TIGRAY

THE GEOGRAPHY OF AN ANCIENT LAND

YOHANNES ABERRA

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Mekelle 2022

Dedicated to the victims of gang-rape in Tigray

Preface

The world knows of the ancient Axumite Civilization, which was the contemporary of Rome, India, Egypt, and Nubia. Unfortunately, not many are aware of the core area of the glorious civilization known as Tigray. About ten million people inhabit Tigray, which is as large in surface area as Bosnia-Herzegovina or Slovakia, or Rwanda and Djibouti combined. Tigray sprung into international attention, in the last two years, in the most dramatically tragic manner. Full of hope that Tigray will emerge soon enough from the dreadful situation it is in this book is written to be of some help to introduce Tigray to the world community and promote it for tourism and investment. It can be useful for Tegaru at home and overseas to know in detail what their beloved homeland has at its disposal. The book can have academic merit as well. It can serve as a supplemental text-book for high schools and universities in Tigray. Backgrounds for research, policy, and development plans in Tigray can use the contents of the book to introduce study areas and missions statements. The book, which contains as much geographic information about Tigray as is needed for non-specialized purposes, is structured in well-illustrated four chapters. Although the largest share is given to the physical aspect of the geography of Tigray; there is significant coverage on environmental issues, as well as urban and rural-agricultural geographies. The base-map of Tigray used in this book is adopted from what is depicted as Tigray from the majority of world-wide-web sources. The author is well aware of the fact that the boundary demarcation, particularly on the Eritrean side, is not finalized. Next editions of the book will make the necessary modifications based on final agreements on border demarcations.

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Location of Tigray

- Tigray is located in the Northern Hemisphere (northern tropical zone) and the Eastern Hemisphere (+3.00 Time-zone)
- Its coordinates are roughly 36.5°E to 40.5°E and 15°N to 12 ° N.
- Tigray is found in the northeastern portion of Africa; in the sub-Sahara region and close to the Sahel zone.
- Adjacent to the eastern edge of Tigray lies the world's most active tectonic zone: the Dalol Depression of the Great Rift Valley.
- The Tekeze (Atbara) River, a major tributary of the Nile River, rises largely from Tigray making it a Nile riparian territory.
- Tigray is located in what has come to be known as the Horn of Africa.
- Geographically, culturally, and historically (Axum) the Middle East is very close to Tigray; and the Red Sea is only about 60 kilometers away from the northeastern tip of Tigray.

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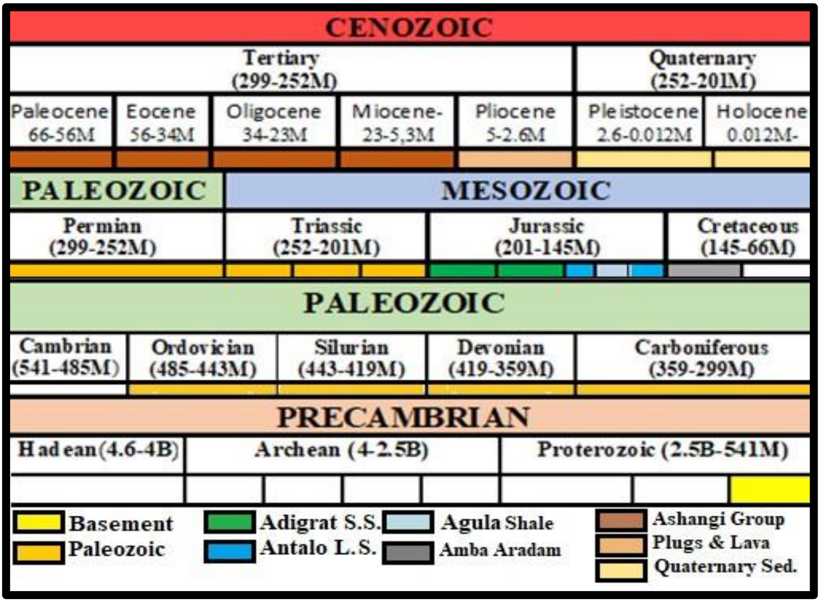
Chapter I: Geology

1.1. Introduction: Rock forming processes in Tigray

Geology is the study of the characteristics of rocks and minerals and the processes responsible for their formation. Tigray is a geological museum; it has rocks formed in all Geologic Eras: Precambrian, Paleozoic, Mesozoic, and Cenozoic. It is uncommon for a relatively smaller area to have all the geologic Eras represented. Even more distinctive is the marked sub-regional differentiation in the location of the rocks belonging to the four Eras. Fig. 1.1 shows that the rocks that can be seen exposed to the surface are either because no other rock was overlain on them or erosion has removed an overlying rock and exposed them to the surface. The rock surfaces of the Precambrian in Northwestern and Central Zones of Tigray were not overlain by other rocks except relatively small areas of volcanic rocks that form the elevated Axum to Addigrat Ridge. The Basement complex exists underneath, covered by later sedimentary and volcanic rocks, in the Southeastern, Southern, and Western Tigray.

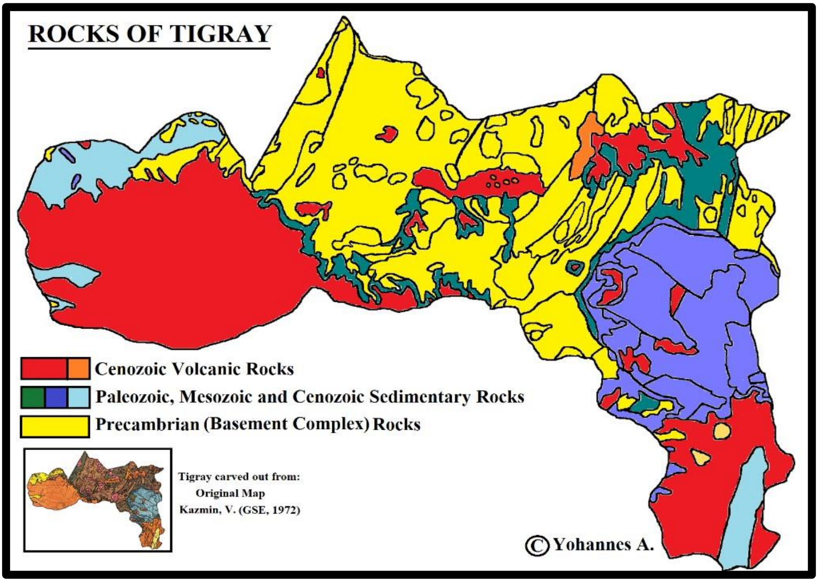
The sequence of stratification of the rocks in Tigray, from bottom to top is as follows: At the bottom of the stratigraphy is the Basement Complex, which was a result of tectonic-orogenic processes that formed the very high mountainous topography of the Precambrian age. Towards the end of the Precambrian a process of peneplaination begun in which the Precambrian mountainous topography was almost flattened by denudation (long period of geological erosion) throughout the Paleozoic Era. Although Paleozoic denudation has removed the Precambrian material and deposited it much farther away from the sources, in Tigray Paleozoic sedimentary formations uniquely exist in situ over a large area along the middle Tekeze River valley and its right-bank tributaries; and a large area in the northeast. Next to the basement complex in the stratigraphic sequences of rocks in Tigray is the thick sedimentary layers of the Mesozoic era.

