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The Greening of Mekelle, Capital City of Tigray in Northern Ethiopia

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Abstract:: *Mekelle is the economic, cultural and social centre of northern Ethiopia. Its area and population, following a period of slow growth, both expanded rapidly in the 1980s to the 2010s. Consequent on a series of droughts and famines in the early 1970s efforts were made to prevent the degradation of the local environment by terracing steep hillsides and planting trees as anti-erosion measures. In the long term these tentatives were less than completely successful. Vegetation in church compounds at that time was – and still is -- an important green area and was partially representative of the historic vegetation of the area. Areas of food crops cultivation close to the town make a considerable contribution to the city's green environment. Home gardens and trees planted by individuals and households are the principal (and largely unconscious) sources of amelioration of the Urban Heat Island effect. Areas nominally designated as green spaces by the city administration remain unconnected and largely undeveloped. Several problems relating to finance, competence, implementation and choice of green species need to be overcome before Mekelle becomes a "green" city.*

Keywords: *urban temperature, public health, climate change, green spaces, rehabilitation*

1. INTRODUCTION

It took more than ten thousand years, up to 1960, for the world's urban population to reach one billion people. The next billion was achieved in 25 years (1960-1985) and the third billion 17 years (1985-2002). The increase in urban populations from three billion to four billion took only 10 years (2002-2012) [1]. Urbanization, the migration of people from rural to urban locations, is among the most important economic and social changes occurring in low- and middle-income nations. Population size and its rate of change in urban centres are influenced not only by international and national factors but also by local factors related to the particular local context such as site, location, natural resource endowment, demographic structure, existing economy and infrastructure (the legacy of past decisions and investments) and the quality and capacity of public institutions [2].

Ethiopia has one of the lowest percentages of urban dwellers in the world. Urbanization is nonetheless proceeding apace. From a little over 6 per cent of the total in 1960 the proportion of urban dwellers rose to over 20 per cent in 2017 [3]. In addition to the factors listed in the preceding paragraph those propelling urbanization in Ethiopia include rainfall variability and its long term decline in a primarily agrarian economy [4-65]. Employment opportunities in cities are one of the main pull factors of rural-urban migration involving higher wages than obtainable in rural areas. Other factors include the provision of education and the availability of medical services. Poor living conditions, limited availability of land for agriculture and the lack of opportunities for paid employment in rural areas are push factors for the move from rural to urban environments.

The impact of urbanization on local temperatures has been investigated since the 1980s and the increase in temperature has been called the "Urban Heat Island" effect. Transition from a rural to an urban situation results in changed landscape conditions and modification of the urban climate with concomitant problems including water use and quality, increased air pollution and production of solid waste and sewage. Rapid and increased urbanization is expected to lead to considerable impacts on a broader scale, especially in developing countries. These impacts will include greater energy use, increased demand for goods and services and other resources demand. Changes in food supplies,

freshwater resources and increases in extreme weather events such as heatwaves and droughts will affect human health in terms of , among others, thermal stress, cardio-respiratory problems, and infectious diseases [7-12].

Urban green spaces can play a momentous role in helping to regulate the climate and in mitigating climate change through the possibility of sequestrating large amounts of carbon [13]. Green spaces should be a fundamental component of urban ecosystem. They can facilitate physical activity and relaxation, be a refuge from noise and through production oxygen help to filter out harmful air pollution and airborne particulate matter [14]. Urban greening helps combat air and noise pollution, soaks up rainwater that may otherwise create flooding, creates a habitat for local wildlife and has shown to lift morale in the people who see it, calming traffic and lessening urban crime. In urban areas that lack green spaces better-off people tend out migrate to live in greener suburbs or rural areas. Increased commuter traffic, traffic jams, accidents, stress and even more damage to the environment are the result. Sustainable development (also sometimes known as ecological city) is a strategy for changing these negative trends and improving the well-being of a urban residents. This could entail returning a more "natural" environment to the urban agglomeration as urban green space provides several critical functions that benefit people's quality of life. Increased traffic and urban heat not only damage the environment but also incur social and economic costs. To provide a better quality of life in high-density settlements green space must be maintained and enhanced [15].

