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Measures for urban pollinator conservation in a planned city park in Dar es Salaam

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Measures for urban pollinator conservation in a planned city park in Dar es Salaam

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Preface

This thesis is the product of the graduation program of the study Applied Biology at Aeres Hogeschool Almere. I have had a fascination with urban pollinator conservation in developing nations for years. So, when I was tasked with writing a thesis my first action was to search for urban green development projects in developing nations. Through an intensive google search I found the plan for the Msimbazi Wetlands and City Park. I was immediately motivated to research whether it was possible to implement pollinator conservation into this ambitious project.

I would lastly like to thank my supervisors Dinand Ekkel and Bram Knegt for providing me with valuable feedback during the process of writing this thesis.

Shuirelio Kortzorg 03-08-2023, Delft

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Abstract

Pollinator biodiversity has decreased in the past decades, but urban areas have increasingly been found to serve as a refuge when compared to the surrounding intensively managed farmland. This offers an opportunity for urban pollinator conservation to play a role in the conservation of pollinators. But research is lacking, especially in tropical and developing nations which can hamper conservation efforts. This is an issue since the ecosystem services provided by pollinators can be beneficial to developing cities such as Dar es Salaam. But like many other rapidly growing cities in the tropics, Dar es Salaam deals with a host of environmental and socio-economic issues. To mitigate some of these environmental issues, a plan was developed by the Worldbank and the Tanzanian government to transform the regularly flooding Msimbazi river into a thriving city park. Even though the addition of pollinator conservation measures within this plan can be beneficial, there is a knowledge gap regarding the most effective measures in rapidly growing cities in the tropical developing nations. To determine which urban pollinator conservation measures, have the highest likelihood of being successful the following research question was asked: Which urban pollinator conservation measures are most likely to be successfully implemented in the planned Msimbazi Wetlands and City Park in Dar es Salaam?

To answer the research question, three sub-questions were used:

1. What are generally successful urban pollinator conservation measures for urban green spaces?
2. What are the constraining factors specific to developing nations in the tropics influencing the implementation of generally successful urban pollinator conservation measures?
3. Which of the constraining factors on the implementation of urban pollinator conservation are present in Dar es Salaam and how can these be mitigated or prevented?

Six pollinator conservation measures were found to be successful in most of the encountered articles. The goal of these measures is to create an ideal urban environment for pollinators consisting of a well-connected network of green areas with ample amounts of nesting sites. The six measures were further researched to determine their design, implementation, and management. Of the six generally successful measures five were negatively impacted by constraining factors specific to tropical developing nations. Most of the constraining factors were socio-economic but the lack of data surrounding pollinator conservation and biodiversity in the tropics was also a significantly constraining factor in the implementation of conservation measures. The constraining factors and socio-economic conditions of Dar es Salaam were further researched and are described within the thesis. This was done to determine whether Dar es Salaam suffers from the constraining factors and whether these can be mitigated or prevented.

Dar es Salaam was found to suffer from all the constraining factors in one way or another. The lack of data surrounding pollinator conservation and biodiversity in the tropics could not be reasonably mitigated in the short term. The main implication of this thesis is that it is possible to determine generally successful urban pollinator conservation measures and that these can be implemented regardless of location. The caveat is that good governance and significant community engagement are prerequisites for their successful implementation and maintenance.

This thesis shows that there are six generally successful urban pollinator conservation measures that can be implemented in the Msimbazi Wetlands and City Park of Dar es Salaam. The constraining factors in Dar es Salaam can mostly be mitigated if not prevented. The most important long-term recommendations are to perform a species inventory and to regularly monitor the diversity of pollinators in the Wetlands and City Park.

Dutch Summary

De biodiversiteit van bestuivers is de afgelopen decennia afgenomen, maar stedelijke gebieden blijken steeds vaker als toevluchtsoord te dienen in vergelijking met de omliggende, intensief beheerde landbouwgrond. Dit biedt stedelijke bestuivers een kans om een rol te spelen in het behoud van bestuivers. Maar er is een gebrek aan onderzoek, vooral in tropische landen en ontwikkelingslanden, wat de bescherming van bestuivers in deze landen kan belemmeren. Dit is een probleem omdat de ecosysteemdiensten die bestuivers leveren gunstig kunnen zijn voor ontwikkelingssteden zoals Dar es Salaam. Maar net als veel andere snel groeiende steden in de tropen heeft Dar es Salaam te maken met een groot aantal milieu- en sociaaleconomische problemen. Om een aantal van deze milieuproblemen te verminderen, hebben de Wereldbank en de Tanzaniaanse regering een plan ontwikkeld om de Msimbazi-rivier, die regelmatig overstroomt, om te vormen naar een bekend stadspark. Hoewel de toevoeging van maatregelen voor het behoud van bestuivers in dit plan gunstig kan zijn, is er een gebrek aan kennis over de meest effectieve maatregelen in snel groeiende steden in tropische ontwikkelingslanden. Om te bepalen welke maatregelen ter bescherming van stedelijke bestuivers de grootste kans van slagen hebben is de volgende onderzoeksvraag gesteld: Welke maatregelen voor het behoud van stedelijke bestuivers hebben de meeste kans om succesvol geïmplementeerd te worden in het geplande Msimbazi Wetlands and City Park in Dar es Salaam?

Om de onderzoeksvraag te beantwoorden werden drie deelvragen gebruikt:

1. Wat zijn algemeen succesvolle maatregelen voor het behoud van bestuivers in stedelijk groen?
2. Wat zijn de belemmerende factoren die specifiek zijn voor ontwikkelingslanden in de tropen die invloed hebben op de implementatie van algemeen succesvolle maatregelen voor het behoud van stedelijke bestuivers?
3. Welke van de belemmerende factoren op de implementatie van stedelijke bestuivers zijn aanwezig in Dar es Salaam en hoe kunnen deze worden gemitigeerd of voorkomen?

Zes maatregelen voor het behoud van bestuivers bleken succesvol in de meerderheid van de gevonden artikelen. Het doel van deze maatregelen is het creëren van een ideale stedelijke omgeving voor bestuivers bestaande uit een goed verbonden netwerk van groene gebieden met voldoende nestplaatsen. De zes maatregelen werden verder onderzocht om hun ontwerp, implementatie en beheer te bepalen. Van de zes over het algemeen succesvolle maatregelen werden er vijf negatief beïnvloed door beperkende factoren die specifiek zijn voor tropische ontwikkelingslanden. De meerderheid van de beperkende factoren waren sociaaleconomisch van aard, maar het gebrek aan gegevens over het behoud van bestuivers en biodiversiteit in de tropen was ook een belangrijke beperkende factor bij de implementatie van beschermingsmaatregelen. De beperkende factoren en sociaaleconomische omstandigheden van Dar es Salaam zijn verder onderzocht en beschreven in het proefschrift. Dit is gedaan om te bepalen of Dar es Salaam last heeft van de beperkende factoren en of deze kunnen worden gemitigeerd of voorkomen.

Dar es Salaam bleek last te hebben van alle beperkende factoren. Het merendeel van de beperkende factoren kan gemitigeerd of zelfs voorkomen worden als er sprake is van goed bestuur of een grote betrokkenheid van de gemeenschap. Het gebrek aan gegevens over het behoud van bestuivers en biodiversiteit in de tropen kon redelijkerwijs niet gemitigeerd worden op korte termijn. De belangrijkste implicatie van dit afstudeerwerkstuk is dat het mogelijk is om algemeen succesvolle maatregelen voor het behoud van stedelijke bestuivers te bepalen en dat deze ongeacht de locatie geïmplementeerd kunnen worden. Een randvoorwaarde is dat goed bestuur en grote betrokkenheid van de gemeenschap voorwaarden zijn voor succesvolle implementatie en onderhoud.

Dit afstudeerwerkstuk toont aan dat er zes algemeen succesvolle maatregelen zijn voor het behoud van stedelijke bestuivers die geïmplementeerd kunnen worden in de Msimbazi Wetlands and City Park van Dar es Salaam. De beperkende factoren in Dar es Salaam kunnen meestal worden gemitigeerd of worden voorkomen. De belangrijkste lange termijn aanbevelingen zijn het uitvoeren van een soorteninventarisatie en het regelmatig monitoren van de diversiteit aan bestuivers in de Msimbazi Wetlands and City Park.

1. General introduction

1.1 Urban pollinator conservation

Pollinators are an essential part of the global ecosystem and provide an irreplaceable ecosystem service. As much as 75% of agricultural crops need pollination for reproduction or fruit production and 87,5% of all plant species require animal pollination. Their irreplaceable value makes the observed global decline a cause for concern and has attracted significant global attention (Silva et al., 2023). One of the main drivers of this decline of pollinator biodiversity and abundance is urbanization. Pollinators in urban environments face significant challenges such as the urban heat island effect, pollution and habitat loss or degradation (Wenzel et al., 2020). But surprisingly, specific urban environments can serve as hotspots of pollinator diversity when compared to surrounding intensively managed agricultural areas. This is caused by the lack of diverse floral resources and pesticide use in the intensified agricultural areas and the relative abundance of floral and nesting resources in urban green areas (Ayers & Rehan, 2021). But these results are not universally true for all pollinators and urban areas generally have more generalist species than specialists. Bee biodiversity in particular tends to be higher in urban areas when compared to other pollinators (Wenzel et al., 2020). In two West African cities, beetles and wasps were found to have a lower biodiversity in urban areas when compared to surrounding agricultural areas. The abundance and biodiversity of bees in cities was comparable to other areas but was dominated by different functional groups (Guenat et al., 2019). In another study the results showed hoverfly abundance and diversity was actually higher in rural areas instead of urban areas (Verboven et al., 2014).

