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity”. In this study, the loss of ecosystems due to urbanisation in itself is viewed as the disturbance, whereas the preservation of ecosystem services is viewed as having the ability to promote the adaptive capacity of the urban area to perform desired environmental functions. Urban areas consume much of the natural resources, accounting for about 75 percent of the world’s resources (UN-Habitat, 2006). In the context of the rapid urbanisation being recorded, especially in sub-Saharan Africa, urban resilience in all aspects, including ecological aspects in particular, has become more relevant. The provision of ecosystem services will absorb, repair, and promote the city’s natural resources, providing the resilience needed by the natural part of the urban environment to enable the ecological balance required to ameliorate the numerous disturbances (heat, CO_2, floods, water pollutants, etc.) emerging from urbanisation.

On the other hand, salutogenesis, according to the originator, Antonovsky (1979), is the theory of “the health of that complex system, the human being” (Antonovsky, 1996: 13). Salutogenesis is also defined as a scholarly orientation that focuses on the study of the origins of health and the assets of health, contrary to focussing on the origin of disease. Its main question is ‘what makes people healthy?’. Therefore, as the question implies, *salutogenesis* theory focuses on the resources, such as the socio-ecological environment or the environmental determinants of health (Mittelmark et al., 2017), that actively promote health, such as the ecological model of health. In urban settings, *salutogenesis* is applied in the sense of how an urban area can facilitate good health through planning, design, and organisation (Maass et al., 2017). Maass et al. (2017) examined the link between environmental resources and health outcomes and concluded and recommended the linking of environmental resources to health. Other research has found associations between greenspace and health (Kytta et al., 2012; Lachowycz & Jones, 2013). In this study, we use the *salutogenesis* theory to argue that the preservation of urban trees in various forms, such as in large urban land acquisitions, has the potential to produce salutary factors that can actively promote the health of city dwellers, thereby linking environmental resources to health outcomes.

4. Materials and methods

4.1 Study settings

The Wa Municipality is the largest urban area in the Upper West Region of Ghana. The Wa Municipality shares administrative boundaries with Nadowli-Kaleo District to the north, Wa East District to the east and Wa West District to the west, and the south. The Municipality lies within latitudes 1º40’N to 2º45’N and longitudes 9º32’W to 10º20’W (GSS, 2010). The urban expansion of the Wa municipality is well-described by Osumanu et al. (2018) as one that emerged from the consolidation of patches of villages, perhaps through infill growth. With a land area of 580 square kilometres, the municipality has a population of 200672, almost doubling from its 2010 population of 107214. The rate of urbanisation of the municipality is rapid, as it was 66.3 per cent urban in 2010 but has become 71.4 per cent urban in 2021 (GSS, 2010; 2021).

4.2 The large urban land acquisition sites

Whereas customary landholding mostly in rural areas is usually in respect of large tracks of land, urban and peri-urban land holding, also known as neo-customary land tenure (Duran-Lasserve and Mattingly, 2003; Sumbo, 2022), is often over fragmented parcels of land (Bertram et al., 2022). Due to the increasing fragmentation resulting from rapid urbanisation and utilisation of the same for urban development, the opportunity for urban trees reduces (York et al., 2019). In the Wa Municipality, whereas individual land holdings were observed to be fragmented, certain neo-customary land holdings, particularly held by religio-educational institutions, tend to be large, providing the tree preservation. The study targeted three of these large urban land acquisitions in the Wa township, labelled sites A, B, and C, which tend to preserve trees while serving the respective purposes of their acquisition. However, it utilised two of the large urban land acquisitions, site A and site B. Among various large parcels in the Township, the selected sites are protected by fence walls preventing encroachment and tree felling. Site A is located west of the Wa township on the Wa-Maase road. It has a total estimated land area of 71.26ac acres. It hosts public residential facilities, private religious, educational, and recreational facilities. The nature of the use, therefore, shows that it is vested in double to multiple owners. Site B is located in the south-western part of the township on the Wa-Nakori-Vieri Road. With an estimated total land area of 133 acres, it hosts private educational and religious properties. Site C is a forest estimated to cover about 560 acres, located south-east of the township between the Wa-Sandema and Wa-Bole roads. While the site C falls under the definition of a large urban acquisition, its purpose is obvious, as it already seeks to preserve trees. The selected areas, site A and site B, have other uses with tree preservation not being the purpose of acquisition, as discussed previously. However, the entire Wa Township (area 15, 808ac) was added as a third site for analysis for comparison with sites A and B.

4.3 Research design and approach

The study adopted is the sequential mixed methods design in which the quantitative analysis in the i-Tree Canopy software was planned and conducted on the preserved trees before the qualitative phase of the study was carried out with human participants. This was to allow the value of the ecosystem services to inform the discussions during the interviews. The research employed a mixed-methods approach involving both quantitative and qualitative methods, instruments, and data. The quantitative analysis involved photo-interpretation, canopy cover analysis, and tree benefit modelling as described below.

4.4 Population and sampling

The population of the study is composed of the first tree population and the human population. With regards to the trees, the canopy cover, not the actual population, is required to conduct the analysis (USDA Forest Service, 2024). The analysis relied on probability models embedded in the I-tree canopy to estimate the land cover classes. These models use random sample points generated by the software and overlaid on the satellite map during the survey stage. The sampling process was intensive as each random point the model generated on the satellite map was photo-interpreted and added to the appropriate class for the system to record a count. In the Wa township satellite map, 496 random points were sampled, with 168 random sample points in Site A and 173 random sample points in Site B. See Summaries of the sample points in Table 1.

The human population is composed of the managers, resident-workers and resident-students in site B, managers, resident-workers, and customers in site B, and other urban dwellers. Nevertheless, the total human population of the study, which was unknown at the time of the study, was not required for the qualitative aspect of the study. The perception of people from each category of participants was adequate for the analysis. A total of 23 participants were included in the study composing of customers (n=4; 1 female, 2 males), resident-workers (n=6; 5 females, 1 male), resident-students (n=10; 5 females, 5 males), general public (n=4; 1 female, 3 males), and managers (n=3; 0 female, 3 males). All participants were purposively sampled based on availability and their knowledge and experience of the benefits of trees in the study sites.