2. Materials and Methods

2.1. The Study Area

The study area is the city of Mekelle and its environs (Figure 1). Mekelle is the capital city of Tigray National Regional State, the northernmost first order administrative entity of the Federal Democratic Republic of Ethiopia. In Ethiopia's administrative hierarchy, Mekelle is a "Special Zone" (second order administrative entity) and comprises seven sub-cities. The fifth largest city in Ethiopia (after Addis Ababa, Dire Dawa, Adama, and Gondar), it is the economic, cultural, and political hub of northern Ethiopia. Government is a major employer followed by numerous industrial enterprises and then small scale enterprises [16]. The city has long been an important marketing and distribution centre for the salt trade from the Danakil Depression to the Ethiopian Highlands [17].

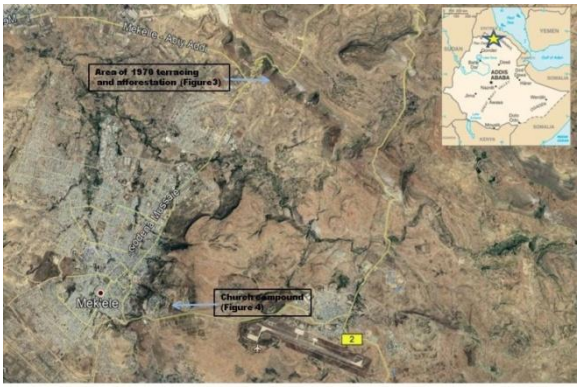

Figure1. *The Mekelle environment and generalised location (inset)*

Located geographically at about 13°29' N and 39° 28' E and at an elevation of 2076 metres above sea level. The climate is of Köppen type Aw (tropical savanna) although it borders both on Cwb (subtropical highland) and Bsk (semi-arid). Day length averages 12.5 hours over the whole year with little variation from 11.7 hours in December to 13.3. hours in June. Average annual temperature is 23.8° C with a low of 17.6 and a high of 26.0. Highest means of 27° C occur in May and June and lowest means of 15° C in December. Annual rainfall of 705 mm falls on 85 days of the year in a distinct wet season in July (200 mm, 22 rainy days) and August (215 mm, 21 rainy days) [18].

Mekelle has apparently evolved from a 13th century hamlet and became a town by the early 19th century. The town had about 5000 inhabitants in 1935 and 12 000 in 1938 when it was occupied by the Italian invaders [19]. The population reached 45 000 in 1975 and since then has expanded very rapidly to over 310 000 in 2016 (Figure 2) [20,21]. In 2012 the city area was 10 937 ha. During the 1983-1985 famine Mekelle housed seven "hunger camps" with 75 000 refugees and a further 20 000 awaiting admittance.

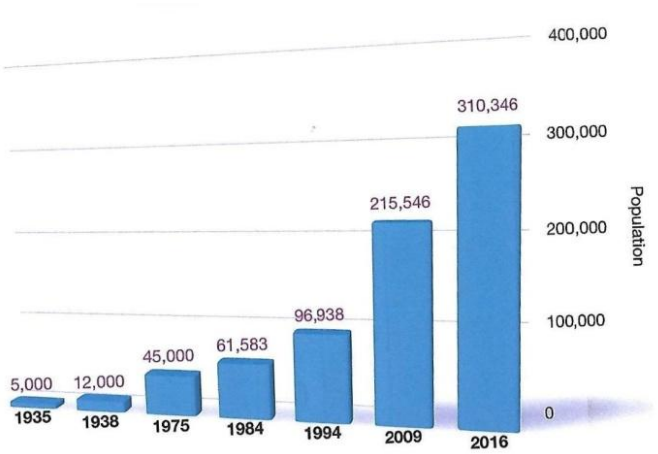

Figure2. *Municipality and City of Mekelle population growth, 1935-2016 (Source: compiled by Author from references cited in the text)*