The positive impact of urban green areas on the biodiversity of some pollinators has caused several international, continental, national and local groups to advocate and initiate urban pollinator conservation strategies. These strategies attempt to conserve pollinator biodiversity by implementing measures such as planting flowers, reducing pesticide use and maintaining urban green areas. The success of these initiatives has been mixed and several knowledge gaps remain (Stout & Dicks, 2022). One of the most severe knowledge gaps about the impact of urbanization on pollinator biodiversity is the lack of data for tropical and developing countries. Silva et al. (2023) performed a systematic review of the literature on urban pollinators and found that over 67% of these studies came from temperate regions. This is especially important since several regions in the tropics are expected to see the largest increases in land use and urbanization (Priya & Senthil, 2021). Another issue is that the response of pollinators to anthropogenic pressures and land use changes might differ in temperate and tropical nations. Part of the reason why this is likely is because of the increased sensitivity of pollinators to temperature changes and greater specialization in the tropics. But the true extent of these differences is unclear (Millard et al., 2021). These knowledge gaps hamper the efficient implementation of urban pollinator conservation measures. The impact socioeconomic differences between nations can have on urban pollinator diversity and conservation is also poorly understood (Turo & Gardiner, 2019). There is some research focused on the impact of urban conservation measures in tropical developing countries. A study in Ghana for example showed that some general management practices such as limiting pesticide application and reduced mowing frequency have a positive impact on pollinator biodiversity in developing tropical cities as well as developed temperate cities (Guenat et al., 2019).

1.2 Dar es Salaam and the Msimbazi Basin

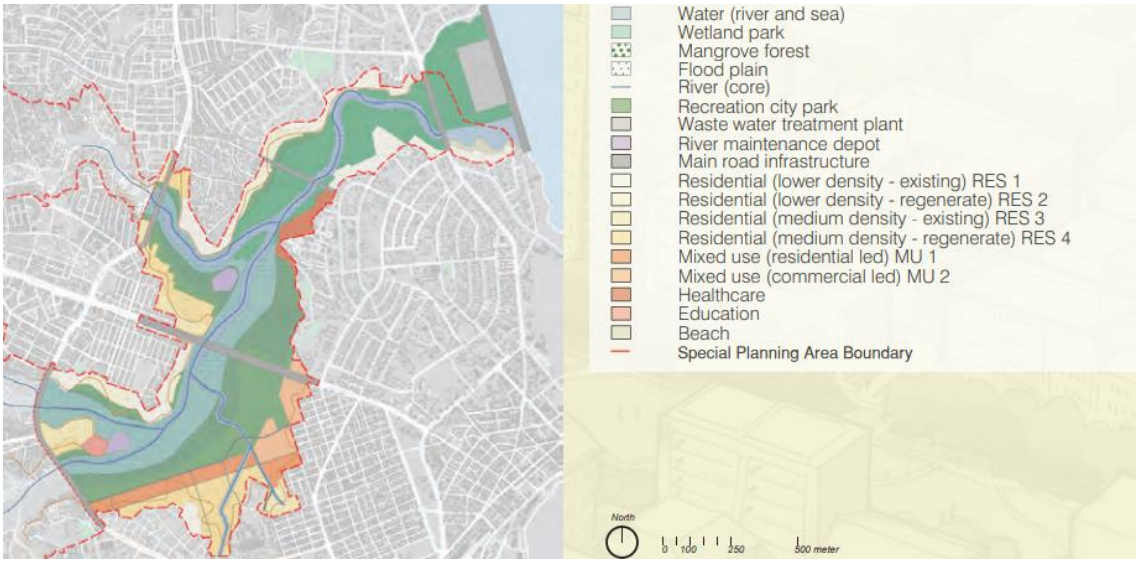
For urban pollinator conservationists and urban planners in the tropics the question which set of measures to take in the context of a rapidly growing city in a tropical developing nation is still under-researched (Baldock, 2020). One of the cities where these urban pollinator conservation measures could be useful is Dar es Salaam. It is a city with a long history of urban farming, and a significant amount of the vegetable crops consumed in the city such as pumpkin or okra are produced by urban farming (Wesselow et al., 2020). In fact, most vegetables in the markets of Dar es Salaam are grown along the Msimbazi river valley flowing within the city (Kihampa & Mwegoha, 2010). Of the most frequently grown crops in Dar es Salaam, several require sufficient pollination for the development of high-quality fruits and seeds (Wesselow et al., 2020). Therefore, the increase in yields associated with a higher abundance and biodiversity of pollinators is a significant incentive (Katumo et al., 2022). Another recent study performed in San Francisco showed that tomatoes pollinated by wild bees in urban areas outperformed controls in fruit set, seed set, yields and fruit mass (Potter & LeBuhn, 2015). In a more rural area in Northern Tanzania researchers showed that watermelon yield was negatively affected by a lack of pollinators in the area (Sawe et al., 2020). These results suggest that urban pollinator conservation could benefit urban farmers, food security and food availability in Dar es Salaam, especially in the Msimbazi basin.

Dar es Salaam is also a city that struggles with significant environmental and social challenges. The city has experienced decades of uncontrolled rapid urbanization consisting mostly of informal settlements (Peter & Yang, 2019). The current urbanization and population growth rates in Dar es Salaam are unprecedented and present a host of different issues. Large patches of neighboring forest are converted into agricultural land and woods are chopped down for fuel. In the Dar es Salaam Metropolitan Area tree cover dropped about one third between 2002 and 2008 and has continued to drop in the years after (Bhanjee & Zhang, 2018). Rivers flowing through the city such as the Msimbazi river and its tributaries are heavily polluted with heavy metals. The levels of lead, copper and chromium are far above globally accepted levels and pose a serious health hazard to the residents of Dar es Salaam. Because of the highly polluted nature of the river, the irrigation of crops using the waters of the Msimbazi river is dangerous. As much as 97 percent of all adults in Dar es Salaam are at risk of developing lead related carcinogenic effects from consuming vegetables grown in the Msimbazi river valley. (Kihampa & Mwegoha, 2010).

Flooding has also been a major issue in recent years. In the years 2009, 2010, 2011, 2014, 2017, 2018 and 2019 floods devastated the city causing major damage to property and infrastructure, dozens of human casualties and disease outbreaks. About 39 percent of the population is affected by the flooding and the estimated cost of flooding in Dar es Salaam is about 2 to 4 percent of the total GDP of the city. The destruction caused by the recurrent floods also harms the economic activity of the city and hampers its economic growth (Anande & Luhunga, 2019). These issues are expected to worsen because of climate change, the further growth of informal settlements and urban sprawl. To address some of the main environmental issues of Dar es Salaam, in the Msimbazi river basin in particular, the government of Tanzania in collaboration with the World Bank has created the Msimbazi Basin Development Project.

The main objectives of the Msimbazi Basin Development Project are to restore the natural ecosystem and ecosystem services of the Msimbazi Basin by cleaning up the river, building necessary infrastructure, removing illegal settlements on the riverbanks and create the Msimbazi Wetlands and City Park in the lower floodplains of the Msimbazi river. The expectation is that these actions will lead to a large number of different benefits including discharge of stormwater, creation of amenity space for the public, provision of grey and drinking water, irrigation and land for urban agriculture, an increase in biodiversity and land for the development of residential or commercial areas (The Worldbank, 2019). The Msimbazi Wetlands and City Park is envisioned as a well-connected urban green space in the heart of Dar es Salaam (The Worldbank, 2019). The land use map of the Lower Msimbazi River included the urban park is shown in figure 1.

Figure 1: Land use map of the Lower Msimbazi River (The Worldbank, 2019)



But the creation and maintenance of urban green spaces in Africa has been difficult because of the lack of financial resources or social and political will (Lindley et al., 2018). Urban green development in Africa is most effective when correctly planned and the ecosystem services such as those provided by pollinators are sufficiently recognized (Schäffler & Swilling, 2013). As stated earlier, the knowledge gaps regarding urban pollinator biodiversity and conservation measures in the tropics are glaring. But research suggests we cannot wait for all these knowledge gaps to disappear before we act. The application of the precautionary principle which states that precautionary measures should be taken to preserve biodiversity even when not all data is available, has been shown to be necessary for the successful conservation of pollinators (Drivdal & van der Sluijs, 2021). There are no established guidelines or set of measures for urban pollinator conservation in the tropics or developing nations. Therefore, using the Msimbazi Wetlands and City Park as an example, this thesis will research the urban pollinator conservation measures with the highest likelihood of being successful in the context of a rapidly growing tropical city in a developing country. This objective has led to the formulation of the following research question: Which urban pollinator conservation measures are most likely to be successfully implemented in the planned Msimbazi Wetlands and City Park in Dar es Salaam?