4.5 Data sources, collection and analysis

The main sources of the quantitative and qualitative data were secondary information and primary data. The secondary information involved a review of literature on urbanisation, ecosystem services and the theoretical framework through a desk study. The main methods of primary quantitative data collection and analysis were software-based. These included the use of satellite mapping, analysis and presentation of land and tree canopy results, and the modelling of tree benefits, all embedded in the i-Tree Canopy online application (USDA Forest Service, 2024). The i-tree canopy (version 7.1), a software-based modelling tool, was used to quantify the monetary value of carbon dioxide sequestration, ozone removal, hydrological impacts and particulate matter filtration. The model applied is based on photo-interpretation of randomly selected points. Following this, a statistical estimate of the amount and coverage in each class is calculated, based on which the tree benefits are computed. Due to randomness inherent in the analysis, an estimate of the uncertainty, Standard Error (SE), is calculated to inform the researcher.

Standard Error (SE) = $\sqrt{(pq/N)}$ where;
N = total number of sampled points
n = total number of points classified as tree
p = n/N
q = 1 – p

A comprehensive description of the I-Tree Canopy air pollutant removal and monetary value, and carbon storage and sequestration models are available in Hirabayashi (2014) and (Nowak et al. 2013), respectively.

The qualitative aspects involved the collection of primary qualitative data on the perceptions of managers, workers and residents of the study sites using an interview guide. The interview guide was prepared based on an extensive review of the literature and the objectives of the study, which informed the formulation of the open-ended questions. The interview guide is composed of two sections, namely a brief background information section and a section on the perception of health and economic benefits of trees in the sites. The latter section had 14 questions, excluding probing questions. Interviews were therefore conducted on the perceived ecological and health benefits of the trees preserved. It also explored factors influencing the owners' or managers' decisions to retain or remove trees, their perspectives on the economic value, and actual and potential challenges of the many trees preserved on their property in Wa township using two sites – A and B. The interviews were conducted by one of the authors with prior experience in qualitative research in the subject area (see Sumbo, 2022; Sumbo et al., 2023) and with the support of one research assistant. The qualitative data were thematically analysed, drawing from the procedure in Braun & Clarke (2006) and Saldaña (2021).

4.6 Measuring the *econlogic* value using the i-Tree canopy approach

The i-tree canopy tool allows the user to define an area of interest on a satellite map, define land cover classes and sample them by classifying randomly selected points, a process termed as a survey. The tool then generates a report for analysis. The report, based on probability models, presents the land and tree cover classes and quantifies ecosystem services, specifically, carbon dioxide, air pollution, and stormwater benefits, with the corresponding standard error (SE). In this study, the various boundaries for the study (Wa township, Site A and Site B) were defined on the satellite images. The boundaries of the Wa Township were defined based on the extent or boundary of physical development, but not the Municipal boundary. The three different areas were prepared in succession: the Wa Township area boundary, Site A area boundary and Site B area boundary. Although the study focused on sites A and B, the addition of the entire Wa town as a separate boundary enabled the researchers to determine the benefits of tree canopy for the entire township relative to that of the two relatively small sites, A and B.

Subsequently, land cover classes were defined for each of the three areas. Seven land cover classes were defined and used for all areas – Grass/Herbaceous, Impervious Buildings, Impervious other such as rocks, Impervious Road such as asphalt and concrete, Soil/Bare Ground, Water surface and the class of much interest, tree/shrub. However, the other classes are also important as they help to estimate the benefits, for instance, the larger the impervious surface, the more runoff water volume and the urban heat island will be warmer. The next step then involved the sampling of random points in each of the areas under study, and using probability models to determine the size of each of the land cover classes, including the tree/shrub canopy size. The tree canopy size is then used to estimate the ecosystem services in quantity and monetary value. Figure 1 is a flow chart of the procedure for using the i-Tree canopy for the analysis.

5. Results

5.1 Analysis of land cover classes for Wa Township

A close analysis of the land cover of the Wa township shows that much of the town land area defined for this study is covered by the cumulative area of grassland (6,118 ac) and soil or bare ground (4,876 ac), with a total area of 10,995 ac. This shows that the cumulative area covered by grassland and bare ground is larger than that covered by impervious buildings (2,451.2 ac). For the grassland, physical observations in the township show that most of it is unimproved grassland with very little being lawn, the latter usually adjoining properties. This showcases the reality of the urbanisation of secondary cities in sub-Saharan Africa. The land cover analysis shows that while generally the township is extensive, the actual area covered by physical urban development is smaller, indicating the extent of urban sprawl. Ordinarily, since the undeveloped land exceeds the developed land, the presence of trees is expected to be high, however, the tree canopy was found to be about 11 percent (1,753 ac) of the land area. The estimates also showed about 1 per cent (160 ac) of blue space, indicating the potential of the wetland ecosystem in the Wa Township.

The analysis shows that sites A and B have similar characteristics per their respective areas covered by trees, with site A (58 per cent) and site B (62 per cent). This is in sharp contrast to the 11 percent tree cover in the entire municipal area (with the forest, Site C, excluded for control) as discussed. The contrast helps to understand the loss of trees due to urban development, since 58 and 60 per cent of trees in sites A and B, respectively, would have given way for development but for the slow physical development within these large urban land acquisitions. However, site B has more trees, with the tree canopy covering over 83 ac of land relative to 41 ac in site A. The estimates also show that site B has fewer buildings but more bare ground compared to site A.

5.2 The ecosystem services and econlogic values of the urban trees under study

This section presents the results on selected measurable ecosystem service provision by trees in the Wa Township, Site A and Site B. Similar to the tree cover analysis presented, the results on the econlogic value show that the respective values from sites A and B each outweigh the econlogic value of the Wa Township, while the combined value of sites A and B is telling of ecological significance and the potential for microclimate regulation and carbon offsetting. The results are presented in the order of three benefits in terms of carbon, air pollution, and hydrological.

5.2.1 The value of urban trees in Wa Township

Carbon (sequestered and stored) Benefits

Carbon sequestration, that is, carbon removed from the atmosphere for photosynthesis and carbon storage in trees, enhances air quality, protects the ozone layer, thereby mitigating climate change (Siera et al., 2021). The benefits are long-term and potentially perpetual. Sequestration occurs as long as the tree is alive, whereas the benefits that are stored persist even when the tree is felled; the carbon is still trapped in the wood unless the wood is ultimately burned. If the wood is burnt, the carbon is released back into the atmosphere, and the cycle continues (Zeng & Hausmann, 2022). There is near-perpetual storage if the wood is used to make a bed, for instance. The total econlogic value of sequestration and storage is $17,861,608, equivalent to Gh₵303,647,336 (using Gh₵17=$1 in October 2024). Out of this, carbon sequestration amounted to $683,992 annually, whereas carbon storage produced $17 177 616 one-time values.