2.2. DATA COLLECTION

The results of the study are from two separate periods. Detailed quantitative surveys of various vegetation types were undertaken in 1974-1975 of which Re-afforestation and Conservation sites (see Figure 1) and Church Compounds are relevant to the present study. These were supplemented by a qualitative survey of the vegetation in the then Mekelle Municipality. The second period was undertaken in October and November 2018 when a new qualitative survey was undertaken in and around Mekelle City

3. RESULTS

3.1. REFORESTATION AND CONSERVATION SITES

Following a series of minor droughts and famines in Tigray in the early 1970s a programme of terracing steep slopes and planting trees was initiated as part of a wider relief and rehabilitation programme (Figure 3). A steep escarpment some 15 km to the north of the centre of Mekelle was one of the sites chosen for the intervention (see Figure 1). Initially only exotic species were planted, mostly without adequate trials. In the early years of the project *Eucalyptus camaldulensis* was the main species planted but many seedlings failed to survive. Several reasons for this failure have been invoked including not doing well on slopes of greater than 20 per cent, slopes not facing north-east, not adapted to limestone soils and infection with the root fungus *Ganoderma lucidum*. Later plantings were mainly of another Australian species, *Acacia saligna*. Other species that were planted included were *E. globulus*, *Casuarina equisetifolia*, *Cupressus lusitanica*, *Melia azederach*, *Schinus molle* and *Caesalpinia*. After three years losses were more than 50 per cent due not only to inappropriate germplasm but also to lack of follow-up, the inexperience of personnel, lack of supervision and problems with funding. Sites were not adequately protected from local livestock. Perhaps the major benefit of the scheme, where patches were protected from livestock was the regeneration of native woody species, especially *Acacia etbaica* accompanied by at least 52 shrub and herb species and more than twenty species of grasses and sedges [22]

Figure3. *Terracing and reafforestation site to the north of Mekelle (Source: Photograph by the Author, 1974)*

3.2. CHURCH COMPOUNDS

It is sometimes claimed that church compounds are the only areas of the Tigrayan plateau that represent the original vegetation. Some compounds may fulfil this concept but most of them are probably secondary planted (re-inforced) communities that still contain a proportion of the original species. The density of growth and the range of the species in these small spaced is nevertheless often spectacular in comparison to adjacent areas (Figure 4)

Figure4. *Church compound vegetation showing variety and dense cover (Source: Photograph by the Author, 1974)*

The main species over 3 metres in height and their proportional representation in one compound of a few hectares on top of a steep knoll (see Figure 1) on the outskirts of Mekelle was:

Carissa schimperi	40.4 per cent	*Cordia africana*	5.8 per cent
Canthium schimperanum	13.5 per cent	*Rhus natalensis*	3.8 per cent
Olea africana	11.5 per cent	*Carissa edulis*	3.8 per cent
Euclea schimperi	9.6 per cent	Other species	5.8 per cent
Dombeya schimperana	5.8 per cent		

Other species included *Mimusops kummel*, *Ehretia cymosa* var. *sylvatica*, *Grewia ferruginea*, *Ficus sycamorus*, *Syzigium guineense* (an important honey tree) and *Juniperus procera*, the latter probably having been planted. Canopy cover at 3 m plus exceeded 80 per cent. The intermediate storey of shrubs and climbers comprised *Adathoda schimperana*, *Capparis tomentosa*, *Calpurnia aurea*, *Hibiscus ludwigii*, *Phytolacca dodecandra* (used to make soap), *Pterolobium stellatum* and *Clematis simensis*. (The number of specific names of "schimp...." here and in the list above is testament to the botanical collections of Georg Heinrich Wilhelm Schimper (19 August 1804-October 1878) who settled in Tigray in 1836, was Governor of Enticho District for a time, married a Tigrayan lady and in 1864-1868 wrote a detailed report on his botanical observations in the area that underlines how little was known of the local flora even in the second half of the nineteenth century [23].) Conspicuous among the ground flora was the Blood Lily *Scadoxus (Haemanthus) multiflorus* as well as several shade-tolerant grasses that are commonly used for basketry (Figure 5). Succulents such as *Euphorbia tirucalli* and *Opuntia ficus-indica* are planted as protection hedges and *Euphorbia candelabrum* grows on shallower and rocky soils. Ephiphytes and parasites adorn the mature trees, especially *Englerina woodfordioides* on olive and the root parasitic *Cistanche tubulosa* [22].