Fig. 1.1 The geologic timeline for rock formation in Tigray



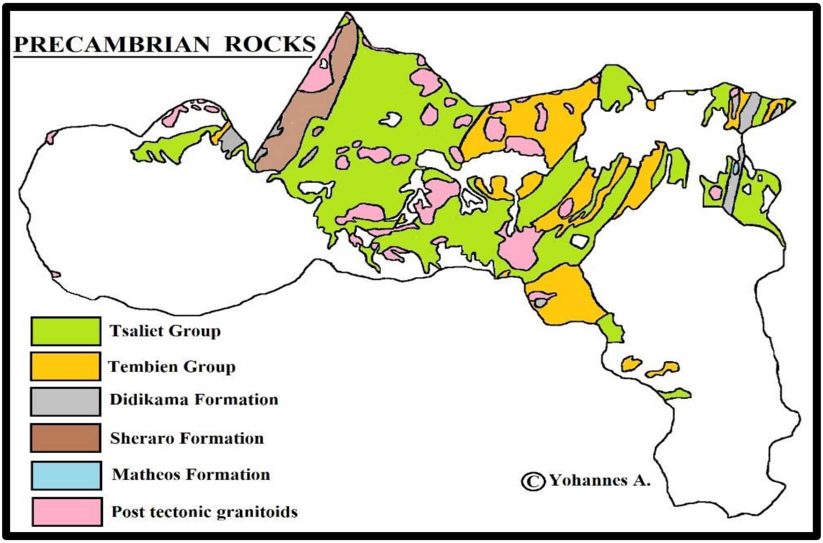
The Precambrian orogeny and the Paleozoic peneplaination was followed by a tectonic process at sub-continental scale which caused the peneplained Precambrian surface to gradually subside significantly. This enabled marine transgression by which the entire northeastern African landmass, in which Tigray is located, came under the sea. Although marine transgression began during the Triassic Period of the Mesozoic Era the laying down of the oldest Mesozoic sedimentary rock in Tigray (Adigrat Sandstone) happened in the Lower and Middle Jurassic Period along the sandy coastlines of the progressively advancing sea. As the sea deepened, settled, and teemed with marine life Antalo Limestone and Agula Shale were laid down on the sea floor and solidified. This happened in the Upper Jurassic Period of the Mesozoic Era.

Fig. 1.2 Distribution of rocks in Tigray



By the close of the Mesozoic Era (Cretaceous Period) the sub-continental landmass began to rise due to reverse tectonic process resulting in marine regression. As the sea retreated it laid down another layer of sandstone and other sedimentary materials. This layer has come to be known as the Amba Aradam formation. Even after the sea retreated and the Mesozoic sedimentary layers emerged from the sea, the uplifting of the landmass continued up to several hundred meters above sea level. The gigantic swelling of the landmass created tension on the Mesozoic surface and deep vents and fissures appeared through which immense quantities of lava covered the uplifted surface. In Tigray the process created the Ashangi (Hashenege) Groups over large area and volcanic plugs in a few places in the Adwa-Axum area. Fig. 1.2.

Fig. 1.3 Distribution of Precambrian rocks in Tigray

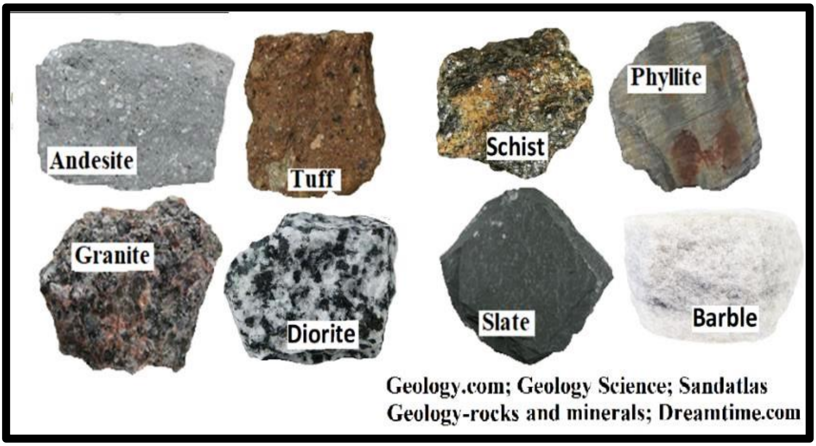


1.2. <u>Basement Complex: 4.6 Billion-541 Million Years Ago</u>

The formation of the Precambrian rocks begins from the beginning of the Earth as a planet, 4.6 billion years ago and spanned for four billion years until the beginning of the Paleozoic Era, 541 million years ago. In this particular context Precambrian geologic time is divided into Lower Complex or Archean (4 to 2.5 billion years ago); Lower-Middle Proterozoic (2.5 to 1.0 billion years ago), and Upper Proterozoic or Riphean (1.0 to 0.5 billion years ago). Precambrian rocks in Tigray are relatively younger belonging to the Upper Proterozoic or Riphean (1.0 to 0.5 billion years ago): Tsaliet group, Tembien group, Didikama formation, Sheraro formation, Matheos formation and Post tectonic granitoids (GSE, 1972).

Fig. 1.4 Basement: metasediments originals

Fig. 1.5 Basement: metavolcanics originals, metamorphics

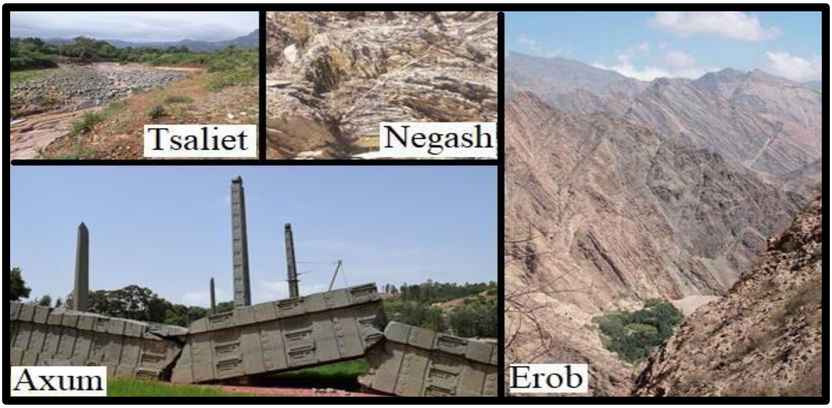


Precambrian geology is also known as the "Basement Complex" because it constitutes a heterogeneous mix of metamorphosed, partly metamorphosed (weakly metamorphosed volcano-sedimentary (Tesfaye, 1993), and un-metamorphosed igneous and sedimentary rocks. There are six categories of the Precambrian basement rocks in Tigray, listed in the order of their age from the oldest to the youngest: Tsaliet Group, Tembien Group, Didikama Formation, Sheraro Formation, Matheos Formation, and the Basement Intrusive (GSE, 1972; Daniel, 2007).

Tsaliet Group has formed between 800 and 740 million years ago. It constitutes: partially metamorphosed volcanic and sedimentary rocks, marble, slate, calcareous siltstone, sericite-chlorite schist, greywacke, andesite lavas, tuff and tuffaceous slates (GSE 1972; Tefera, Chernet, and Haro, 1996; Sembroni, Molin, and Dramis, 2019); in the Negash area: metavolcanics, metavolcaniclastics, and metasediments (Solomon, Bheemalineswara, and Fiseha, 2012); in Tahtay Logomti area: basic to acidic metavolcanic, basic to intermediate metavolcanoclastic, meta-agglomerate and metatuff rock (Azeb, 2018); in the Atsbi area: metavolcanic (metabasaltic andesite and metaandesitic) and metavolcaniclastics (metabreccia) and Phanerozoic sandstone., tuffaceous layers and slate (Mekuria, 2014); in Wuqro area: breccias, agglomerates, bedded tuffs and lavas, inter-bedded with marine clastics, rare limestones, tuffaceous slates, redeposited ash, and greywacke composed partly of volcanic fragments (Daniel, 2007).