Air pollution benefits

The removal of pollutants such as excess CO and particulate matter promotes a healthy environment and has the potential to enhance overall health. The results show that the trees in the Wa Township remove a total of 117,557.51 pounds of gases and particulate matter annually, which pollute the air with a margin of uncertainty of ±14,846.78. This translates to an annual enconlogic value of $459,132 with a margin of standard error of ±58,376. This value is equivalent to GH₵7,805,244.

Hydrological benefits

The hydrological benefits relate to benefits related to flood control by slowing and avoiding runoff water through absorption and retention of water in parts of trees and by intercepting or slowing down runoff water. Whiles are not available for all these benefits to compute the *econlogic* value, except the avoided runoff, clear hydrological benefits relating to ecosystem provisioning services exist for these, namely, evaporation and transpiration (which promote humidity levels) and interception, which help prevent runoff water from accumulating too soon, thereby preventing flooding. The *econlogic* value of the measurable avoided runoff was valued at $339,204, equivalent to GhȻ5,766,468. The analysis shows that the total econlogic measurable value related to carbon, air pollution mitigation and hydrological amounted to $18,659,944 or GhȻ317,219,048. By juxtaposing this with the estimated tree population of 190,088 in Wa Municipal, each tree on average produces an econlogic value of $98.16 or GhȻ1,669.

5.2.2 The value of preserved trees in site A

Carbon (sequestered and stored) Benefits

Site A yielded $ 16,123 (GhȻ274,091) annually for sequestration and $404,905 (Gh6,883,385) for the storage of carbon. The total of the econlogic value of carbon sequestration and storage in site A amounted to $421,028, with a Ghana cedi equivalence of GhȻ7,157,476. As can be seen, although there is 60 percent tree cover in site A, the size of site A, 71.26 ac, is small relative to the Wa Township (15,808 ac).

Air pollution benefits

The total amount of pollutants removed by the trees annually, in site A, was computed as 2,768.60 pounds (lbs). Air pollution in site A produced a total annual value of $11,050 (GhȻ187,850) with the greatest contribution emerging from the removal of particulate matter larger than 2.5 microns ($7,536), followed by the removal of particulate matter 2.5 microns and smaller ($2,750).

Hydrological benefits

The econlogic value for avoided water runoff, which is the only measurable hydrological benefit, is $1,100 or GhȻ18,700. The analysis gives a total *econlogic* value from carbon, air pollution and hydrological benefits of $433,178 or GhȻ7,374,026 for site A.

5.2.3 The value of preserved trees in site B

Carbon (sequestered and stored) Benefits

Site B, with a total land size of 133 ac and a tree cover similar to Site A, produced an *econlogic* value of from carbon sequestration ($32,545 or GhȻ553,265 and carbon sequestration ($817,328 or GhȻ13,894,576). This amounts to a total of $849,873 or GhȻ14,447,841.

Air pollution benefits

The total pollutants removed annually by trees in site B was estimated at 5,588.61 pounds (lbs), amounting to an econlogic value of $22,306 or GhȻ379,202. Again, the greatest contribution yielded from the removal of particulate matter was $20,764.

Hydrological benefits

The total hydrological benefits amounted to a value of $2,221 or GhȻ37,757, again from avoided runoff water as the only measurable variable.

The overall value from carbon, air pollution removal and hydrological benefits for site B was found to be $874,400 or GhȻ14,864,800. This is more than twice the value for site A ($433,178), yet the land size for site B (133 acres) is less than twice the size of site A (71.26 acres), indicating more benefits from trees in site A. Indeed, as analysed in section 5.1, the tree cover in site B was 62.43 percent while that of site A was 57.74 percent, supporting the difference in *econlogic* value even when related to the land size.

The total carbon (sequestered annually 169.55 kT, stored = 4257.82 kT) from both sites amounted to 4427.37 kT. The value of carbon, air pollution removal and hydrological benefits from site A and site B, with a total land area of 204.26 ac, summed up to $1,307,578 or GhȻ22,228,826 relative to the $18,659,944 or GhȻ317,219,048 for the entire Wa Township. The land area for sites A and B represents 1.29 percent of the entire land covered for the Township (15,808), however, the value they produce represents 7 percent of the econlogic value of the trees in the Township. If there were enough sites that occupy a quarter of the land area of the Township, the value produced, thus, $25,298,875 or GhȻ430,080,879 would have far outweighed that of the Township.

An analysis of the annual value contributed was also made to consider the temporal dimension of *econlogic* value. The annual *econlogic* value from site A amounted to $27,173, while site B was $54,851, and together summing to $82,024 or GhȻ1,394,408. This means that in 5 years the trees in sites A and A produce $ 410,120 or Gh6,972,040 cumulative value. This is without considering the growth in the size of the trees within that period and the resultant increased benefits. This, together with the one-time contribution from storage, indicates the enormous *econlogic* value of these trees.

5.3 Perception of preserved trees by property owners/managers and residents/workers

Qualitative data were collected through interviews to understand the perception of the ecological and health benefits of the trees preserved, factors influencing the owners' or managers' decisions to retain or remove trees, their perspectives on the economic value, and actual and potential challenges of the trees preserved on their property. The data analyses reveal that managers experientially perceive trees to produce direct benefits on their property. These include wind breaking, provision of fruits, absorption of dust, provision of wood for roofing, furniture and fuel in the school and provision of animal feed. A manager at site B explained that their fuel wood needs for the kitchen of the school are met by dry wood from the trees and that the school authorities occasionally fell selected trees for furniture wood. Similarly, both managers interviewed at site B described these benefits, adding that they often use dead trees for charcoal and firewood. All the managers who were interviewed also attest that the preserved trees make the environment cooler and greener compared to the environment outside. One of the managers at site B remarked that

> "Feel this room that we are sitting in, the windows are closed and there is no air conditioning or fan, but you can feel the ventilation. This promotes productivity at work" (Interview no. 2, Site B – 28/11/2024).

The manager at site A added that because of the trees on their site, they have never had an instance of destruction of the roofs of their properties, a situation that is common within the Municipality during storms. The manager at site A continued to reveal that the students here attest that the conducive environment here helps them to learn effectively and that several groups and individuals hold mini events within the area because of the cooler environment created by the trees. A young female restaurant worker at site A explained that the serenity of the environment and the relatively cool area attract more customers to the restaurant.

In terms of the health benefits of the trees, all managers explained that the trees practically cleanse the air by absorbing dust and vehicular emissions generated from within and outside their premises. A manager particularly explained that there is a noticeable difference in the air quality whenever he returns to the premises after a period of stay outside the premises. He stated that

> "The foremost benefit we derive from the trees as individuals who are living here is the very serene atmosphere that the presence of the trees bring. Because if I step-out into town right now where we do not have a lot of trees or where we do not have trees at all, and I get back here. The moment I enter this compound I can immediately feel the vast difference between when I was in town and when I returned." (Interview no. 2, site A – 4/12/2024).