Figure5. *Woman weaving dish with local grass and examples of finished products (Source: left image by the Author, 7 November 2018; right image photo by the Author of basketry products in Author's collection)*

3.3. Arable Fields and Home Gardens

The central northern part of Mekelle is a low-lying area that, in late 2018, was being intensively farmed (Figure 6). In 2012 it was estimated that there was 107 ha of irrigated land 1288 ha rain fed cultivation. The most widely grown food crop is 'tef' *Eragrostis tef* (which is gluten-free) followed by emmer wheat (*Triticum dicoccum)* and there are minor plantings of barley (*Hordeum vulgare*), finger millet *Eleusine coracana* and pearl millet *Pennisetum glaucum* (these last two also being gluten-free). A variety of legumes and pulses is also grown. Volunteer plants, especially on field boundaries, are also common and there is a plethora of annual weeds: some of these are of economic, food or medicinal value including castor (*Ricinus communis*) and "tobacco" (*Nicotiniana glauca*) which is a very aggressive invasive alien plant species [24]. Other alien and aggressive plants elsewhere considered as weeds have often found themselves incorporated into the Tigrayan pharmacopoeia and cuisine. Among these last are the Dead Sea Apple (*Calotropis procera*), Thorn apple (*Datura stramonium*) and Mexican Poppy (*Argemone mexicana*) (Figure 7).

Figure6. *Aerial view of Mekelle showing lower north central area used for cultivation (Source: Photo by the Author taken from a commercial aircraft approaching Mekelle airport, 1 November 2018)*

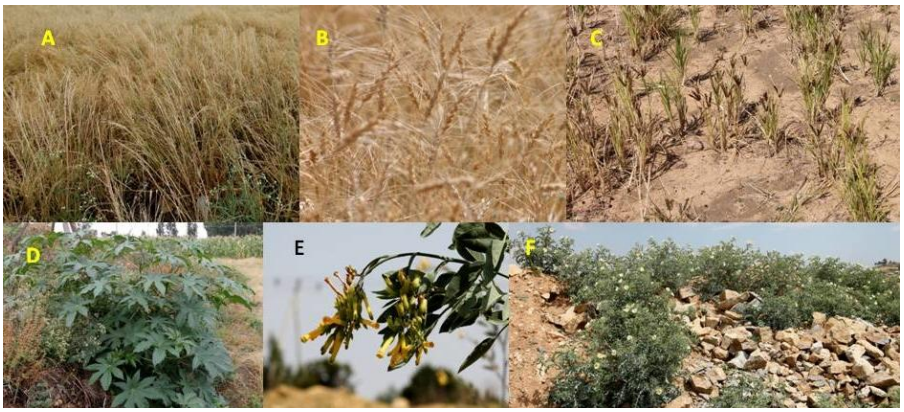

Figure7. *Cultivated crops and "weeds" from the Mekelle City area: (Eragrostis tef); B - emmer wheat (Triticum dicoccum); C - finger millet (Eleusine coracana); D - castor (Ricinus communis); E - "tobacco" (Nicotiniana glauca); F - Mexican Poppy (Argemone mexicana) (Source: all photographs by the Author, October and November 2018)*

Home gardens are a veritable cornucopia of food, medicinal, fragrant and ornamental plant species grown primarily for the benefit of the household and it domestic animals. They normally comprise three layers, the topmost of mature often indigenous trees that pre-date the construction of the dwelling, an intermediate layer of fruit trees and a ground layer of shrubs and vegetables. *Cordia africana* is perhaps the most common homegarden tree and has been describes as one of Ethiopia's remarkable multipurpose trees with a variety of economic, ecosystem, and social benefits [25]. Other upper storey trees include *Cupressus lusitanica*, *Eucalyptus globulus* and *Grevillea robusta*, all of which are fast growing species with easily worked wood (except *Eucalyptus*) and provide excellent