Tembien Group of the Precambrian basement in Tigray developed from about 740 million years ago. This group comprises of: slates, chlorite, graphite phyllite, limestone, and dolomite (GSE 1972); in Negash: metasediments, slate, phyllite, metalimestone, and pebbly diamitite slate (Solomon, Bheemalineswara, and Fiseha 2012); in Tahtay Logomti: lower slate, lower metalimestone, upper slate and upper metalimestone (Azeb, 2018); in Wuqro: clastics with subordinate carbonates, mainly slate and limestone with inter-bedded phyllites, black massive fine grained limestone- partly algal and oolitic, thin inter-beds of dolomite and thinly bedded limestone (Daniel 2007).

Fig. 1.6 Basement Rocks in Tigray (Granite civilization in Axum)



Didikma Formation is composed of slates and dolomites (GSE 1972; Miller et al, 2011); and in Wuqro it consists of creamish to white dolomite alternating with grey, black or variegated slates, yellowish medium grained dolomite inter-bedded with grey black or colored slate (Daniel 2007). Matheos Formation is known only in Negash area and is composed of limestone with stromatolites, dolomitic limestone and dolomite (GSE, 1972; Daniel 2007) and black limestone, calcareous slate, diamictite (Miller et al, 2011). Sheraro Formation is made up of polymict sandstone and conglomerates (GSE 1972; Miller et al, 2011). Basement Intrusive or the post-tectonic granitoids, which intruded into Tsaliet and Tembien Groups 690-450 (620-520) million years ago, constitutes granite locally associated with diorite and granodiorite (GSE 1972; Daniel 2007; and Bekele and Gangadharan, 2016).The basement is sometimes referred to as the “Crystalline Basement” owning to the dominance of rocks that have been subject to enormous heat and pressure from folding and compression in the process of orogeny (mountain building) for billions of years. Such processes have resulted in the constituent minerals in the rocks to grow into large and visible crystals. This adds their value as mineral ores for economic extraction. In Tigray the Precambrian rocks are sources of precious and industrial metallic minerals: gold, copper, silver, iron, zinc, lead and nickel; gold in Shire-Adiabo and Wer'ie Leke and blue sapphire in Mereb Leke and Laelay Maychew (Yihdego et al, 2018).

Precambrian rocks cover the entire Northwestern and Central Tigray and two large patches in the northeast. Fig. 1.3. The Tsaliet Group accounts for about two-third of the total area of the Basement Complex and half of that is in Northwestern Tigray. Tsaliet Group is more widely distributed throughout the Precambrian zone; whereas, Tembien Group is geographically restricted to Mereb Leke, Wer'ie Leke, and Tanqua-Abergele. In the Central Zone of Tigray.

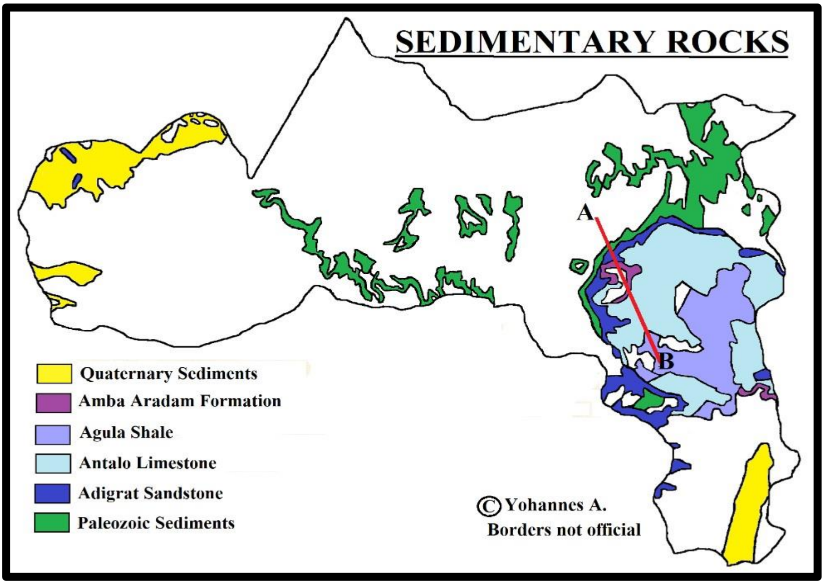
Didikama Formation has smaller areas of exposure in Erob, Saese'ieTsaeda-Emba, and along the Tekeze River banks of northeastern Kafta Humera. A wide strip of Sheraro Formations extends from the banks of Tekeze River to the northern tip of Tahtay Adiabo-Shire. The only location identified so far for the Matheos Formation is the central part of Saese'ie-Tsaeda-Emba. There are close to 40 medium and large granitic outcrops intruded into the Tsaliet and Tembien groups, spread throughout the Precambrian zone of Tigray. One of them is found near Axum from which the granitic obelisks may have been carved out. Fig.1.6. Granite is a very important material for the construction to add glamour to private and public buildings. The granitic outcrops are commercially quarried and processed in Tigray.

Fig. 1.7 Satellite images of selected Precambrian surfaces in Tigray

1.3. Sedimentary Rocks and Sediments: Since 541 M.Y.A.

The sedimentary rocks and sediments in Tigray are laid down in three Eras: Paleozoic, Mesozoic, and Cenozoic. The sequence of sedimentation is: Paleozoic sandstone, shale, and glacial tillites; Mesozoic Adigrat sandstone, Antalo limestone, Agula shale, and Amba-Ardam formation; and Cenozoic-Quaternary sediments. The earliest sedimentation occurred during the Paleozoic-Triassic (485201 M.Y.A.) in which sandstone, shale, glacial deposits were laid down over the peneplained Precambrian surface.

Fig. 1.8 Sedimentary Rocks in Tigray

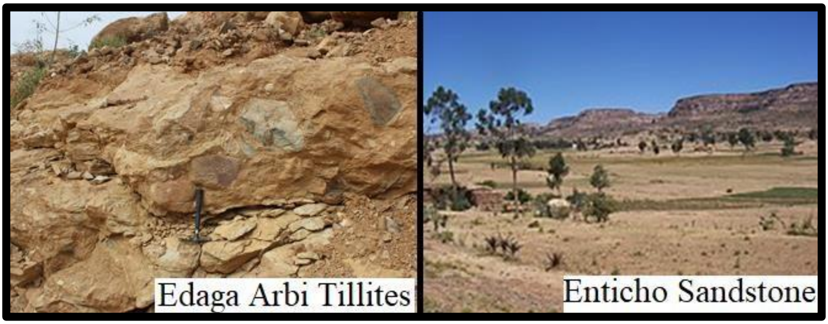


Tigray had experienced glaciations during the Early Paleozoic (Late Ordovician); and in the Late Paleozoic (Carboniferous-Permian) (Bussert, 2019). In the process of glacial erosion and deposition the moraines were consolidated into tillites. Edaga Arbi Tillites and

Enticho Sandstones are Paleozoic formations both connected to a glacial environment overlying the Precambrian Basement

(Tesfamichael et al, 2010). Deposition of the Paleozoic sediments began in the Ordovician or in the Carboniferous-Permian (Dow, Beyth, and Tsegaye, 1971; Beyth, 1972; Abbate, Piero, and Mario 2015; Bussert, 2019). The Edaga Arbi Tillites and the Enticho Sandstone deposition extended into the Triassic Period of the Mesozoic Era (Bosellini et al, 1997). Fig. 1.1.