The absorption of noise by the trees was also mentioned by two managers, and this contributes to the relevance of the trees within their property. Residents and workers within sites A and B revealed similar benefits in the interviews, adding the use of certain trees for medicinal purposes and that such trees are now rare in the general urban space. One of the interviewees mentioned that having access to the fruits of such rare trees reminds them of fulfilling childhood memories. List of some species identified within the preserved trees in sites A and B that are rare in the general urban space.

The data from both sites indicate certain challenges to tree preservation. The key challenges revealed included interference with electricity lines and damage to buildings, and security concerns. A resident at site B recounted incidents of theft in which the perpetrators escaped into the trees, thereby indicating a challenge of balancing tree preservation with security concerns. The resident worker at site B mentioned that the roots of trees infiltrate their borehole, obstructing water flow rate and producing debris in the storage tank, and the availability of the trees leads to invasion of bats. As a result of the challenge related to the obstruction of electricity lines and damage to buildings, removal and pruning of affected trees happened at both sites. Nevertheless, owners and managers of both sites continue to plant trees. In site B, the manager indicated that the school continues to plant trees, although not extensively, whereas both the manager and resident worker at site A, confirmed by the resident interviewees, explained that they continue to nurse and plant trees. Indeed, the senior manager mentioned that each tree felled was replaced by transplanting two seedlings. He noted that

> "Trees that dry on their own naturally, we convert them into firewood for our kitchen thereby reducing the amount of money we spend on fuel… but when we cut such trees, we plant like two trees" (Interview, no. 2, site A – 4/12/2024)

6. Discussions

The analyses show that the large parcels of neo-customary land studied do provide better tree cover and ecological benefits relative to fragmentation land holdings under the same tenure. The study results have demonstrated that the delineated Wa Township area studied is not dominated by buildings. Rather much of the area is occupied by grassland and bare grounds, totalling 10,995 ac, followed by buildings (2,451.2 ac) and the next largest land cover being trees (1,753 acres), constituting 11 per cent. Several authors have examined land cover and urban expansion in Wa and the implications on loss of green space and trees (Korah et al., 2018; Osumanu et al., 2018; Bonye et al., 2021; Abdulai et al., 2022). Notably, the area delineated for analysis across these studies is often different in focus and at times temporally. These studies often focus on the entire boundary of the Municipality, while the current study contributes to this literature by delineating only the Township for analysis. As a result, the existing literature reported higher proportions of the land cover classes and, therefore, forms a little basis for comparison. One important finding from this literature is that both bare ground and built classes consistently increase while green spaces like grassland and tree cover reduce over the periods of the studies. For instance, Abdulai et al. (2022) found 15 per cent and 3.5 per cent increases in built area and bare ground, respectively, as closed and open woodland changed by -3.86 and 1 per cent between the same period, 2006 and 2019. Similarly, Osumanu et al. (2018) found a 23.7 and 1.3 per cent increase in built area and bare ground as opposed to -23 and -0.6 per cent change in shrubs and grassland and woodland land, respectively. One of the key findings from the current study is that there is a significant difference in tree population between the general urban space in Wa Township and the large urban land acquisition sites studied. Whereas the tree canopy covers of 58 per cent and 62 per cent. This is an indication that, whereas the literature shows a consistent decline in green space in the Municipality (Korah et al., 2018; Osumanu et al., 2018; Bonye et al., 2021;

Abdulai et al., 2022), these sites have the potential to provide ecosystem services and compensate for the loss of ecological resources in the general city space in secondary cities in SSA to achieve urban ecological sustainability (Garcia, 2017). The result is its contribution to urban resilience (Meerow et al., 2016) as these preserved trees produce rippling benefits for the urban area in terms of temperature control, flood prevention, urban air quality and overall urban ecosystem balance.

The analysis of the econlogic value of the ecosystem service provision in the large urban land acquisition sites was found to help understand the significance of the preserved trees. First, the value produced is a measure of the usefulness of the urban trees; hence, the ecological importance of large urban land acquisitions that allow trees to persist. For example, the analysis arrived at the econlogic value of the average preserved tree as $98.16 or GhȻ1,669. It is re-emphasised that this value is not equal to the market value of the tree, for instance, for its fuel potential, or other uses. As indicated by the interviewees, several benefits, including fuel, medicinal uses, and food, are obtained from the trees besides the ecological importance as observed by several authors (Dumenu, 2013; Shackleton et al., 2015; Garcia, 2017; Yeshitela, 2020). As a result of this ascertained value, the large urban land sites studied can serve to influence urban planning decisions in the context of incentivising, particularly in this era of carbon offsetting through carbon crediting for climate mitigation. Similarly, econlogic value can serve as a supporting basis for environmental impact assessment (EIA) of urban development projects. The econlogic value of a mapped urban development site can determine the value of trees and therefore ecological services to be affected to support decisions relating to ecosystem impacts.

Carbon sequestration, storage, air pollution mitigation and hydrological benefits can be practically linked to health outcomes. The relevance of carbon sequestration and storage to climate mitigation has been well researched (Brindal & Stringer, 2009; Shackleton et al., 2015; Nowak & Greenfield, 2018; Yeshitela, 2020; Isaifan & Baldauf, 2020). Carbon removal by trees is seen to help manage the greenhouse gas effect and improve air quality for a sustainable and healthy environment (Brindal & Stringer, 2009). In addition, the association between air pollution and disease have been established (Jin et al., 2022). Direct health benefits, therefore, result from the removal of air pollutants such as particulate matter, as urban air pollution greatly impacts human health (Hewitt et al., 2020). It is an accepted finding that overall air quality is better with more trees in the city because particulate matter is removed from the air and temporarily sticks on the plant surfaces until it is washed off to the ground by precipitation (Yeshitela, 2020). Therefore, the removal of the pollutants under study, including carbon dioxide and monoxide, and particulate matter, has implications on health outcomes besides the econlogic value. This supports the salutogenesis model of health (Antonovsky, 1979), as more of these benefits would promote healthy living, hence promoting health and wellbeing.

The perspectives of the managers, residents and workers in the study sites complement this discourse by highlighting those actual benefits derived from urban trees, the motivations for preservation and the challenges in maintaining and promoting tree preservation. All the interviewees pointed to many economic, cultural and everyday uses of the trees and several direct and indirect health benefits that they practically derive from the preserved trees as discussed previously in section 5.3. Also, as interviewees mentioned of fulfilling memories of childhood, the trees have tourism potential as these places can hold mini recreational hiking which is gaining research interest (Wang et al., 2022; Owusu et al. 2024).