To answer the research question, the following sub questions will be used:

1. What are generally successful urban pollinator conservation measures for urban green spaces?
2. What are the constraining factors specific to developing nations in the tropics influencing the implementation of generally successful urban pollinator conservation measures?
3. Which of the constraining factors on the implementation of urban pollinator conservation are present in Dar es Salaam and how can these be mitigated or prevented?

The expectation is that by providing answers to these questions the thesis will be able to demonstrate what urban pollinator conservation measures will likely be successful in the context of the planned Msimbazi Wetlands and City Park in Dar es Salaam. In addition, it can offer a guideline for researching which urban pollinator measures can be successful in a tropical city. The thesis does this by determining the most generally successful urban pollinator conservation measures, establishing the constraints faced by tropical cities in developing nations and providing an example of how this information can be used to determine necessary pollinator conservation measures during the planning of urban green spaces in tropical cities. Recommendations made within the report regarding the measures that will likely be successful can be used to support further initiatives and proposals. The main beneficiaries of the thesis will be the developers of the Msimbazi Basin Development Project, conservationists in Tanzania, conservationists and urban planners in other tropical or developing nations, the city council of Dar es Salaam and the citizens of Dar es Salaam.

2. Methodology

2.1 Research approach

The research question and the associated sub-questions was answered using an integrative literature review (Lubbe et al., 2020). The data was gathered by making use of two search methods, database search and snowball search. The database search was used to identify a set of sources that fully satisfy the search criteria. This was done by using several online academic search engines and databases. These are Google Scholar, Nature, Scopus, Science Direct and Springer Link. After identifying these sources, a snowball search looked for relevant sources within the list of references of the study and citations of the study in other articles. This process was repeated until there were no more sources that satisfied the search criteria. Using this method past and recent relevant articles were identified in a systematic way (Wohlin et al., 2022). Official documents of the World bank and the Tanzanian government were used to gather information about the Msimbazi basin development project and pollinator conservation in Tanzania.

2.2 Search terms

To identify the relevant articles, a set of key terms related to the main concepts of the research were used. Synonyms of these key terms were included to avoid exclusion of relevant data. These key terms were used in combination with sub-question specific terms. To ensure that the database searches were as productive as possible, boolean operators such as AND, OR and NOT were used to combine or exclude certain key terms and sub-question specific terms. Multiple sub-question specific terms were combined with the key terms if it led to relevant data. The key terms and sub-question specific terms that were used are shown in table 1.

Table 1: Key terms and sub-question specific terms

Key terms	What are generally successful urban pollinator conservation measures for urban parks?	What are the constraining factors specific to developing nations in the tropics influencing the implementation of generally successful urban pollinator conservation measures?	Which of the constraining factors on the implementation of urban pollinator conservation are present in Dar es Salaam and how can these be mitigated or prevented?
Pollinator biodiversity	Urban, peri-urban, urban park, conservation measures	Urban, peri-urban, developing nation, Southeast Asia, Brazil, Latin America, South Asia, Africa, poverty, rapid urbanization, tropics, conservation measures	East African Coastal Forest, Tanzania
Dar es Salaam	-		Pollinator biodiversity, poverty, green space management, deforestation, mitigation, Dar es Salaam
Msimbazi Basin	-		Green space, pollution, development project, ecosystem, biodiversity, Msimbazi, heavy metal

2.3 Inclusion and exclusion criteria

To be included in the research a source needed to satisfy all the criteria shown in table 2. Data needed to be from reputable and veritable sources such as scientific journals, official governmental documents or documents from international bodies like the world bank. They needed to be written in English or Dutch. The publication date of the source was preferably as recent as possible. This means articles older than the year 2000 (except for species descriptions) were generally excluded from the research but especially relevant older articles that were cited frequently in multiple found articles were included. Lastly another criterion for experimental studies was whether there was a follow-up study or long-term data. In most cases this criterion was not necessarily used to exclude sources, but to highlight the most useful sources. In the case of a clear lack of data which is also highlighted in the article or document itself these articles will be excluded. This does not include review articles.

Table 2: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
From a reputable and veritable source	Popular scientific articles, opinion pieces, unveritable sources
Written in English or Dutch	Written in languages other than English or Dutch
Publication date of source not before 2000	Source publication date is older than 2000
Has a follow up study or long term research	Has no follow up study or not long term research. And results are unreliable due to a lack of data

2.4 Analysis of generally successful measures for an urban pollinator conservation strategy and constraining factors of tropical developing nations

To determine the successful measures for an urban pollinator conservation strategy, relevant urban pollinator conservation studies were categorized into 2 categories:

- Positive impact
- Negative impact

In this context the impact indicates the effect of the measures on the biodiversity of pollinator species. Measures which have a positive impact increased or maintained biodiversity and those with a negative impact decreased biodiversity. For the measures that were found to have a positive impact a general overview was made describing the requirements for their implementation and maintenance.

When these generally successful measures were established, data concerning the constraining factors influencing urban pollinator conservation in tropical developing nations was compiled. There was a focus on constraining factors mentioned in articles related to socioeconomic factors or differences between the conservation of tropical and temperate pollinators.

2.5 Analysis of the constraining factors on the implementation of urban pollinator conservation in Dar es Salaam and how these can be mitigated or prevented

Governmental and scientific data were compiled to provide an overview of the socioeconomic factors in Dar es Salaam that were found to be relevant in the previous sub question. Afterwards this data was analyzed and compared with the constraining socio-economic and pollinator conservation related factors for the implementation of urban pollinator conservation measures in tropical developing nations, to determine which of these are present in Dar es Salaam. Ways of mitigating or preventing the constraining factors that were found to be present were described.

Using the results of these sub questions, the research question was answered and a set of recommendations for the implementation of urban pollinator conservation in the Msimbazi Wetlands and City Park was made.

3. *Results*

3.1 What are generally successful urban pollinator conservation measures for urban green spaces?

Six urban pollinator conservation measures were found to have a positive impact in most of the articles, and 3 showed a negative impact. The measures that were found to have a positive impact were based on creating conditions suitable for pollinators within urban environments. These included creating an abundance and diversity of floral resources, connecting urban green and natural areas and creating appropriate nesting sites (Baldock, 2020). The ideal urban environment for pollinators consists of a well-connected network of green areas with ample amounts of nesting sites (Wilson et al., 2017). The different measures were not mutually exclusive and were frequently used in combination with each other. In fact, a recent study suggests combining measures is necessary to achieve satisfactory results (Iwasaki & Hogendoorn, 2023). Table 3 shows the measures and whether they had a positive or negative impact.

Table 3: Impact of measures

Measures with a positive impact	Measures with a negative impact
Flower meadows (Hoyle et al., 2018)	Introducing and managing nonnative bees (Iwasaki & Hogendoorn, 2022)
Pollinator friendly mowing regiment (Aguilera et al., 2019)	Pesticide use on ornamental plants or agricultural crops (Lentola et al., 2017)
Pollinator friendly city trees and shrubs (Pardee & Philpott, 2014)	
Minimize impervious cover (Quistberg et al., 2016)	
Artificial trap nests (Fortel et al., 2016)	
Green roofs (Hofmann & Renner, 2018)	

3.1.1 Flower meadows

Artificial flower meadows are usually patches or linear strips of planted flowers. The goal of artificial flower meadows is to sustain an abundance of floral resources in urban areas (Hoyle et al., 2018). It is an increasingly popular measure and is one of the most mentioned recommendations in urban pollinator conservation studies (Baldock, 2020). Flower meadows have been shown to increase the biodiversity of pollinators significantly when compared to amenity grass lawns (Davis et al., 2017). Most floral meadows attempt to provide a higher density and diversity of flowers in an area. But there is evidence suggesting the species composition of a floral meadow is more important than its size, diversity or density (Prendergast et al., 2022). Figure 2 displays an example of small high diversity urban flower meadow patches.

Figure 2: Examples of flower meadow patches in urban area (Griffiths-Lee et al., 2022)

Design and implementation

Flower meadows vary in design and implementation greatly depending on the context and preferred results but there are a few key considerations. Preferably use native flowering species that allow more specialist pollinators to benefit (Hoyle et al., 2018). This ties in with the need to properly source seed or seedling mixes suitable for the local climate and conditions (Hoyle et al., 2018). Unsuitable species selection usually leads to the death of the flower meadow. But proper species selection is not only based on the direct environment. It is also necessary to select species with a diversity of flowering periods to ensure floral resources throughout the year (Hoyle et al., 2018). A diversity of flower colors within the flower meadow was also found to increase the abundance of pollinators (Braman & Griffin, 2022). When a proper set of species are selected try to create large and connected flower meadows, as these are generally higher in biodiversity and more cost effective (Baldock, 2020). Since most meadow species suitable for flower meadows are intolerant of shade make sure to plant or sow them in a sunny or lightly shaded area (Magda et al., 2015)

Management

The management of a flower meadow is partly determined by the local conditions. To create attractive conditions for pollinators, make use of a pollinator friendly mowing regiment, see chapter 3.1.2 (Baldock, 2020). Another important part of management is continued engagement with the public to ensure continued support for the flower meadows (Baldock, 2020). Lastly invasive and persistent weeds with low benefits to pollinators should be removed (Braman & Griffin, 2022).