Fig. 1.9 Paleozoic sedimentary Rocks in Tigray

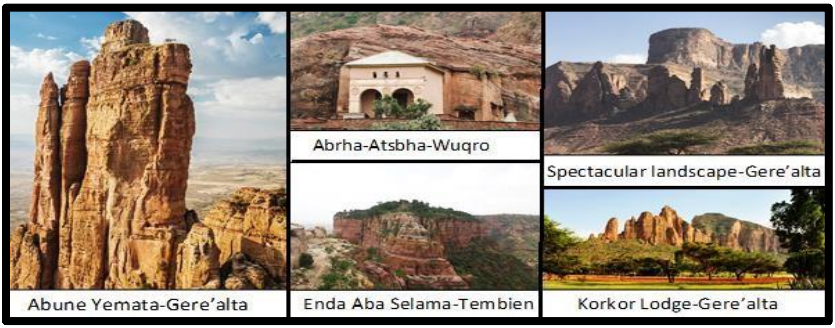


Enticho Sandstone consists of quartz-rich arenite or eolian quartzarenites (Sembroni et al, 2017, Sembroni, Molin, and Dramis, 2019); while the Edaga Arbi Glacials are mudstone-rich tillites (Bussert, 2019), with grey, black or purple clay and silt often containing dispersed pebbles or boulders (Sembroni et al, 2017). Bussert and Jan Nyssen (2019) asserted that the Paleozoic Edaga Arbi Tillites and Enticho Sandstones are one of the few occurrences in the world where such deposits are well exposed and can be easily accessed. The Paleozoic sedimentary formations are found exposed along the banks of the middle course of the Tekeze River (Tselemti) and the right bank tributaries; but the largest area lies extensively in most parts of Northeastern Tigray including Hawzen, Saeseie

Tsaedaemba, and Ganta Afeshum. The Paleozoic sedimentary formations are also found exposed along a narrow arc extending from Hawzen, KolaDegu'a Tembien, and Tanqua-Abergele. They underlie the Adigrat sandstone layer. Fig. 1.7.

The Paleozoic sedimentary formations also include oil shale which are laid between the Edaga Arbi Tillites below and the sandstones above. From oil shale liquid hydrocarbons or shale oil can be produced. Oil shale resources in Tigray are estimated to be approximately 4 billion tons. (Yohannes et al, 2018). Paleozoic sedimentary rocks are not limited to their economic values; they also possess spiritual values as ancient centers of monastic life. A large part of the rock-hewn churches of the Atsbi and Sinkata-Adigrat clusters have been carved in Enticho Sandstone (Bussert, 2019).

Fig. 1.10 Sacred and spectacular sandstone landscapes in Tigray



With the advent of marine transgression in Tigray at the beginning of the Triassic period of the Mesozoic Era the first sandstone layer of marine origin was laid on some areas of the Paleozoic sedimentary rocks, but largely on the basement complex. The age of the upper limit of Adigrat Sandstone is between Late Callovian (Late-Middle Jurassic: 166-164 MYA) to Early Oxfodian (Early-Upper Jurrassic: 201-157 MYA) and its lower limit is diachronic and Triassic (Sembroni et al, 2017). Kazmin (1972) puts the date for the Adigrat Sandstone (Lower Sandstone) in the Lower to Middle Jurassic (201164 MYA). In Tigray, the exposure of Adigrat Sandstone is limited to the geologic area known as Mekelle outlier (east-central Tigray). Similar to the Paleozoic exposures Adigrat Sandstone is also found as a narrow exposure along the Hawzen, Kola-Degu'a Tembien, and Tanqua-Abergele arc. Tigray is home to 121 rock-hewn churches, believed to represent the single largest group of rock-hewn architecture in the world. The rock-hewn churches in these three areas are almost entirely sculpted into Amba Aradam Formation (misnomer of Emba Ar'adom), Adigrat Sandstone and Enticho Sandstone. (MoCT 2018). Fig.1.1; 1.7; 1.9.

Fig. 1.11 Antalo/Hintalo Limestone civilization Enderta, Tigray

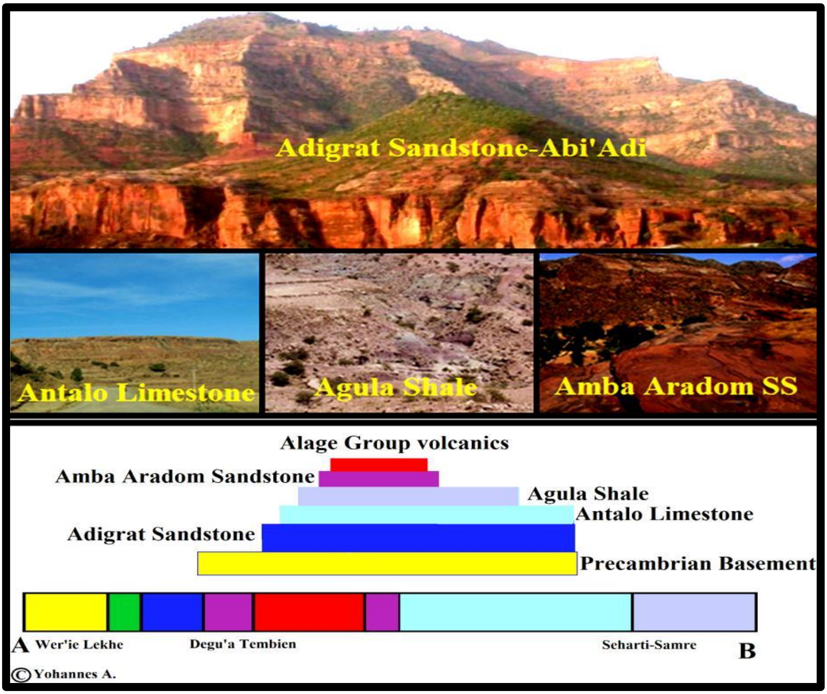
Overlying the Adigrat Sandstone is the Antalo Limestone (misnomer of Hintalo, a district in Enderta, Tigray), which was laid down on top of the Adigrat Sandstone in the Late Callovian to

Kimmeridgian age: 166-152 MYA (Sembroni et al, 2017). Antalo Limestone is predominantly fossiliferous yellow limestone containing thin beds of marl and calcareous shale; and occasionally arenaceous bands appear near the top; sandy oolitic facies, also suggest a near shore environment of deposition, while black limestone and shale indicate deeper water conditions (Daniel, 2007; Tesfamichael et al, 2010). According to Kazmin (1972) Antalo Limestone constitutes marls; oolitic, detrital, fine and micro grained limestone; and are Upper Jurassic: 163-145 MYA. Antalo Limestone is limited to and covers the entire Enderta in the east-central of Tigray. It is the top most rock in the area. Limestone is widely used for construction and production of cement.

On top of the Antalo Limestone lies the Agula (Agula'e) Shale, which is composed of well-sorted and cross-bedded fine quartzarenites; laminated black shales and mudstones; dolomites and gypsum beds; and oolitic limestones (Sembroni et al, 2017). Daniel (2007); Tesfamichael et al (2010) characterize the Agula Shale as constituting gray, green, and black shale; marl and clay-stone interlaminated with finely crystalline black limestone; some thin beds of gypsum and dolomite; and a few beds of yellow coquina. Agula Shale belongs to the Late Jurassic (Kimmeridgian: 157-152 MYA) and its formation is an indication of marine regression (Daniel, 2007; Sembroni et al, 2017). Agula Shale is found on top of the Antalo limestone over a large area left and right of the road from Hiwane via Mekelle to Wuqro. Fig. 1.7.