Again, the findings in this study are expected to promote understanding in the study of the econlogic value of urban trees, termed in this study as econlogy. The analysis in this study can help examine the econlogic importance of urban trees with implications for the planting, maintenance, preservation and removal of urban trees by the relevant city authorities and state agencies. As has been discussed in section, there is increasing interests in the value of urban ecosystems services including the quantification of such services, the potential for monetisation the need for new approaches to promote urban ecosystems services, and the potential contribution for achieving the SDGs (Blahna et al., 2017; Richard & Thompson, 2019; Tate et al., 2024). Finally, while there is urban land fragmentation and persistent decline in urban trees and urban green spaces in secondary cities, the analysis shows that large urban land acquisition presents an opportunity to preserve urban trees and contribute to urban ecological balance, creating a novel nexus between the nature of urban land tenure and urban ecology.

7. Conclusions and recommendations

This study has demonstrated the ecological importance of urban trees preserved within Wa Township, particularly in large urban land acquisition sites by analysing their econlogic value. The study found that, unlike the general urban area, where green spaces are declining and tree cover is only 11%, these sites maintain substantial canopy cover of 58% and 62%. The ecological value of preserved trees, estimated at $98.16 (GHȻ1,669) per tree, highlights their critical role in providing ecosystem services such as temperature regulation, flood prevention, air quality improvement, and carbon sequestration. These findings affirm the potential of such sites to enhance urban resilience and sustainability, while also contributing to climate mitigation, public health and the achievement of the SDGs, particularly those related to climate action, sustainable cities, and good health and well-being. Stakeholders in the study sites emphasised the socio-cultural and economic value of urban trees, pointing to their everyday uses, health benefits, and tourism potential. These reinforce the idea that urban trees not only contribute to ecological balance but also serve as spaces for recreation and cultural preservation. Such findings highlight the importance of integrating tree preservation into urban planning to ensure a balance between development and ecological sustainability. The study provides a new perspective on the value of urban ecosystem services, offering insights that can guide urban planning, policymaking, and environmental management. It emphasises the need for a balanced approach to urban development that ensures the preservation of ecological resources while addressing the needs of rapidly urbanizing secondary cities in Sub-Saharan Africa. One implication for urban land tenure policy is to re-interrogate the significance of 'large urban land acquisitions', particularly in terms of ecological services and in the context of the emergent carbon economy. Finally, it carves a novel niche in the relationship between urban land tenure and urban ecology.

The study recommends that policymakers incorporate ecological valuation into urban planning processes and environmental impact assessments to promote sustainable urban development. Incentives such as carbon credit schemes and tax benefits can encourage private landowners and developers to preserve trees. Further, city authorities should prioritise the integration of green spaces into urban development plans, promote afforestation initiatives, and actively engage communities in the maintenance and protection of urban ecosystems amid the declining green spaces in the rapidly urbanizing sub-region. Recognizing the tourism potential of preserved urban green spaces, policies could also encourage. There is, therefore, a need to deliberately create large urban acquisitions evenly distributed in the urban environments to accrue these benefits while encouraging the preservation of individual trees. Secondary cities have the potential to adopt this as there is a better opportunity for urban planning and development control to allocate large parcels of land than in primary cities, where land is already put to other uses. Finally, the relevant urban authorities need to leverage eco-tourism and recreational activities such as hiking, providing economic benefits while fostering community appreciation for urban greenery.

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Appendices

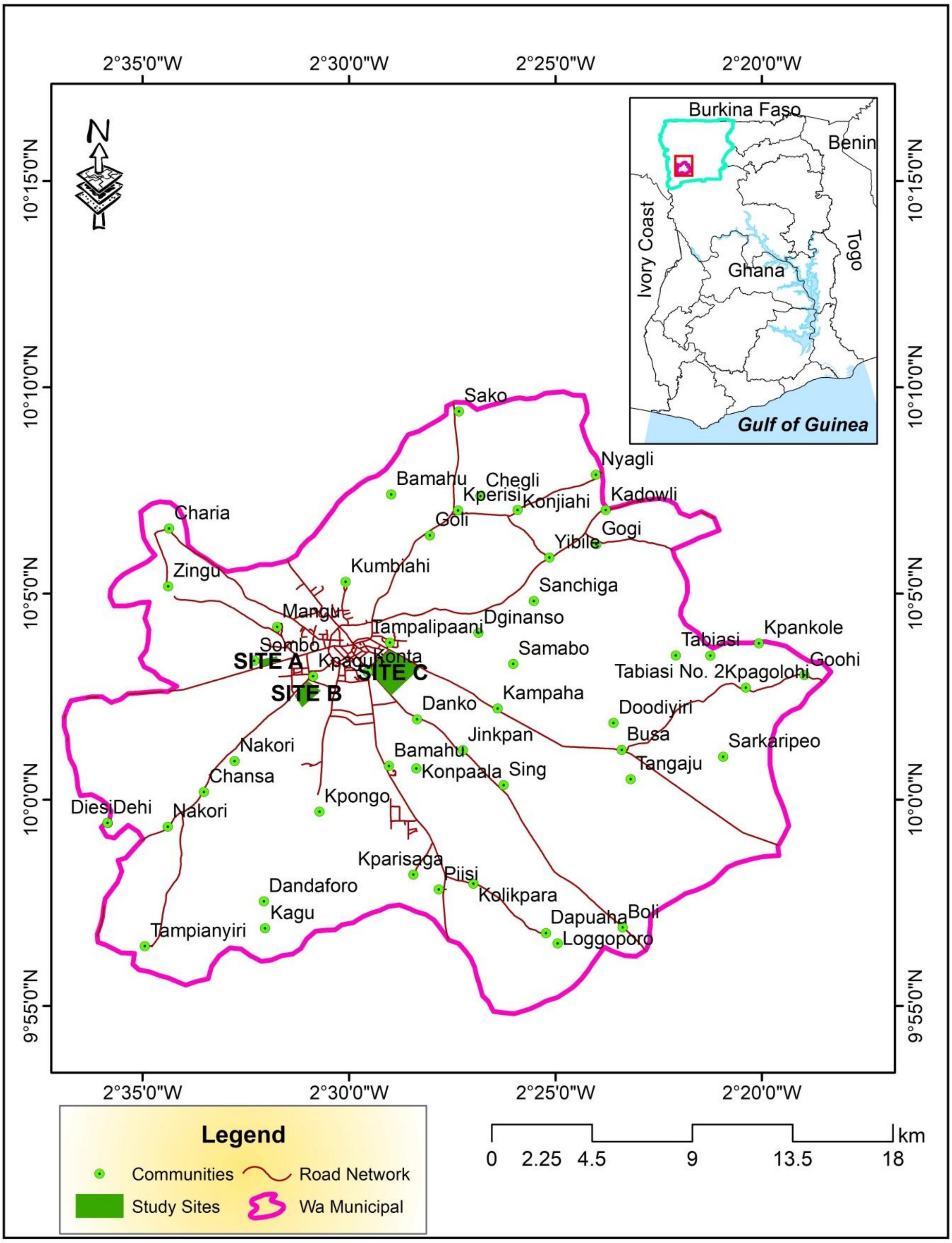

Figure 1: Map of Wa Municipal showing the study site
Source: Authors (2025)