3.1.2 Pollinator friendly mowing regiment

A pollinator friendly mowing regiment is used to combat the lack of floral resources and low biodiversity characteristic of urban amenity grasslands (Aguilera et al., 2019). Pollinator friendly mowing regiments can be implemented alongside floral meadows but can also be used without sowing or introducing plants to recreate semi natural grassland (Banaszak-Cibicka et al., 2018). Semi natural grasslands consisting of spontaneously established flora have a high biodiversity. This high biodiversity is maintained by the regular reduction of light competition because of regular mowing (Johansen et al., 2019).

Design and implementation
Citizens can perceive a pollinator friendly mowing regiment to be unmanaged or messy when compared to regularly mowed amenity grassland. Because of this common perception, citizen engagement and a clear mowing schedule plan suited to the needs of people and pollinators before implementation is a necessity (Johansen et al., 2019).

Management
A heterogenous mowing frequency which creates heterogenous areas of intensively and rarely mowed areas is characteristic of a well-managed pollinator friendly mowing regiment (Johansen et al., 2019). When determining which areas to mow intensively the number of flowering plants in a patch should be considered. The patches with a high density of floral resources can be left alone until after most of the plants have set seed (Banaszak-Cibicka et al., 2018). The main management consideration in areas with high fertilizer use is to remove lawn clippings, these can cause eutrophication of the soil which can negatively impact the floral diversity (Aguilera et al., 2019).

3.1.3 Pollinator friendly city trees and shrubs

Planting trees and shrubs as a measure for urban pollinator conservation was less commonly mentioned in the reviewed articles when compared to flower meadows. But flowering city trees and shrubs are highly attractive to pollinators and have the ability to support a high abundance and diversity of pollinators **(**Pardee & Philpott, 2014). Trees and shrubs play several important roles for pollinators in cities including but not limited to offering nesting sites and floral resources (Somme et al., 2016). Mass flowering trees can increase local pollinator abundance significantly, even to the degree that they might draw away pollinators from other floral sources. But the increase in pollinator abundance increases pollination and therefore yield or reproductive success in surrounding plants after the mass flowering event is finished (Grab et al., 2017). This process is illustrated in figure 3.

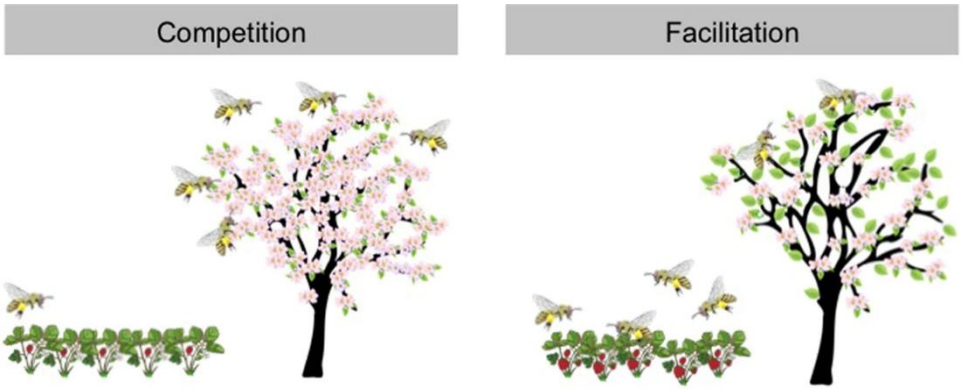


Figure 3: Process by which the attraction of pollinators to mass flowering trees increases pollination in surrounding plants after the mass flowering event is finished (Grab et al., 2017).

Trees and shrubs are especially important for vertebrate pollinators such as bats and birds. The density of suitable flowering trees and shrubs is the main determinant of the occurrence of nectivorous sunbirds in South African cities (Coetzee et al., 2018). For nectivorous bats, flowering trees are not only important for supplying nectar but also provide crucial roosting sites (Kelm et al., 2008).

Design and implementation
When selecting suitable species, the focus should be on native species adapted to the local climate and trees and shrubs that flower at different points in time to increase floral resources throughout the year (Pardee & Philpott, 2014). If the

appropriate trees and shrubs are selected a diversified environment can be created in areas with ample amounts of space such as parks by creating a gradual transition from woods to shrublands and grasslands. These diversified landscapes can support a high diversity of pollinators (Gomes et al., 2023). The pollinator diversity can be further heightened by selecting native bat and bird pollinated trees and shrubs, which can be an invaluable resource for urban vertebrate pollinators (Diniz et al., 2019). To increase the abundance of pollinators in a local area, planting mass flowering trees is an effective measure (Grab et al., 2017).

Management
The management depends on the local conditions and the individual species but there are some generally effective management measures. Nesting sites can be provided by allowing dead wood to remain within an area **(**Pardee & Philpott, 2014). Another effective measure to provide nesting sites is to retain trees with hallows or cavities in urban areas (Kelm et al., 2008). To increase the floral resources in an area trees and shrubs should not be cut before flowering **(**Pardee & Philpott, 2014). When they are cut this can be done periodically depending on the local conditions to decrease light competition (Somme et al., 2016).

3.1.4 Decreasing impervious cover

Impervious surfaces in urban environments have a negative impact on bee abundance and biodiversity (Burdine et al., 2019). Not only because they decrease the amount of bare soil suitable for ground nesting species but also because they increase urban temperature. In a study performed in the United States, bee abundance decreased as much as 41% every time urban temperature increased a single degree (Hamblin et al., 2018). The negative impact of impervious cover on ground-nesting bee species is well-established (Prendergast et al., 2022). Thus, increasing the amount of bare soil in urban green areas is a simple yet effective measure for urban pollinator conservation (Somme et al., 2016). The degree of impervious cover and the temperature in urban areas was in fact found to be more predictive of bee abundance than the availability of floral resources (Hamblin et al., 2018).

Design and implementation
To effectively support soil nesting bee populations, provide sufficient floral resources within 500 meters of the bare soil patches (Burdine et al., 2019). These patches of bare soil should be maintained in different environments such as grasslands and riverbanks (Somme et al., 2016). Preferably in the sandy areas used by many ground-nesting bees (Prendergast et al., 2022). In more urban areas where there are large continuous areas with impervious cover such as parking spaces, more permeable materials can be used to increase the amount of bare soil (Prendergast et al., 2022).

Management
Very little management is necessary except the regular removal of mulch and vegetation to maintain bare soil patches (Burdine et al., 2019)

3.1.5 Artificial trap nests

Artificial trap nests also called bee hotels are a measure that provide nesting sites to cavity nesting bee and wasp species. They typically consist of a wooden box filled with bamboo, hollow shrub branches and reed. Several different types of artificial trap nests or bee hotel are illustrated in figure 4 (Fortel et al., 2016).

Figure 4: Different types of artificial trap nests or bee hotels (Rahimi et al., 2021).

The effectiveness of artificial trap nests for the conservation of native bee species was found to be mixed in some areas, with one study suggesting bee hotels are predominantly inhabited by invasive bee or wasp species (Geslin et al., 2020).

But an extensive review of the efficiency and nest occupancy of bee hotels showed that bee hotels are effective in most of the cases (Rahimi et al., 2021).

Design and implementation
Structural features of bee hotels such as size were not found to be important, but the placement and protection from the climate was found to be important, the box should be protected from rain and wind (Rahimi et al., 2021). Care should also be taken to place the bee hotels entrance faced to either the north in hot climates or south in temperate climates (Wilson et al., 2020). To ensure that pollinators can use the bee hotel, it should be placed in proximity to sufficient floral resources (Araújo et al., 2020). The tubes and hollows within a bee hotel, partly determine whether a bee hotel gets occupied, easy access to these tubes and hollows is thus a necessity (Rahimi et al., 2021). The tubes should have different lengths and diameters catering to the preferences of multiple species (Araújo et al., 2020). They can be made from smooth cardboard, bamboo, or wooden tubes and plastic should be avoided (McCallum et al., 2018). Lastly, there is some evidence suggesting the color of a bee hotel influences its success. Blue, yellow, purple, white or green were preferred by females of *Centris analis* (Boff & Friedel, 2021).

Management
Th management of artificial trap nests is relatively simple. Firstly, tubes or hollows should be periodically renewed, and boxes need to be regularly inspected for invasions of parasitic species or ants (Rahimi et al., 2021).

3.1.6 Green roofs

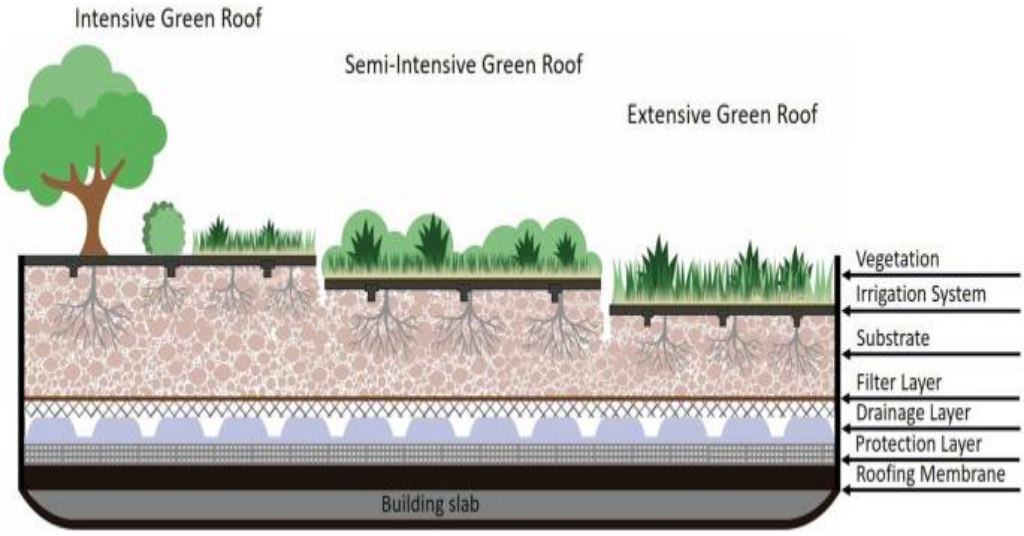


Figure 5: Visual representation of the different types of green roofs (Calheiros & Stefanakis, 2021).