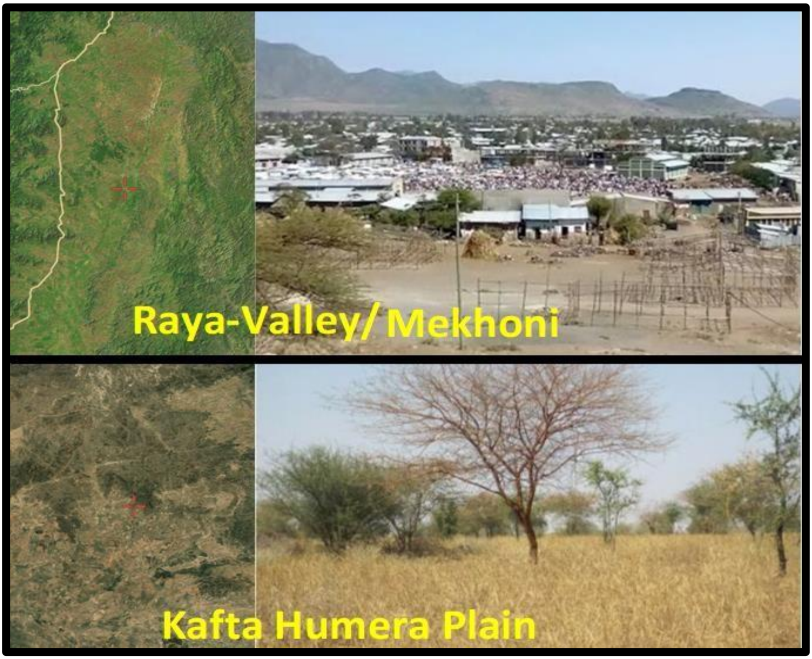
Amba Aradam Formation was laid down over the Agula Shale and Antalo Limestone during the Lower Cretaceous (Aptian–Albian: 125-100 MYA) in the age of marine regression (Kazmin, 1972; Daniel, 2007; Sembroni et al, 2017). The Formation is composed of clay, silt, sandstone conglomerate (Kazmin 1972); siliciclastic sediments; hard rock containing pebbles of quartz; purple, violet or yellow fluviatile sandstone and shale; and thick laterite (Daniel, 2007; Tesfamichael et al, 2010). Sembroni et al (2017) describe the Amba Aradam Formation as white or red in color inter-bedded with purple to violet silt and mudstones, lateritic paleosols, and lenses of conglomerates. The sedimentary formations of the Mesozoic Era in Tigray are rich in non-metallic minerals such as silica, sand, kaolin, gypsum, marble, lime, and dolomite (Yihdego et al., 2018).

Fig. 1.12 Mesozoic Rocks in Tigray; Stratification and Transect



The most recent sedimentary formations are the less consolidated sediments of the Quaternary Period of the Cenozoic Era (2.6 MYA to the Present). They are made of conglomerates, sands, silts and clays (Kazmin, 1972). They are overlain on Precambrian and Mesozoic formations by fluvial deposition. In Tigray they are found in the Western and Southern administrative zones forming fertile agricultural soils in Kafta Humera and Mekhoni-Raya. The latter is famously known as "the Raya-Valley" because of its narrow and elongated shape flanked by mountainous topography. The Quaternary sediments in Kafta Humera are more extensive and located in a hot and semi-arid environment. Fig. 1.7; 1.10.

Fig. 1.13 Quaternary Sediments Kafta Humera and Raya-Valley

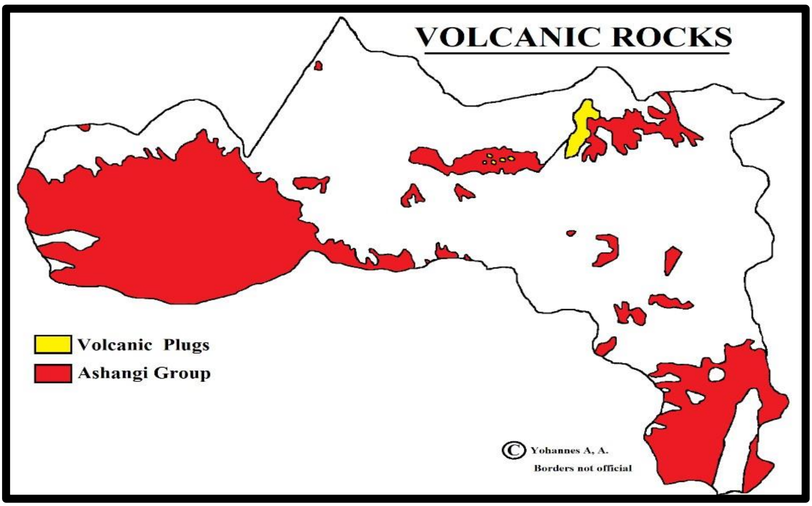


1.4. <u>Volcanic Rocks of the Cenozoic Era (Since 66 MYA)</u>

Volcanic rocks belonging to the Cenozoic Era cover almost the entire Western Tigray and Southern Tigray administrative zones. They are also found on the Ridge which divides the Mereb and

Tekeze Basins along the Adigrat-Adwa-Axum-Shire highway. Elsewhere they are found as scattered pockets in the southern half of the Northwestern zone, and the Enderta and Tembien s. Fig. 2.10. Eruption of the enormous and extensive flood lava of the Trap-series (Ashangi /Hashenege Group) that formed the thick volcanic layers and built the huge mountainous topography occurred during the Paleocene-Oligocene-Miocene (66 to 5 MYA) (Kazmin, 1972). Sembroni (2019) puts the date to Eocene-Oligocene (56-23 MYA). The layer constitutes: alkali olivine basalts, tuffs and rare rhyolites (Kazmin, 1972). The Ashangi (Hashenege) Group of the Trap series are found extensively in Western Tigray and Southern Tigray. Fig. 1.14.

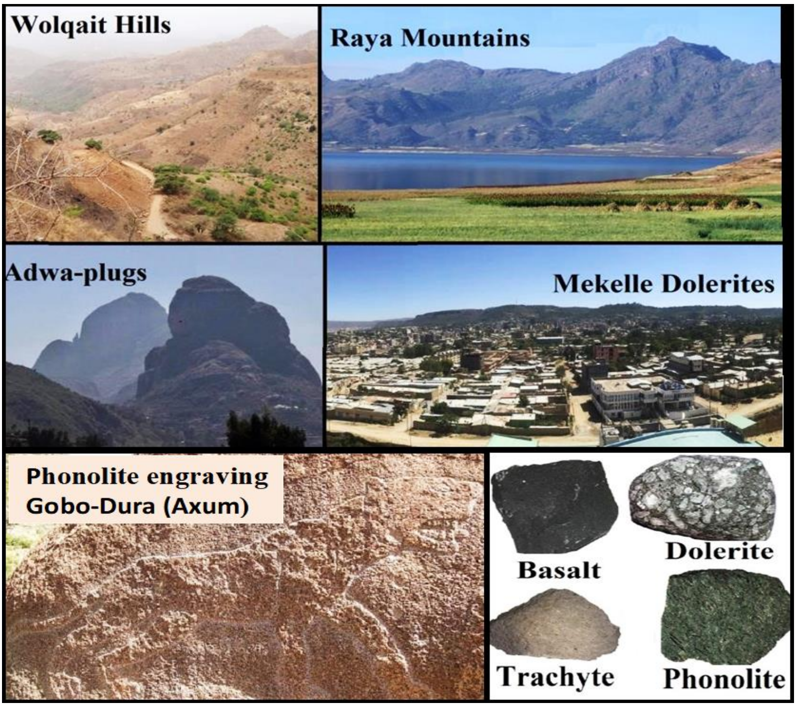
Fig. 1.14 Cenozoic Era volcanic rocks in Tigray



Another group of volcanic rocks in Tigray are the dolerite sills and gabbro-diabase intrusions (Kazmin, 1972). One of such formations is the Mekelle Dolerite that intruded the Mesozoic sediments following joints and faults (Bosellini et al, 1997). The Mekelle

Dolerites are Oligocene in age (34-23 MYA) and consist basaltic to gabbroid sills and dykes as typified by the dolerite deposit lying on top the Agula Shales immediately east of Mekelle city (Sembroni, 2019). The third category of volcanic rocks in Tigray are what are known as the Axum-Adwa Plugs, overlying the Ashangi (Hashenege) Basalts, constitute silica-poor volcanic to hypabyssal phonolite–trachyte rocks (Sembroni, 2019). The trachyte-phonolite plugs have intruded in the Early Miocene: 23 to 16 MYA (Bosellini et al, 1997); but Kazmin (1972) dates the alkaline plugs to the Pliocene Epoch (5-2 MYA). Fig. 1.14; Fig.1.15; Fig. 1.16.