firewood. Several fruits constitute the intermediate layer including pawpaw (*Carica papaya*), avocado *Persea americana*, guava (*Psidium guajava*), two or three species of citrus, banana (*Musa paradisiaca*), cotton (*Gossypium* sp.) and coffee *Coffea arabica*). Three grasses are prominent in the ground level mix: giant reed *Arundo donax* is used as a building material, to make fences, as a distaff for spinning cotton or wool and as a flute-like musical instrument; lemon grass or citronella *Cymbopogon citratus* is an introduced species, strongly scented, as its name suggests, and used both as a flavouring and as a medicine and can provide an essential oil; and, *Eleusine floccifolia*, sometimes known as goosegrass which is endemic to the Horn of Africa and a major contributor in Ethiopia to basketry (see Figure 5). Wormwood *Artemesia afra* is used as a perfume but also has many medicinal properties and basil *Ocimum basilicum*0 which is a culinary herb as well as a medicinal plant are found in many gardens. Several species of tubers and roots and leafy vegetables are grown for immediate use. Chilli pepper (*Capsicum* spp.) Is a major ingredient in the exceedingly hot Ethiopian spice mixture known as "berbere" which also contains rue (*Ruta* sp.), niger seed ('nug', *Guizotia abyssinica*), fenugreek (*Trigonella foenum-graecum*) and other species little known outside Ethiopia such as Ethiopian cardamom ('korarima', *Aframomum corrorima*). Home garden boundaries – the division between private and public domains – are usually covered in a dense mat of colourful scandent and rambler plants (Figure 8).

Figure8. *Dense vegetation marking the boundary between private and public space: Morning glory at the house once occupied by the Author, 29 October 1997; jasmine Jasminum fruticans, 2 November 2018; morning glory Convolvulus species, 2 November 2018 (Source: all photographs by the Author)*

3.4. Roads and Public Spaces

In the mid 1970s totals of 17 "ornamental" and 13 "economic" woody species were identified in the Mekelle urban area although the distinction between the two divisions was rather blurred [22]. Some of these species have already been listed under the previous subsection but most were – and apparently still are – planted at random by individual persons on the town's streets. In addition to the obvious purpose of providing some shade and possibly some "beauty" these trees provide habitats, living space and food for urban wildlife. Some species are salt and drought tolerant. In general a wide range of uses in addition to "green" is provided by urban trees including fibre, livestock feed as browse or in concentrates, carpentry and construction timber, carving (especially now for the burgeoning tourist trade); traditional medicines and fuel wood and charcoal (Figure 9).

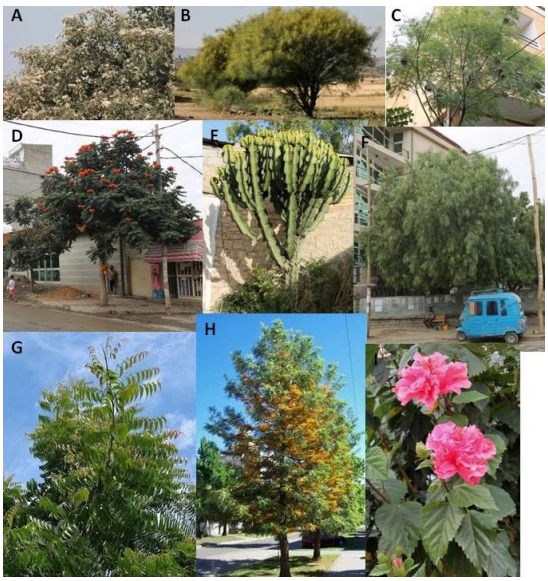

Figure9. *Common trees along road and streets in Mekelle: A - Cordia africana; B - Jerusalem thorn Parkinsonia aculeata; C - Jacaranda Jacaranda mimosifolia (note weaver bird nests); D - African Tulip tree*