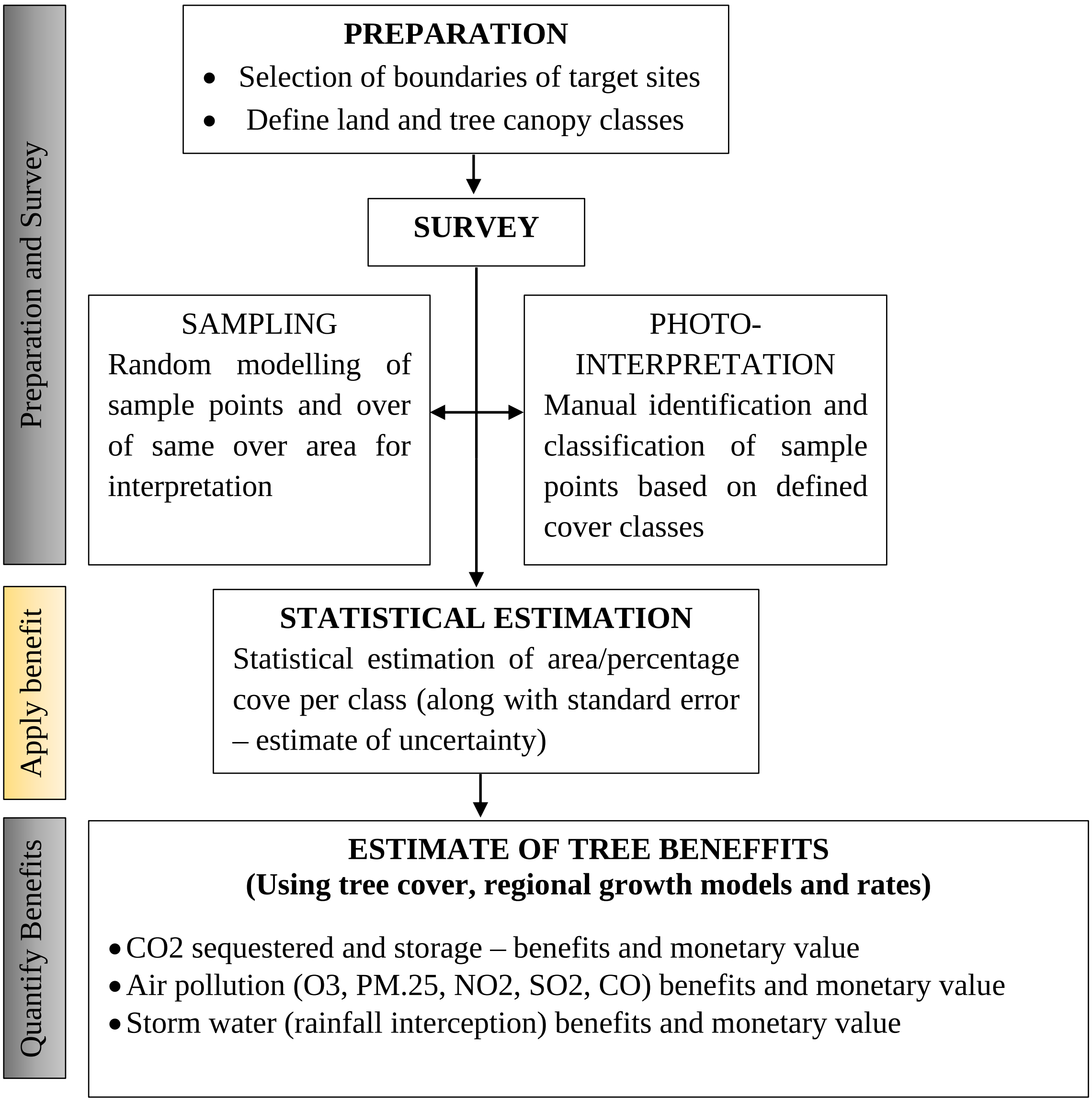

Figure 1: Flowchart of the processes for quantifying the regulating services using i-tree canopy
Source: Authors (2024)

Figure 2: Consolidated Map Showing Sample Points for the Three Areas
Source: Authors (2024)

Table 1: Summary of Sample points, percentage and land cover classes, and the tree canopy covered.

Cover class	Wa Township			Site A			Site B		
	ample points	Percentage Cover ± SE	Area Cover (ac) ± SE	ample points	Percentage Cover ± SE	Area Cover (ac) ±SE	ample Points	Percentage Cover ±SE	Area Cover (ac) ± SE
Grass/Herbaceous (H)	92	38.71±2.19	6118.4±345.6		23.21±3.26	16.54±2.32	3	13.29±2.58	17.69±3.43
Impervious Buildings (IB)	7	15.52±1.63	2451.2±256	8	10.71±2.39	7.64±1.70	1	6.35±1.86	8.46±2.47
Impervious Other (IO)		1.01±0.45	160±70.4		0.00±0.00	0.00±0.00		0.00±0.00	0.00±0.00
Impervious road (IR)		1.81±0.60	288±96		1.19±0.84	0.85±0.60		1.73±1.00	2.31±1.33
Soil/Bare ground (S)	53	30.85±2.07	4876.8±326.4	2	7.14±1.99	5.09±1.42	7	15.61±2.76	20.76±3.67
Tree/Shrub (T)	5	11.09±1.41	1753.6±224	7	57.74±3.81	41.15±2.72	08	62.43±3.68	83.06±4.90
Water (W)		1.01±0.45	160±70.4		0.00±0.00	0.00±0.00		0.58±0.58	0.77±0.77
Total	96	100	15, 808	68	100	71.26	73	100	133.04

Source: Authors (2024)