Green roofs can be categorized into three general types extensive, semi-intensive and intensive. These types are illustrated in figure 5. Green roofs differ in maintenance, cost, soil depth, irrigation and floral composition (Passaseo et al., 2020). Extensive green roofs in urban areas were found to have a positive impact on urban pollinator biodiversity by providing floral resources in otherwise inhospitable areas **(**Hofmann & Renner, 2018). They provide suitable habitat for multiple pollinator groups including less commonly considered groups such as wasps and beetles (Braaker et al., 2017). More intensively managed green roofs do host a larger diversity of species when compared to their more extensive counterparts (Passaseo et al., 2021).

Design and implementation
Although green roofs are highly variable there are some generally successful designs and implementation choices. The first consideration should be whether the current roof can support the additional weight of the vegetation and substrate even after rainfall (Langemeyer et al., 2020). Generally, a deeper substrate with patches of bare soil is preferred to attract ground nesting species. But the carrying capacity of the original roof determines if a deeper substrate is possible (Tonietto et al., 2011). The selection of the vegetation that is planted on a green roof is usually done beforehand. The spontaneous establishment of other species should be allowed since these species might be better adapted to local conditions than those initially selected. (Langemeyer et al., 2020). The ground level areas surrounding the green roof, should also contain adequate floral resources, the green roofs will otherwise become

isolated (Tonietto et al., 2011). In fact, green roofs should preferably be part of a larger network to avoid isolation (Langemeyer et al., 2020).

Management
Extensive green roofs are characterized by being relatively low maintenance when compared to the more intensive roofs. The maintenance can be as simple as watering if the region is experiencing drought and periodically removing excess vegetation (Zhang et al., 2012). Semi-intensive and intensive green roofs in contrast need more intensive management similar to a garden or city park (Berndtsson, 2010).

3.1.7 Measures with a negative impact

As mentioned in table 3 there are also measures that can have a negative impact on pollinator biodiversity. Introducing and focusing on managed bees in areas where they are not native can have a negative impact on native species for example. Managed species such as honeybees and bumblebees are strong competitors and can outcompete native bees leading to a decrease in native biodiversity (Iwasaki & Hogendoorn, 2022). But a measure which might be even more harmful is the application of pesticides to ornamental and agricultural crops. There is a strong body of research which suggests that the current decrease in pollinator diversity is at least partly caused by pesticide use (Lentola et al., 2017).

3.2 What are the constraining factors specific to developing nations in the tropics influencing the implementation of generally successful urban pollinator conservation measures?

To determine which constraining factors are influencing the implementation of generally successful urban pollinator conservation measures discussed in the previous chapter, a literature review was performed. Of the 6 generally successful urban pollinator conservation measures, 5 were found to be constrained by factors regularly encountered in the conditions of developing nations in the tropics. Constraining factors related to socioeconomic conditions influencing the establishment and management of urban green areas were the most prevalent. Most generally successful measures needed effective management to be successful but urban green management was commonly insufficient in developing countries (Chishaleshale et al., 2015). Only the maintenance of bare soil was found to not be influenced by constraining factors in developing nations because these countries generally have less built-up area and this measure has very low costs (Guenat et al., 2019). Table 4 shows the constraining factors influencing the successful implementation of urban pollinator conservation measures.

Table 4: constraining factors influencing the successful implementation of urban pollinator conservation measures specific to developing tropical nations.

Constraining factors	Reference
High population density and low wealth	Richards et al., 2017
Lack of funds for the implementation and management of urban green areas	Chishaleshale et al., 2015
Lack of manpower for the management of urban green areas	Chishaleshale et al., 2015
Low community engagement	Richardson & Shackleton, 2014
Weak zoning laws	Narh et al., 2020
Vandalism, firewood collection and livestock damage	Richardson & Shackleton, 2014
Informal settlement in urban green spaces	Adegun, 2018
Significant tangible and perceived ecosystem disservices	Thorn et al., 2021
Significant pollution of urban green areas related to inadequate waste management	Adegun, 2018
Lack of research on the nesting and floral resource preferences of tropical pollinators	Silva et al., 2021
Few urban vertebrate pollinator conservation measures described in literature	Winfree et al., 2011
Needing to provide abundant floral resources throughout the entire year	Basilio et al., 2006

The constraining factors can be broadly categorized into 5 types: Governance issues, lack of data, ecosystem disservices, land use disputes, and lack of wealth.

3.2.1 Socioeconomic factors negatively influencing urban pollinator conservation

Lack of wealth

Socioeconomic factors were found to influence the establishment and management of urban green areas in tropical developing nations. Population density and wealth were the main determinants of the quantity and structure of urban green areas in tropical Southeast Asia. Large cities with a high population density and low wealth showed the lowest quantity of urban green areas. The urban green spaces in these cities were also highly fragmented. In contrast, smaller less densely populated cities and wealthy cities had more urban green spaces and higher connectivity between urban green areas (Richards et al., 2017). In South Africa the wealth and population density of small towns was correlated with the size and amount of managment of urban green spaces. With low-income towns having significantly lower amounts of urban green spaces (McConnachie et al., 2008). The phenomenon of wealthier areas having higher quantity, better connected and better-quality public and private urban green spaces has been called the ''luxury effect'' (Chamberlain et al., 2019). The phenomenon occurs in several different cities and countries ranging from developed to developing (Leong et al., 2018). Even in extremely poor countries such as Burundi differences in wealth have a significant impact on the quantity and quality of urban areas (Bigirimana et al., 2012). But the luxury effect seems to be less pronounced in wet tropical areas when compared to temperate or arid areas. This might be related to the relatively rapid growth and establishment of plants in wet tropical areas (Leong et al., 2018).

Governance issues

Governance issues pertaining to the planning, implementation and maintenance of public green areas are especially challenging factors in tropical developing nations because of unique factors. The governments of developing nations are more likely to not recognize the value of green urban areas and make use of outdated planning models (Roy et al., 2018). The planning and implementation can be hindered by corruption or political interference. The will to implement and maintain urban green areas is also highly subject to the political cycle (Muderere, 2011). This leads to a lack of funds and coordination between the different governmental bodies during all the phases of urban green area development. This lack of funds and coordination prevents local governments from providing regular maintenance of their urban green areas (Chishaleshale et al., 2015). Neglectful maintenance and low community engagement encourages vandalism, firewood collection and livestock damage in the urban green areas of developing nations (Richardson & Shackleton, 2014).

Land use disputes

Informal or illegal development in urban green areas has a large impact on the management of urban green spaces. Inadequate waste management in these informal communities can cause environmental degradation and unhygienic conditions. To prevent the establishment of informal settlements increased management and surveillance is necessary, exacerbating already severe deficits in manpower or budgets (Adegun, 2018). Weak zoning laws contributed further to the issue of encroachment of urban green areas (Narh et al., 2020). Competing interests regarding the use of urban green areas were also found to be prevalent in developing countries and negatively influence the successful implementation of urban green development (Francis et al., 2023).

Ecosystem disservices

Ecosystem disservices are a major concern for the residents of cities in the developing world. The lack of maintenance of green areas were a significant source of dissatisfaction with urban green areas in poor communities of South Africa. These included the increased risk of animal attacks, pests, diseases caused by mosquitos or bats, risk of falling branches and infrastructure damage caused by tree roots. The perception of these risks was not unique to poor communities but was especially pronounced in this group, likely because the ecosystem disservices of unmanaged urban green areas are most prominent in poor communities (Adegun, 2018). The perception of ecosystem disservices can be so negative that contrary to developed nations proximity to green areas can lower home prices in certain South African cities (Cilliers & Cilliers, 2015).

3.2.2 Differences between temperate and tropical pollinators affecting urban pollinator conservation

Pollinator diversity and composition were found to differ significantly between temperate and tropical areas. The abundance and percentage of animal pollinated plants is higher in the tropics compared to temperate zones. Almost 94% of tropical plant communities required animal pollination compared to just 78% of temperate plant communities (Ollerton et al., 2011). The reason for the lower amount of wind pollinated species in the tropics is unknown (Schemske et al., 2009). The high biodiversity of animal pollinated flora is also reflected in greater specialization of tropical pollinator species. This can make conservation efforts more complex (Ollerton et al., 2011).