Fig. 1.15 Cenozoic Era volcanic rocks in Tigray



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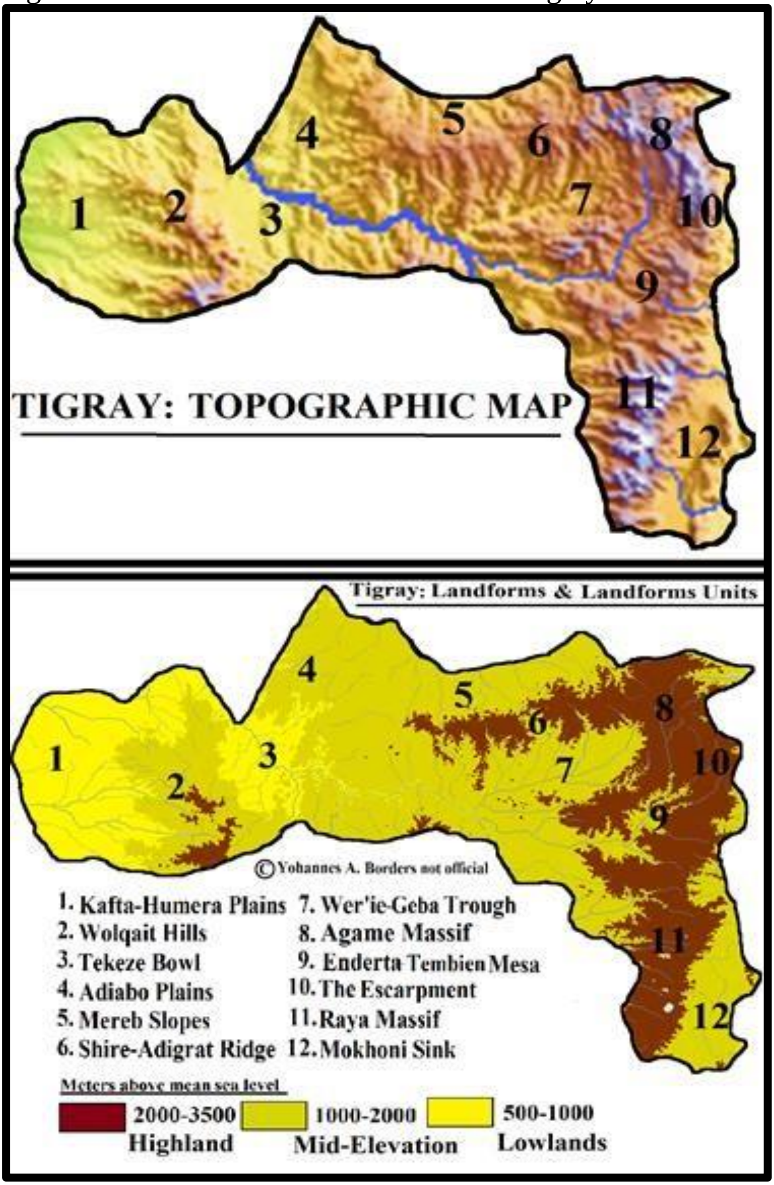
Chapter II: Geomorphology

2.1. Landforms and Landform-Units in Tigray

Geomorphology, as the term implies, is the analysis of landforms on the surface of the Earth. Chapter 1 described the geologic processes that formed the various types of rocks in Tigray throughout the four geologic eras. A working knowledge of geology is needed for geomorphologic analysis because the processes of rock formation suggest how and in what the terrain features are built. There are mountains, hills, and s built by volcanic rocks. The plains in large parts of Tigray are the outcomes of Precambrian peneplanation of the basement rocks and the uplifted Mesozoic sedimentary rocks.

The other aspect of landforms is the surface configuration created by the process of drainage. Complex network of valleys of different sizes and length add to the breathtaking landscape of Tigray. Relief-landforms and drainage-landforms are separable only for the purpose of analysis; otherwise the two are integrated parts of the landform system. Tigray is a mega landform unified by the Tekeze River
Basin. Geomorphologically speaking Tigray can be referred to as the "Tekezeland". The largest portion of the relief-landforms in Tigray are drained by the Tekeze River and its tributaries. The general aspect of the slope of landforms in Tigray is westwards following the direction of flow of the Tekeze River and its tributaries. Only relatively small segments of Tigray in the north and northeast have aspects of slope facing the north and the east respectively. In this chapter geomorphology is given a physical and a human face.

Fig. 2.1 Landforms and landform-units in Tigray



2.2. Relief-Landforms

Relief is defined as the elevation of land, a variation in height of the land surface. This refers to the configuration of highlands and lowlands in a particular topographic region. The analysis of the configuration of the relief features of Tigray in this section uses differences in elevation, location, and extent as a framework.

2.2.1. Lowlands (500-1000 meters)

There are two lowland areas in Tigray: 1. Lowland Plains of Kafta-Humera and 2. The Tekeze-Trough. Both of these land features are located in Western Tigray. The flat and rolling Kafta-Humera lowland plains lie in the western most territory of Tigray that shares borders with Sudan in the west and the Tekeze River and the Eritrean Gash-Setit (district) in the north. In the south the lowland plains extend to the Angereb River divide. The Kafta-Humera Plains are separated in the east from the Tekeze Trough by the elevated hills of Welqait. Fig. 2.1; Fig. 2.2.

The Lowland plains are one of the most forbidding places in Tigray that were not settled as early as the other parts of Tigray. How low-lying and hot the area is can be discerned from the elevation of Humera Town (585). When anti-malaria drugs were not available, these lowlands were death fields due to malaria infestation. Before the advent of commercial agriculture the Plains were a no-go areas for humans. Tegaru in the adjacent highlands were the first to conquer the Kafta-Humera Lowland Plains to establish commercial farms and urbanize them. Fertile alluvial and volcanic soils cover the entire stretch and several rivers notably the Kaza River and its tributaries flowing to Sudan have dissected the flat, rolling, and hilly lowland Plains.