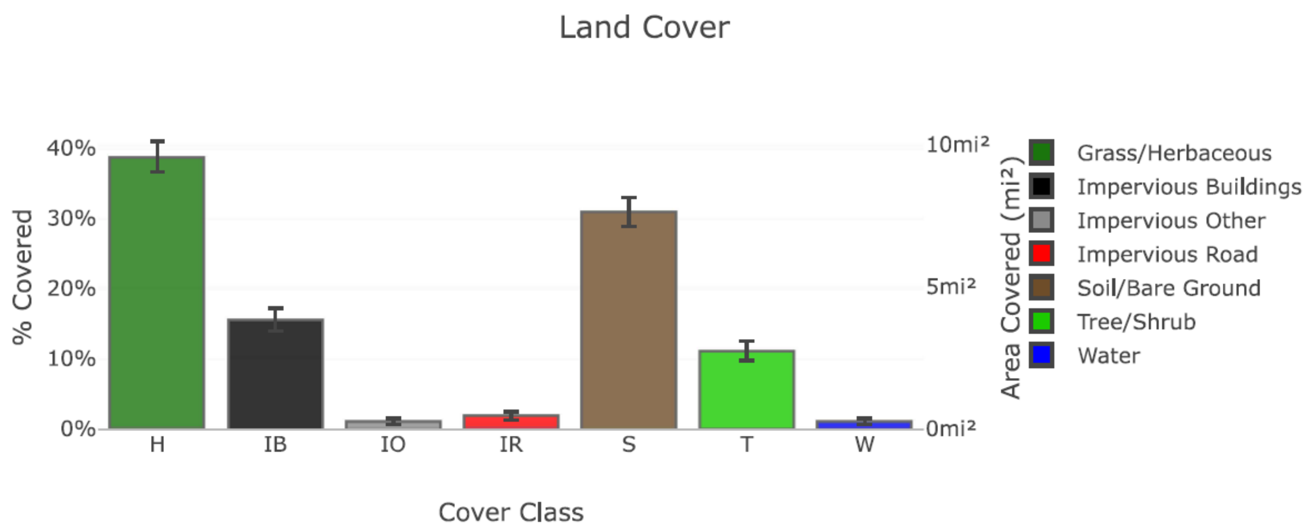

Figure 2b: Site A

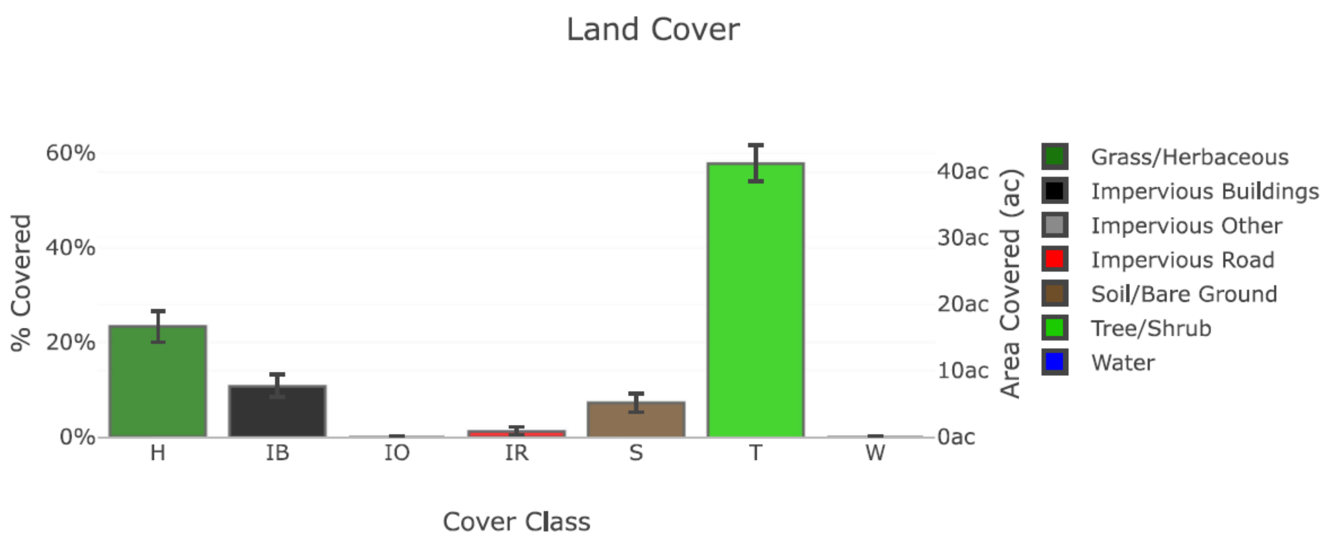

Figure 2c: Site B

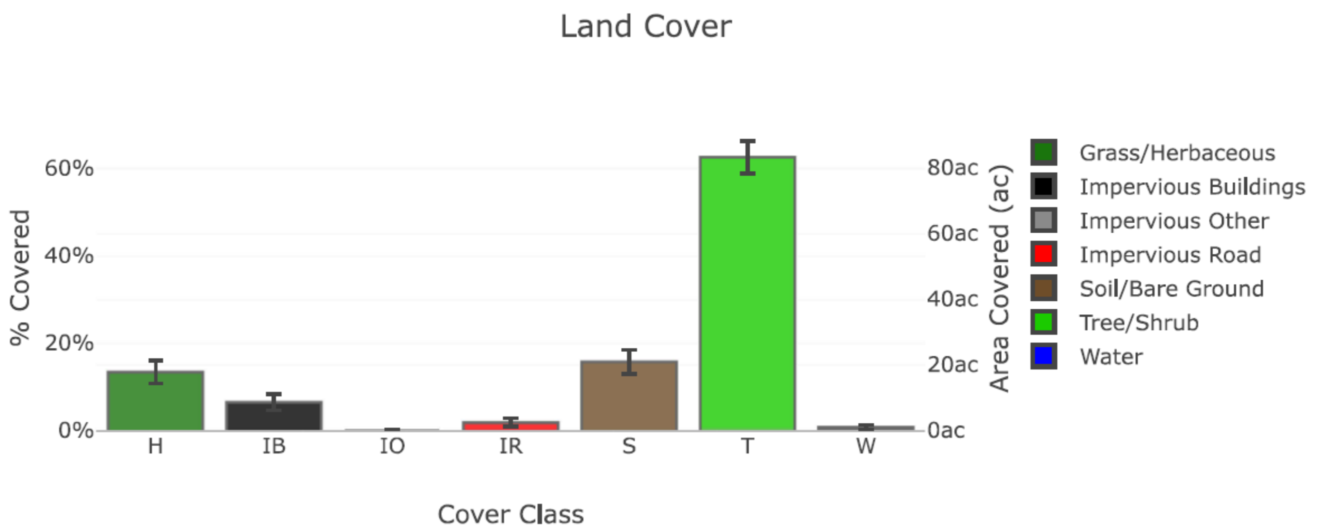

Figure 2a,b &c: Percentage of Land Cover Classes for Wa Township, Site A and Site B
Source: Authors (2024)