Lack of data

The lack of research on the pollination systems and nesting or floral resource preferences of tropical pollinators is a significant constraining factor for successful urban conservation efforts. Both tropical insect and vertebrate pollinators are underrepresented in pollinator related research (Silva et al., 2021). The lack of data concerning vertebrate pollinators is an almost uniquely tropical problem, since the tropics host a far larger diversity of vertebrate pollinators compared to temperate areas. This poses issues for tropical urban pollinator conservation since the few articles studying vertebrate pollinators found them to be sensitive to urbanization (Winfree et al., 2011). But the response of vertebrate pollinators to urbanization is not uniform. Some bat species prefer urban areas, while others are threatened by habitat fragmentation (Russo & Ancillotto, 2015). Nectivorous birds in South Africa can generally persist in suburban areas but they were found to avoid densely built-up city centers (Coetzee et al., 2018).

Lack of wealth

Pollinator abundance and richness in tropical urban city parks was found to be relatively stable throughout the year in Bangkok (Stewart & Waitayachart, 2020). This contrasts with pollinators in more temperate areas that show lower activity in winter (Basilio et al., 2006). Thus, the provision of continuous floral resources throughout the entire year in tropical areas is necessary, which might increase the maintenance costs of urban green spaces (Stewart & Waitayachart, 2020).

The pollinator related issues discussed in this chapter can be considered to be pan-tropical, in contrast to the socio-economic constraining factors which vary more among localities.

3.3 Which of the constraining factors on the implementation of urban pollinator conservation are present in Dar es Salaam and how can these be mitigated or prevented?

This chapter attempts to determine whether constraining factors influencing the implementation of urban pollinator conservation are present in Dar es Salaam and how these could be mitigated or prevented.

3.3.1 Overview of the socio-economic conditions of Dar es Salaam

Dar es Salaam is exemplary of several rapidly growing cities in Africa. Urbanization is not necessarily correlated with development or employment. African urbanization is in fact characterized by a limited employment, endemic poverty levels, rapid growth and nonexistent or deteriorating public service provision (Peter et al., 2019). The rapid growth of the city is mostly in the form of densely populated low-income informal settlements, which contain almost 70% of the city's population. They are often concentrated in vulnerable urban green areas prone to flooding such as the Msimbazi basin (Kironde, 2006). Land use intensification in Dar es Salaam associated with rapid informal settlements has had a negative impact on the quantity and quality of urban green spaces. The high density of low-income residents living in flood prone areas with poor waste management infrastructure led to green space degradation and health hazards for the population (Roy et al., 2018). The rapid growth of informal settlements has also exacerbated the so-called luxury effect within the city. The wealthier predominantly planned ward of Kawe has almost twice as many green urban spaces as the wards dominated by informal settlements (Mwageni & Kiunsi, 2021). Figure 6 illustrates the rapid urbanization in Dar es Salaam between 2000 and 2015. Most of this urbanization has been characterized by the informal settlement of former green spaces (Msuya et al., 2021). There are also distinct differences in the use of the available urban green spaces when comparing high density, wealthy and suburban areas. In the areas adjacent to the city center with their high population density and informal settlements, trees are very common. For poorer residents they are one of the only ways to escape the heat during the day. Green areas in wealthy areas consist of semi natural vegetation, ornamental gardens, urban farms and amenity lands. Trees are less commonly planted for shade because of the prevalence of indoor air-conditioning. Sub-urban areas can be wealthy or poor, but they are characterized by a prevalence of urban farms and semi-natural landscapes (Mwageni & Kiunsi, 2021). The current socio-economic conditions in Dar es Salaam have deep roots in colonial era and present-day urban planning (Peter et al., 2019).

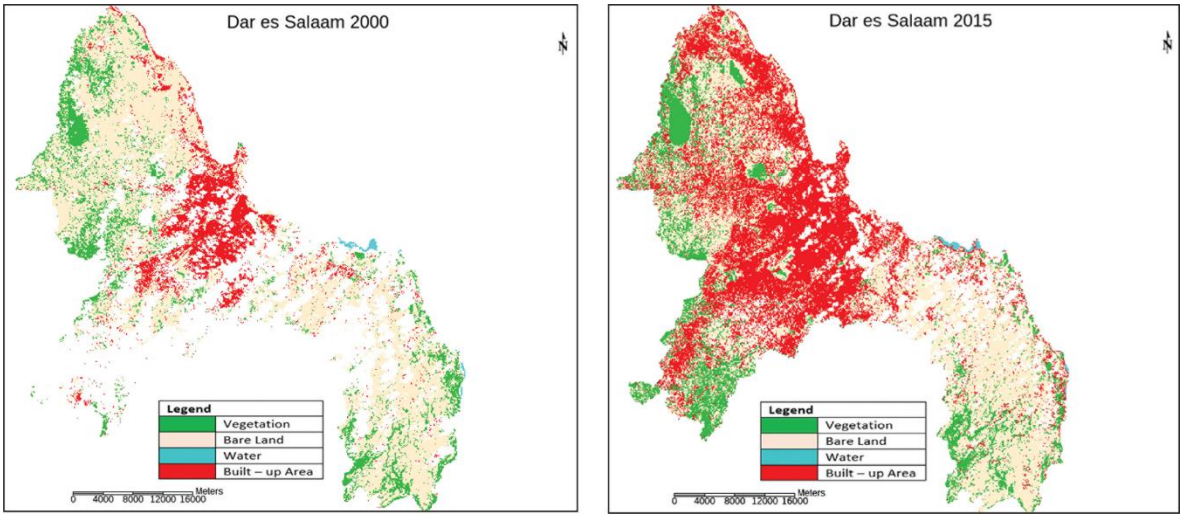


Figure 6: Land use change Dar es Salaam 2000-2015 (Msuya et al., 2021)

Most of the urban planning in Dar es Salaam is done in the form of a Master Plan, which is based on a top-down enforced vision for the city originating from the colonial era. In Dar es Salaam the main goal of the Master Plan is to plan formal housing, economic zones and transportation infrastructure. But the city has never successfully implemented a master plan because of a set of issues related to the lack of zoning law reinforcement, civic engagement, manpower and budgets (Peter et al., 2019). The implementation of the Master Plan is further hampered by the competing interests of different actors in the city. This issue is especially pronounced in the planning of urban green areas, since the vision for these areas differs significantly. National governmental actors, municipal level actors and community groups all show competing interests (Francis et al., 2023). The interests of these groups in relation to urban green area development are illustrated in figure 7.

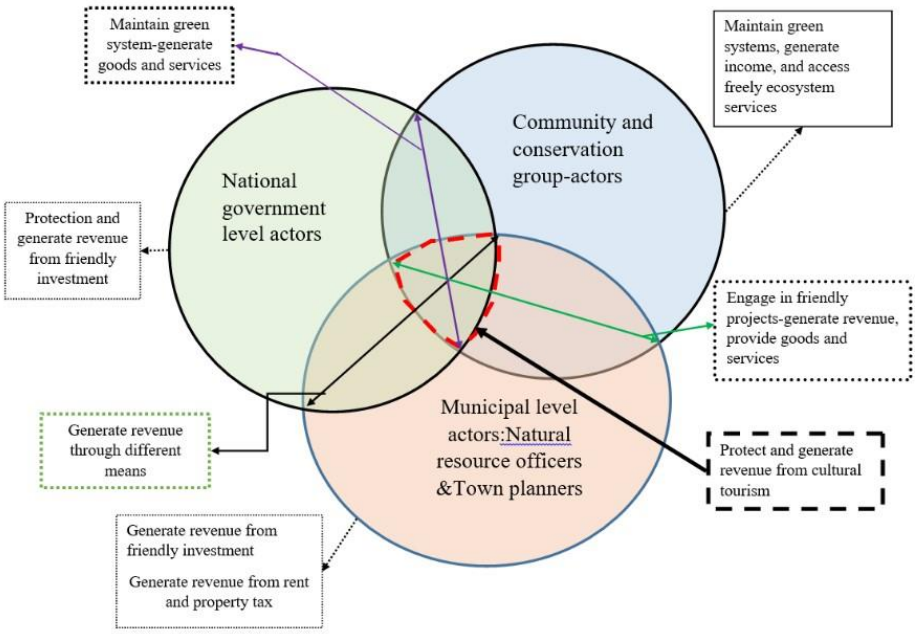


Figure 7: Interests of actors in urban green areas of Dar es Salaam (Francis et al., 2023).

Several of the interests expressed by different actors contribute either directly or indirectly to urban green space degradation. Community use of urban green areas for revenue generation without clear agreements and land development by national or municipal actors led to further degradation of urban green areas (Francis et al., 2023). At the same time, revenue generation was badly needed since the current budget for urban green space development and management in Dar es Salaam is insufficient (Tibesigwa et al., 2020). In a recent study more 52% of residents of Dar es Salaam were unsatisfied with the current maintenance of urban green spaces. Ecosystem disservices such as animal attacks or criminal activity such as theft in urban green areas were considered to be significant reasons for dissatisfaction with green areas (Thorn et al., 2021).