Fig. 2.2 Kafta-Humera Lowland Plain

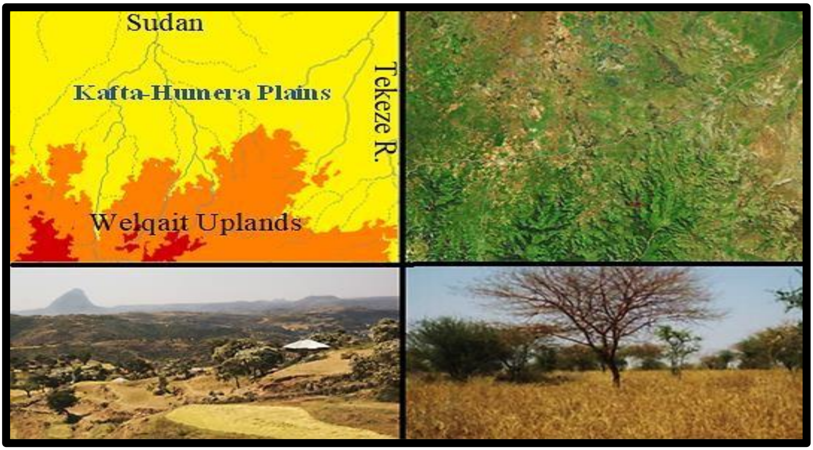
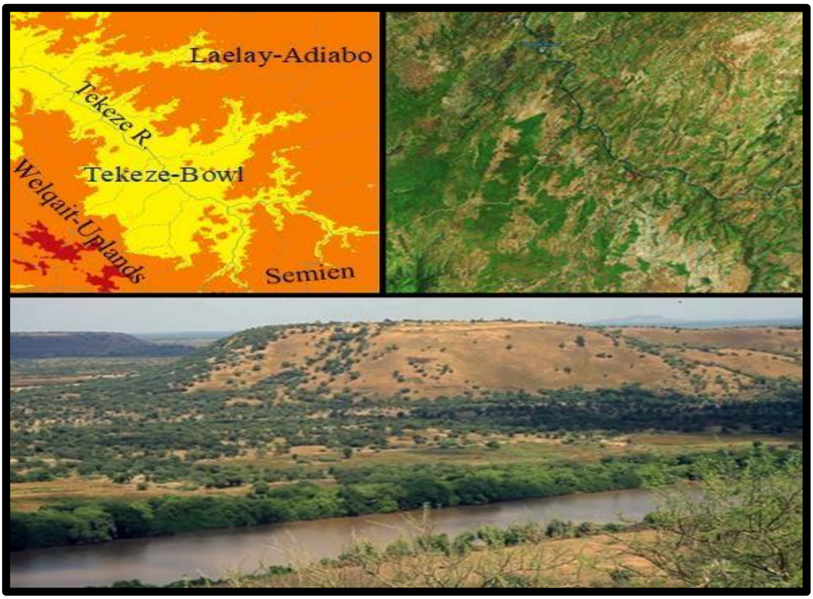


Fig. 2.3 Tekeze-Bowl and the Kafta-Sheraro National Park

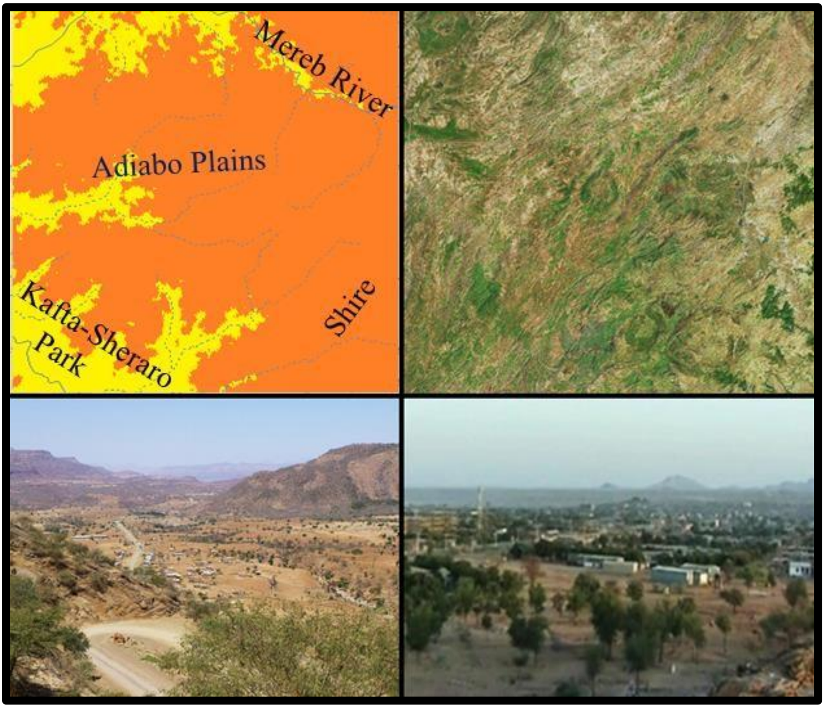


The Tekeze-Bowl is another lowland area which has the shape of a huge circular depression. The Bowl is flanked by the Shire-Adigrat Ridge in the east and the Welqait Hills in the west. On the northern side the Adiabo Plains show lesser contrast in elevation. The rolling-plains of Adiabo very gently slope into the Tekeze Bowl. This lack of big contrast has enabled the Sheraro Plains in Adiabo and the Tekeze-Bowl to form a single ecological district in the Kafta-Sheraro National Park. The amazing natural paradise supports large mammals like elephants and other species of mammals. The Tekeze-bowl is covered the Paleozoic rock formations along the banks of the Tekeze River. The rest of the bowl is made up of the Precambrian rocks and scattered remnants of the peneplain. Fig. 2.1; Fig. 2.3. The biotic community in the Park include Acacia-Commiphora, Combretum-Terminalia, dry-evergreen, montane and riparian woodlands; 167 mammal (lion, leopard, caracal, aardvark, greater kudu, roan antelope, red-fronted gazelle); 95 bird (red-necked ostrich); 9 reptile species; about 100 African elephants; and migratory demoiselle crane (EWCA, 2015, Blanc et al, 2007, Gebremedhin and Demeke, 2011).

2.2.2. Mid-Elevation (1000-2000 meters)

One of the four mid-elevation relief districts in Tigray is the Adiabo low hills and rolling plains. This land feature is bounded by the Mereb River valley in the north, the Eritrean Gash-Setit (district) in the west, the Kafta-Sheraro National Park in the south, and the Shire-Adigrat Ridge in the east. Fig. 2.1; Fig. 2.14. The Plain land is a Precambrian peneplain composed of Sheraro-Formation, the Tsaliet Group and a large area of granite outcrops. Tahtay Adiabo, the wereda centered by Sheraro (1246m), was the home of the TAHADU (Tahtay Adiabo Hadegti Agricultural Unit), which was established before 1974. The extensive warm and wooded plain is also famed for its Barka-breed cattle (Begait), which are reared by the virtuous communities of the Kunama People. The historical significance the Adiabo Plains is marked by their role as the cradle of the struggle of the people of Tigray against national oppression.

Fig. 2.4 Adiabo Plains



The Mereb-Slopes is another mid-elevation relief district in Tigray. It is the southern half of the narrow and elongated upper-middle basin of the Mereb River. The name of the Mereb River valley is much bigger than the volume of water that flows in it. It was used as a divider of the heirs of the Axumite Kingdom, by Italian colonialists and the Abyssinian King. In fact, the Valley is not worth the name of a natural border between Tigray and Eritrea, because the slopes on both sides of the valley are so gentle that the residents of both banks of the River belong to the same community, sharing grazing lands and cattle watering points besides the strong kinship ties the people retained. The Mereb-slopes lie between the Adiabo Plains in the west, The Shire-Adigrat Ridge in the south and the Eritrean side of the basin in the north. The eastern limit of the Mereb-Slopes is the elevated Gulomekeda tableland, where in the famous Zalambessa is located. Fig. 2.1; 2.5.

The Mereb-slope is covered by the Tsaliet and Tembien Groups as well as several pockets of granite outcrops belonging to the Precambrian Era. The central portion of the Mereb-Slope is Mereb-Leke Wereda; the northern parts of Lailay-Adiabo and Ahferom Weredas are also included in the relief district. One of the key features of the Mereb-slopes is the highway from Yeha and Axum, the ancient centers of Tigray, to the Red Sea littoral cites of Asmara and Massawa. At the height of the Axumite Empire the same route was used to link the African interior, Axum, and the ancient Red Sea port of Adulis. At the base of the slope is located the cute little town of Rama, where irrigated gardening of fruit-trees has been a widespread practice for several decades.

The Wer’ie-Trough is the most centrally located mid-elevation relief district in Tigray. The dominant rocks in this terrain district are the Tsaliet Group of the Precambrian. There are also the Tembien group and granite outcrops along the banks of the main Wer’ie River.