Table 2: Econlogic value of carbon in Wa Township

Benefit description	Carbon (kT)±SE	CO2 equivalence (kT)±SE	Value (USD)±SE
Carbon sequestered annually in the trees in Wa Township	2.39±0.30	8.77±1.12	$683,992±86,966
Carbon stored in the trees in Wa Township (Note: this value is not annual)	60.08±7.64	220.30±28.01	$17,177,616±2,184,037

Source: Authors (2024)

Table 3: Econlogic value of air pollutant removal in Wa Township

Abbr.	Description	Amount (lb, Pounds) ±SE	Value (USD) ±SE
CO	Carbon monoxide is removed annually	1,005.18±127.80	$543±69
NO2	Nitrogen Dioxide is removed annually	2,0987.96±2668.50	$1,939±246
O3	Ozone removed annually	69,806.80±8,875.54	$36,911±4,693
SO2	Sulphur Dioxide is removed annually	2,811.33±357.44	$96±12
PM2.5	Particulate matter<2.5microns removed annually	9,906.37±1,259.54	$171,245±21,773
PM10*	Particulate matter>2.5<10microns removed annually	13,039.87±1,657.95	$248,399±31,583
Total		**117,557.51±14,846.78**	**$459,132±58,376**

Source: Authors (2024)

Table 4: Econlogic value of hydrological benefits in Wa Township

Abbr.	Benefit	Amount in Millions of gallons (Mgal)±SE	Value (USD) ±SE
AVRO	Avoided Runoff	41.41±5.90	$339,204±43,128
E	Evaporation	261.88±33.30	N/A
I	Interception	263.23±33.47	N/A
T	Transpiration	732.98±93.19	N/A
PE	Potential Evaporation	657.40±83.58	N/A
PET	Potential Evapotranspiration	511.07±64.98	N/A

Source: Authors (2024)

Table 5: Econlogic value of carbon in site A

Benefit description	Carbon (kT)±SE	CO2 equivalence (kT)±SE	Value (USD)±SE
Carbon sequestered annually in the trees in site B	56.17±3.71	205.94±13.59	$16,123±1,064
Carbon stored in the trees in site B (Note: this value is not annual)	1,410.54±93.11	5,172.00±341.39	$404 905±26,726

Source: Authors (2024)

Table 6: Econlogic value of air pollutant removal in site A

Abbr.	Description	Amount (lb, Pounds) ±SE	Value (USD) ±SE
CO	Carbon monoxide removed annually	24.33±1.61	$16±1
NO2	Nitrogen Dioxide removed annually	497.37±32.83	$37±2
O3	Ozone removed annually	1663.74±109.82	$709±47
SO2	Sulphur Dioxide removed annually	66.42±4.38	$2±0
PM2.5	Particulate matter<2.5microns removed annually	200.27±13.22	$2,750±182
PM10*	Particulate matter>2.5<10microns removed annually	316.46±20.89	$7,536±497
Total		**2,768.60**±182.75	**$11,050**±729

Source: Authors (2024)

Table 7: Econlogic value of hydrological benefits in site A

Abbr.	Benefit	Amount in thousands of gallons (Kgal)±SE	Value (USD) ±SE
AVRO	Avoided Runoff	149.97±9.90	$1,100±73
E	Evaporation	5,458.31±360.29	N/A
I	Interception	5485.05±362.05	N/A
T	Transpiration	17,507.90±1,155.64	N/A
PE	Potential Evaporation	15,431.01±1,018.55	N/A
PET	Potential Evapotranspiration	11,996.24±791.83	N/A

Source: Authors (2024)

Table 8: Econlogic value of carbon in site B

Benefit description	Carbon (kT)±SE	CO2 equivalence (kT)±SE	Value (USD)±SE
Carbon sequestered annually in the trees in site B	113.38±6.69	415.71±24.52	$32,545±1,920
Carbon stored in the trees in site B (Note: this value is not annual)	2,847.28±167.94	10,440.03±615.78	$817,328±48,208

Source: Authors (2024)

Table 9: Econlogic value of air pollutant removal in site B

Abbr.	Description	Amount (lb, Pounds) ±SE	Value (USD) ±SE
CO	Carbon monoxide removed annually	49.12±2.90	$33±2
NO2	Nitrogen Dioxide removed annually	1,003.98±59.22	$74±4
O3	Ozone removed annually	3358.36±198.08	$1,430±84
SO2	Sulphur Dioxide removed annually	134.07±7.91	$4±0

PM2.5	Particulate matter<2.5microns removed annually	404.27±23.84	$5,552±327
PM10*	Particulate matter>2.5<10microns removed annually	638.81±37.68	$15,212±897
Total		**5,588.61±329.63**	**22,306**±1,316

Source: Authors (2024)

Table 10: Econlogic value of hydrological benefits in site B

Abbr.	**Benefit**	**Amount in thousands of gallons (Kgal)±SE**	**Value (USD) ±SE**
AVRO	Avoided Runoff	302.73±17.86	$2,221±131
E	Evaporation	11,017.97±649.87	N/A
I	Interception	11,071.94±653.05	N/A
T	Transpiration	35,340.89±2,084.49	N/A
PE	Potential Evaporation	31,148.54±1,837.21	N/A
PET	Potential Evapotranspiration	24,215.22±1,428.27	N/A

Source: Authors (2024)

Table 11: Selected preserved trees that are rarely found in the general urban space

Tree species	**Local Name**	**Scientific name**	**Comparative Availability (Site A)**	**Comparative Availability (Site B)**
Dawadawa	*Duo*	*Parkia biglobosa*	✓✓✓✓	✓✓✓
Shea	*Taangaa*	*Vitellaria paradoxa*	✓✓✓✓	✓✓✓✓✓✓✓
Ackee apple	*Kyiraa*	*Blighia sapida*	✓	✓
West African Ebony	*Gaa*	*Diospyros mespiliformis*	✓✓	✓✓✓
Coast rubber vine	*Or-raa*	*Saba senegalensis*	✓	✓✓✓
African Mahogany	*Kogo*	*Kyaya anthotheca*	✓✓✓	✓✓✓✓✓✓✓
Detar	*Kpagraa*	*Detarium microcarpum*	✓✓	✓✓✓✓✓✓✓

Source: Authors 2024