3.3.2 Constraining factors and ways to mitigate or prevent them

Comparing the conditions in Dar es Salaam to the constraining factors illustrated in table 4 shows that Dar es Salaam can be reasonably considered to suffer from all the described socio-economic constraining factors. Land use disputes, a lack of wealth, governance issues and ecosystem disservices are all significant constraining factors for the implementation of urban pollinator conservation measures in Dar es Salaam. There is also a general lack of data regarding pollinator biodiversity in Tanzania as a whole. The few studies that have done preliminary work have tended to focus on either the rural savannah regions or around Mt. Kilimanjaro (Classen et al., 2015). The coastal forests in which Dar es Salaam is situated are poorly researched (Lasway et al., 2021).

Not all constraining factors can be sufficiently mitigated or prevented. Adequate governance or community involvement are a necessary prerequisite for the successful implementation and maintenance of urban green area developments in developing nations (Shackleton & Njwaxu, 2021). Urban pollinator conservation measures are likely to fail in cases where public engagement is low and there is inadequate governance (Brom et al., 2020). But when there is a basic level of governance or significant community involvement, urban green development and thus urban pollinator conservation is possible. Many of the constraining factors associated with urban green development in Sub Saharan Africa (SSA) can be mitigated with appropriate public participation. Figure 8 illustrates some of the key barriers and possible enablers for the success of urban green areas in SSA found by a comprehensive review of the available literature (Thorn et al., 2021).

Figure 8: Key barriers and enablers for the successful planning, implementation and management of urban green areas in Sub Saharan Africa (Thorn et al., 2021).

After researching the concepts in figure 9, it was determined which enablers could contribute to preventing or mitigating the constraining factors for the establishment of urban green areas and thus urban pollinator conservation measures. Governance issues, lack of data, ecosystem disservices, land use disputes, and lack of wealth.

Governance issues

Governance issues can be mitigated by building the capacity of the community living around urban green areas. Capacity building is a useful tool to inform the community about the benefits of urban green areas and to allow them to come up with their own initiatives. The information regarding urban green development can be shared by governmental bodies, universities, NGO's and others in the community through grass-roots capacity building (Thorn et al., 2021). The most important requirements for capacity building are provisioning sufficient capacity building resources such as data or information, showing successfully implemented ideas or examples, developing solutions for local conditions and the continuous implementation of new research (O'Connell et al., 2019). In Africa capacity building has already had success in Namibia where it not only increased local stewardship and thus shared responsibility but also participation in co-designing solutions for a drought (van Rensburg & Tortajada, 2021). Capacity building and community engagement also had a positive influence on the connection and discourse between different stakeholders (Thorn et al., 2021).

Lack of data

There is no real solution for the lack of data but a way to mitigate this constraining factor is the application of the precautionary principle, thus applying general best practice conservation measures until more data is available (Drivdal & van der Sluijs, 2021).

Ecosystem disservices

The ecosystem disservices in Dar es Salaam are concentrated within the poorest sectors of the city. This necessitates a focus on improving the green areas in and around informal areas (Thorn et al., 2021). Proper education of the population is necessary to inform them of possible ecosystem services but also disservices associated with certain measures. Community management of the environment can also significantly reduce ecosystem disservices and the improve the perception of green areas. An example of this was in Zambia where during a malaria prevention program, a combination of education and environmental management by the community prevented the deaths of about 14000 people between 1930 and 1950 (Utzinger et al., 2002). Capacity building and an integrated landscape approach involving all stakeholders was found to be an effective way to manage ecosystem disservices (Thorn et al., 2021).

Long term maintenance

As stated earlier the long-term maintenance of urban green areas is a recurring issue in tropical developing nations and exacerbates ecosystem disservices. This particular constraining factor was thus further explored separately from other governance issues. Capacity building and community participation or engagement throughout every stage of urban green development were able to mitigate some instances of vandalism or theft in South Africa (Shackleton & Njwaxu, 2021). In South Africa civic led greening initiatives achieved a similar diversity of plants and insects as expert led initiatives (Anderson et al., 2014). Community participation during the planning, implementation and management stages of urban green area development in developing countries is increasingly found to be highly effective. In Malawi a community led initiative to reforest the Sadzi hill in Zomba City succeeded in halting soil displacement and devastating mudslides. When comparing satellite images of the community conserved Sadzi hill and a nearby unmanaged Chiperoni hill, the results are clearly visible (Likongwe et al., 2021). Satellite images of the Sadzi and Chiperoni hills illustrating the distinct difference in vegetation cover are illustrated in figure 9.

a) *b)*

Figure 9: Google satellite images from 2021 showing difference between vegetation cover of community managed Sadzi hill and unmanaged Chiperoni hill. (a) Sadzi hill and (b) Chiperoni hill (Google, n.d.).

The biodiversity of the Sadzi hill was also higher than that found on the Chiperoni hill. The community was able to achieve these results by taking collective action to clean up the area, plant and maintain trees and pay for two guardians to surveil the area. In the beginning stages of the initiative governmental support and funds were not available, but after the success was apparent the city council provided the community with a budget to maintain the area (Likongwe et al., 2021). Community management was found to have positive and negative impacts on the green infrastructure of Nairobi. The community generally appreciated the green areas but was burdened by the maintenance and the need for technical expertise during planning. This suggests that sole community management is not always adequate but collaboration between the community and government is necessary (Mulligan et al., 2020).

Land dispute

Land dispute issues were found to be almost wholly dependent on the perceptions and laws of a country's government. Adequate governance and actual enforcement of zoning laws is the only way to prevent or mitigate this constraining factor (Thorn et al., 2021).

Lack of wealth

The lack of wealth on a national or community level has a strong influence on the success of urban green development. Not only because of the earlier mentioned luxury effect but also because wealth determined the community's perspective and use of urban green spaces in Africa. Wealthier and better educated citizens tend to value the regulating services more strongly such as shade and recreational value of urban green areas (Dumenu, 2013). This contrasts with poorer residents that value direct ecosystem provisioning such as fuel wood and food production to a higher degree (Adekunle et al., 2013). Creating urban green areas designed around the needs of the community increased their likelihood of success, with urban green areas in wealthier neighborhoods focusing on regulating services and those in poorer neighborhoods focusing on provisioning services (Du Toit et al., 2018). Capacity building through workshops aimed at improving the effectiveness of urban farming methods can increase household incomes of the poorest residents, community participation and appreciation of urban green areas. In an informal settlement in Makassar City, Indonesia, urban farming capacity building programs were responsible for a direct increase of community wealth by 27,77% (Surya et al., 2020). Urban beekeeping was also found to have a positive impact on household income,

community participation and especially appreciation of urban green areas. In a community living close to Njiro forest, Arusha, an urban forest in Tanzania, residents reported that urban bee keeping was a significant benefit to the community. The majority was also in favor of maintaining the forest and wanted fences to protect the area from thieves, stray dogs and people that deposit waste within the forest. Both managed honeybees and wild stingless bees were positively regarded as deserving conservation. Interestingly, very few residents were aware of the role bees play in pollination, suggesting that raising awareness can further improve the community view on pollinator conservation (Massawe et al., 2019).

Another possible way to mitigate the issues caused by low government budgets is to charge a low sum to visitors of nature, multi-use and neighborhood parks, through domestic and international visits or ecotourism. Families in Dar es Salaam were willing to pay as much as US$0.27 - US$0.69 per month for access to multi-use parks (Tibesigwa et al., 2020). Implementing this measure can directly increase revenue generated by urban green spaces, increasing the budgets for their implementation and maintenance.

4. Discussion

In this thesis a literature review was performed to determine which urban pollinator conservation measures were likely to be successfully implemented in the context of a rapidly urbanizing city in a tropical developing country.

4.1 What are generally successful urban pollinator conservation measures for urban green spaces?

Literature regarding generally successful urban pollinator conservation measures was widely available and the database search went according to plan. There were no issues retrieving data, but some measures consistently showed mixed results. Artificial nectar feeders, for example, were excluded from the generally successful conservation measures because of insufficient and contradictory data (Coetzee et al., 2018). Another measure that showed contradictory results was the impact of exotic vegetation on native pollinators. With some studies suggesting that exotic plants have a negative impact on native pollinator biodiversity and mostly benefit generalists or exotic species (Grass et al., 2013). While others suggest that exotic plants can play a pivotal role in supplying floral resources in urban environments. But even this study recommended planting more native species in urban areas since both native and exotic plants play a role in maintaining urban pollinator biodiversity (Zaninotto et al., 2023). This thesis aimed to create an accurate list of generally successful urban pollinator conservation measures, but the excluded measures with mixed and contradictory results might have still been genuinely successful measures in specific contexts. That being said, an extensive review of the main determinants of urban bee abundance and diversity found similar results. The main determinants were tree cover, floral diversity and density, impervious cover, amount of native flora and connectivity (Prendergast et al., 2022). The desired results of the generally successful urban pollinator conservation measures in this thesis, reflect these main determinants.

4.2 What are the constraining factors specific to developing nations in the tropics influencing the implementation of generally successful urban pollinator conservation measures?

During the literature review of the constraining factors influencing the implementation of urban pollinator conservation measures in tropical developing countries, it became clear the lack of data was itself an important constraining factor. Most articles were focused on constraining factors for the implementation of urban green spaces in general. Although it is likely that constraining factors of urban green areas are similar to those faced by more pollinator focused measures, this could not be sufficiently scientifically supported. Socio-economic constraining factors were more frequently encountered compared to articles investigating the influence of differences between temperate and tropical pollinators on tropical urban pollinator conservation. This might have led to an underestimation of the role that pollinator related constraining factors play in the conservation of pollinators in tropical urban environments. The most significant constraining factor that was mentioned in the literature regarding tropical pollinators and their conservation was the lack of data surrounding these concepts (Zakardjian et al., 2020). This hinders making a more detailed description of possible constraining factors related to pollinators specifically.