Spathodea campanulata; E - Candelabra tree Euphorbia candelabra outside house formerly occupied by the Author); F - False Pepper Tree Schinus molle (note shade function in this and tulip tree!); G - Neem Azadirachta indica; H - Silky Oak Grevillia robusta; I - Hibiscus Hibiscus rosa-sinensis (note double flowered cultivar) (Source: all photograph by the Author, October and November 2018)

More than 100 km of roads of varying standards traverse the Mekelle urban area. As indicated in the previous paragraph many trees on these thoroughfares are the result of individual endeavour. Where new roads have been built the local authority has made some attempts to introduce trees both along road sides and in central reservations on dual carriageways (Figure 10). In many places these efforts have failed as trees have died from lack of protection against errant livestock and inadequate watering regimes. In other cases the choice of species has not been helpful to survival. One such is the Norfolk Island Pine *Araucaria heterophylla*. This tree is not a true pine and as its common name indicates it is a native of the tropical Norfolk Island in the South Pacific Ocean. Widely planted as an exotic species with a pleasing appearance it has a fairly broad climatic adaptability but does best in regions with Mediterranean and humid subtropical climate and prefers deep sandy soils. As it also needs regular watering in its early growth stages it is unlikely to be the ideal tree for the Mekelle environment.

Figure10. *Public actions to enhance greenery in urban Mekelle: Palm trees in an established major thoroughfare; trees in the central reservation of a new dual carriageway; failed plantings of trees on the verge of a new road (Source: all photographs by the Author, October and November 2018)*

Some 242 ha in a continuous block is allocated as a green forest area in one of Mekelle's sub-cities. There are at least seven football (soccer) pitches in Mekelle but these mostly have hard surfaces with little greenery on them. Urban greenery management in the city is outsourced to cooperatives, of there are about with a membership of about 1450 members. According to the city master plan the urban area has five large parks and many green areas of the city but these are not functional [26].

4. DISCUSSION

The multiple benefits and functions of green spaces have been considered in various national planning documents. Among these are:

- The Environmental Policy of Ethiopia, formulated in 1997, has for objective to plan and create green spaces within urban areas that provide recreational activities, habitats for plants and animals and ameliorate urban microclimates;
- The Urban Greenery and Beautification strategy, formulated in 2015, aims to develop green spaces to reduce environmental degradation, pollution and urban floods and to promote environmental sustainability in urban areas;
- The Ethiopian National Urban Green Infrastructure Standard of has a goal to create ecologically well functioning, aesthetically pleasing and socially beneficial green spaces in cities and provide suitable, sufficient and ecologically viable green spaces for recreational, social, economic and environmental needs of the community; and
- The Green Infrastructure Based Landscape Design Supporting Manual, developed in 2011, proposes to develop street tree plantings for shading, mitigating the urban heat island effect, reducing runoff and sequestering carbon [27].

Much "greening", carbon sequestration and air scrubbing results from unconscious activities carried out by individuals or families as part of their daily lives. Ethiopian legislation is often based on international norms but urbanization in the country largely takes place through unplanned growth which aggravates environmental problems [28] and even where it is planned, as in Mekelle, there is little space left for green areas (see Figure 5). The role of green infrastructure in overcoming many

challenges is little known. As an example a planning document for Addis Ababa proposed development of a green infrastructure based on the principles of and multifunctionality but the step from principle to practice is a rare phenomenon [29]. One project in Addis Ababa hopes to raise the current green cover of 0.3 square metres per person to 7.0 square metres in line with the average green cover for Africa as a whole.

Whereas most attention to greening in Ethiopia has been centred on Addis Ababa the results and lessons to be learnt are relevant to other large cities including Mekelle. Communication and social inclusiveness in implementing green infrastructure components is lacking in planning documents for connecting green space physically and/or functionally and as a result green spaces are developed (if at all!) in a fragmented way. Top-down planning, vague and out-of-date plans that fail to keep up with the rapid pace of urbanization, lack of awareness, financial constraints, insufficient professional knowledge, absence of collaboration, poor involvement of the local community and stakeholders and the non-statuary status of plans are the major challenges for green infrastructure development. These problems must be given adequate attention and a high order of priority in order to achieve green development and make it relevant to the needs and aspirations of the ordinary citizen [29].

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