4.3 Which of the constraining factors on the implementation of urban pollinator conservation are present in Dar es Salaam and how can these be mitigated or prevented?

The status of Dar es Salaam as a city dealing with significant issues was established in the introduction. It was thus expected that a majority, if not all the constraining factors specific to developing nations would be present in Dar es Salaam. While researching ways to mitigate or prevent the constraining factors it was determined that adequate governance or significant community engagement was a prerequisite for successful urban green development. If these prerequisites were available, then urban pollinator conservation measures had a significantly higher chance of success. An example of the effectiveness of community engagement is the earlier mentioned city in South Africa where a community led urban greening project increased pollinator biodiversity as much as the greening project led by experts. In fact, the civic led areas had a similar pollinator biodiversity as the nearby conservation areas even though the structure of the floristic composition differed (Anderson et al., 2014). This suggests the constraining factors related to governance issues, ecosystem disservices, long term maintenance and lack of wealth can possibly be mitigated or prevented.

As mentioned earlier future research should focus on researching tropical pollinators in an urban setting. The effectiveness of conservation measures on tropical pollinators also presents a knowledge gap in the available literature. The lack of data regarding tropical pollinators in urban contexts was in fact so glaring that the subject could not be sufficiently researched. A possibility is also that the search terms used were insufficient to retrieve suitable articles on such a poorly researched subject. The in- and exclusion criteria might have also had a negative impact on the articles that were found. Articles older than 2000 and not written in Dutch or English were not included in the study. This means that important older studies or articles in foreign languages that were excluded, might have contained valuable information regarding tropical pollinators. But since urban pollinator conservation is a relatively rapidly developing field, older articles had a high likelihood of containing outdated information. Because of using predominantly recent studies the results can be said to reflect the most current available data.

4.4 Implications

The results of this thesis have several implications for the different stakeholders of in Dar es Salaam and even other stakeholders in tropical or developing nations. Generally successful urban pollinator conservation measures can be identified. This suggests that these measures can be successful regardless of the climate or country. But while the local conditions within regions are important, significant differences can also be found between regions. The differences between tropical developing nations and temperate or developed countries were large. The so-called luxury effect was present on a global level between nations and regions (Chamberlain et al., 2019). The global lack of data regarding pollinator biodiversity in the tropics and constraining factors related to socio-economic conditions were also found to be more prevalent in tropical developing countries. This suggests that solutions or ways to mitigate these constraining factors can be useful not only on a local level but also on a regional or even global level. Two main mitigating factors were found to be successful; these were good governance or significant community engagement. In the case of Dar es Salaam this means that all the stakeholders play a pivotal role in the successful implementation and maintenance of urban pollinator conservation measures in the Msimbazi Wetlands and City Park. The government can promote incentives such as urban beekeeping and ensure proper tenure rights (Massawe et al., 2019). The community in turn can play an important role in the implementation and management of the Msimbazi Wetlands and City Park (Anderson et al., 2014).

5. *Conclusion and Recommendations*

The goal of this thesis was to determine urban pollinator conservation measures with the highest likelihood of being successful in the context of a rapidly growing tropical city in a developing country, using the case of Dar es Salaam. The following research question was used: *Which urban pollinator conservation measures are most likely to be successfully implemented in the planned Msimbazi Wetlands and City Park in Dar es Salaam?*

Using a literature review it is now possible to answer the research question and the sub-questions.

1. What are generally successful urban pollinator conservation measures for urban green spaces?
2. What are the constraining factors specific to developing nations in the tropics influencing the implementation of generally successful urban pollinator conservation measures?
3. Which of the constraining factors on the implementation of urban pollinator conservation are present in Dar es Salaam and how can these be mitigated or prevented?

To answer the first sub-question an overview of generally successful urban pollinator conservation measures was made including a description, general implementation and management practices. These generally successful urban pollinator conservation measures for urban green areas are:

- Creating flower meadows or strips with a high diversity of different species
- Making use of a pollinator friendly mowing regiment aimed at creating suitable conditions for the establishment of a semi-natural grassland
- Planting pollinator friendly flowering city trees and shrubs while maintaining older trees with hollows or cavities
- Decreasing impervious cover and increasing the amount of bare sandy soil
- Setting up colorful artificial trap nests with smooth hollows of bamboo, cardboard or wood close to floral resources in urban areas
- Placing green roofs in proximity to each other and other green spaces while allowing native flora to grow alongside initially planted species

To answer the second sub-question, the constraining factors specific to developing nations in the tropics influencing the implementation of generally successful urban pollinator measures were compiled. These are illustrated in table 4 and could be categorized into 5 types: governance issues, lack of data, ecosystem disservices, land use disputes, and lack of wealth. The influence of differences between temperate and tropical pollinators on urban pollinator conservation could not be sufficiently established because of a lack of data. This was in itself a constraining factor.

The last sub-question was answered by comparing the socio-economic conditions of Dar es Salaam to the constraining factors specific to developing nations in the tropics that influenced the implementation of generally successful urban pollinator measures. Community participation and adequate governance were found to be requirements for the successful implementation. If these are present a multitude of different measures can be implemented to mitigate or prevent the most constraining factors. The exception was constraining factors related to tropical pollinators, these could not be established because of a lack of data on pollinators in Dar es Salaam.

Having answered all the sub-questions, the research question can now be answered too. The research question was: *Which urban pollinator conservation measures are most likely to be successfully implemented in the planned Msimbazi Wetlands and City Park in Dar es Salaam?* The answer to the research question is to implement the generally successful urban pollinator conservation measures for urban green areas illustrated in table 3 and to apply the ways to prevent or mitigate the constraining factors present in Dar es Salaam measures mentioned in chapter 3. Dar es Salaam can look to the Njiro Forest of Arusha where an urban forest and the ecosystem services the pollinators of this forest provide are greatly appreciated by the community. The city can distinguish itself from other cities in Africa by taking a distinctively different approach to urban green development. Dar es Salaam can also benefit strongly by planting several pollinator attracting trees across the city. These were use by many in the city for shade and can increase the pollinator abundance in the city which can increase the yields of the urban agriculture which is so common in the city.

The expectation was that by providing answers to the sub and research questions the thesis would be able to demonstrate what urban pollinator conservation measures will likely be successful in the context of the planned Msimbazi Wetlands and City Park in Dar es Salaam. This was done successfully, but the knowledge gaps related to the urban conservation of tropical pollinators remain roadblocks for a more specific urban pollinator strategy.

Recommendations

For the successful implementation of urban pollinator conservation measures in the Msimbazi Wetlands and City Park, it would be best to use the precautionary principle and apply the generally successful conservation measures mentioned in this thesis. The goal should be to start implementing urban pollinator conservation measures into urban planning even with the current knowledge gaps. Another important consideration would be to avoid implementing negative measures to ease the maintenance of the Msimbazi Wetlands and City Park, such as using pesticides (Lentola et al., 2017). The city park is subject to the socio-economic conditions of the city. These are generally not very conductive to the proper functioning and maintenance of urban green areas and thus urban pollinator conservation measures. But by proper planning and community engagement it is possible to achieve the envisioned goal of creating a well-connected urban green space in the heart of Dar es Salaam.

The 10 main recommendations are:

1. Research how the recommended generally successful urban pollinator conservation measures can be best adapted to local conditions. This can be done by considering the climate and available resources before the measures are implemented. An example would be to determine the carrying capacity of the roofs surrounding the Msimbazi Wetlands and City Park to determine whether they can sustain an extensive or even intensive green roof.
2. Make use of low maintenance plant species and a low mowing frequency to decrease maintenance costs
3. Plant trees and shrubs attractive to pollinators especially in proximity to urban farming areas and pathways to provide shade
4. Place bee hotels in the City Park with signs explaining their function
5. If financially possible, incentivize developers of the residential and commercial areas around the Msimbazi Wetlands and City Park to include green roofs in their design
6. Include local communities during every phase of the development of the Msimbazi Wetlands and City Park
7. Make use of capacity building to educate residents about the benefits of urban green spaces and pollinator conservation with an emphasis on how regulating and provisioning ecosystem services have tangible benefits to their lives
8. Use capacity building to incentivize communities to benefit and maintain at least part of the Msimbazi Wetlands and City Park through urban farming and urban bee keeping
9. Involve the local communities in the maintenance and surveillance of the Msimbazi Wetlands and City Park
10. Charge a low entrance fee to parts of the Msimbazi Wetlands and City Park to generate extra revenue

If these recommendations are taken into consideration, it is likely that urban pollinator conservation measures will be successfully implemented and maintained in the Msimbazi Wetlands and City Park.

A species inventory focused on pollinators in the Msimbazi Wetlands and City Park can be useful to establish a basic knowledge of the local biodiversity. Long term community or expert monitoring of the pollinator biodiversity in the Msimbazi Wetlands and City Park after this species inventory can be used to determine the effectiveness of the implemented measures. In the long term this can help make the general measures more specific and possibly even more effective.

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