Fig. 2.5 the Mereb-slopes

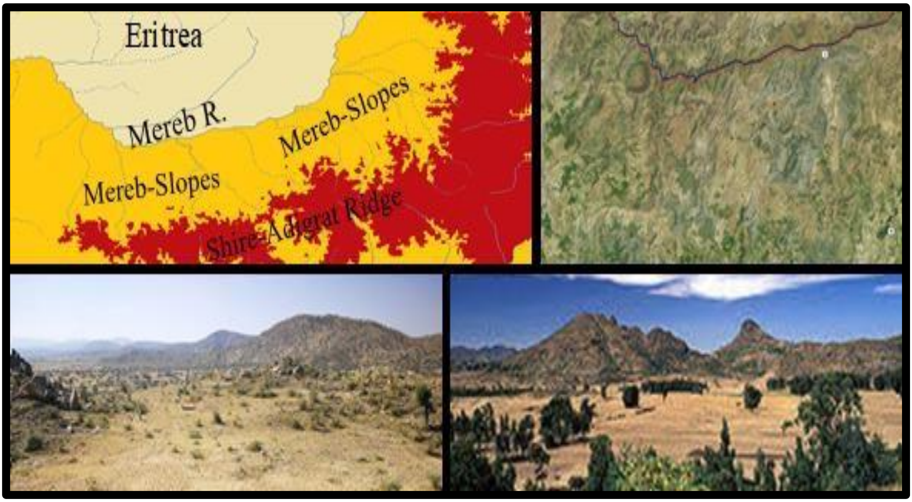
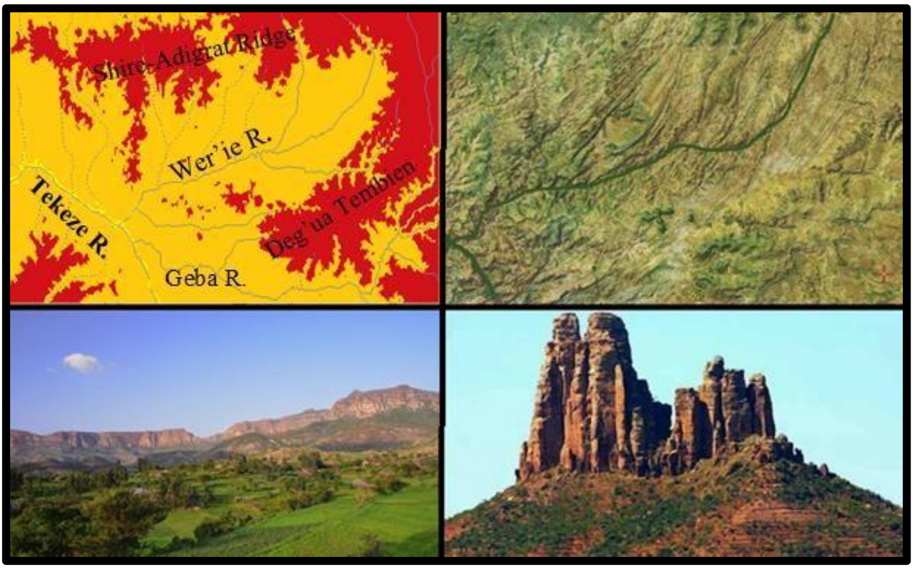


Fig. 2.6 the Wer'ie-Trough



The Wer'ie Trough possesses numerous amazing landscape features the most prominent of which is the Emba-Seneiti of Nebelet: "a chess-tower" (Fig. 3.6). The Wer'ie-Trough falls within the three weredas of Wer'ie-Leke (named after the feature), Naeder-Adet, and Kola Tembien. The dominant feature of the Wer'ie-Trough is the Wer'ie River valley; but the lower course valley of the Giba River is also included which lies between Kola-Tembien and the northern boundary of Tanqua-Abergele Weredas. Wer'ie River is one of the three major tributes of the Tekeze River that have their sources from the highlands of Tigray. The other two are Giba and Tselere Rivers. The Wer'ie-Trough is the most enigmatic of all river valleys in Tigray. It is so extensive, covered throughout by highly dissected hills and sparsely settled that historically it was an arena for testing velour. The Wer'ie-Trough is a historical thoroughfare between two highland regions in the northern and eastern- central parts of Tigray.

The Mokhoni-Sink is a long and narrow depression that has created a spectacular contrast with the Raya-Massif. Fertile soils have formed over the quaternary sediments throughout the entire stretch of the Sink. The Mokhoni-Sink is bounded distinctly by the Raya-Massif in the west and the western edge of the Afar-Triangle in the east. The typical elevation is represented by Alamata Town (1520m). A new detour highway to Mekelle has provided the opportunity for the terrain district to experience a more rapid trend of urbanization. The high groundwater table has allowed well-based irrigation. Raya-Valley is a mammoth irrigation project to help local farmers increase their agricultural productivity. Mokhoni-Sink is well known for the Raya-breed cattle and the prickly-pear cactus for animal feed. The terrain district is inhabited by the Raya-Tegaru who are famed for their beauty and kindness.

Fig. 2.7 the Mekhoni-Sink and the associated Waja Plains

2.2.3. Highlands (2000-3500 meters)

There are six relief districts that fall within this category: the Welqait-Hills, the Shire-Adigrat ridge, the Agame-Massif, the Enderta-Tembien Plateau, the Rift-Valley Escarpment, and the Raya Massif. These distinct classes of landforms are found in all parts of Tigray: West, North, East, and South. Fig.2.1.

The Welqait-Hills relief district differs from the rest in the category of Highlands in its characteristic mix of Mid-elevation (1000-2000) and Highlands (2000-3500). It includes the uplands of Tsegede and Tselemti. Welqait is the western most highland area in Tigray, bounded by the Kafta-Humera Plains in the west, the Kafta-Sheraro Park in the east, the Tekeze River in the north, and the Semien Massif in the south. Tsegede lies along a narrow land strip on the southern slopes of the Welqait-Hills; whereas the Tselemti upland is the north-side foothills of the Semien Massif. In this relief district the highlands and mid-elevation uplands are the results of Trap-lava eruption of the Cenozoic Era which formed rocks belonging to the Ashangi (Hashenege) Group. The Chinese CAMC Engineering Company has built a huge sugar processing plant in Welqait with a processing capacity of 24,000 tons of sugar cane. The fertile volcanic and alluvial soils in the area have the potential for the expansion of commercial agriculture. The Kaza River, which joins the Angereb River in the Sudan has its sources in the Welqait-Hills. Adi Remets (1870m) is the capital of Wolqait wereda of Tigray. The meaning of the Tigrigna name of the town is 'a very hot place'. This elevation is expected to be warm not hot. This could hint its historical geography.

The Shire-Adigrat Ridge a long and narrow divide of Wer'ie and Mereb Rivers. It is a ridge of Trap-volcanic origin in the Ashangi-Group. There are also two pockets of a more recent volcanic eruption which resulted in numerous plugs spread throughout the Axum and Adwa areas. The relief district stretches from Laelay-Adiabo to the serpentine pass of Mugulat near Bizet town. Included here are Shire (1953m), Axum (2131m), Adwa (1907m), and Enticho (1964m): all located along the crest of the ridge. The highest peak in the Ridge is Soloda (2436m) near the City of Adwa.

This is the historical core of Tigray; this was where it was born. The Axumite civilization, which flourished as an empire stretching to Nubia and Arabia was centered on this ridge. The counting of the 3000 years of the history of statehood in Tigray started on this Ridge. After the ceding of the littoral region of the ancient Axumite Kingdom to Italian occupation the old core on the Ridge became the closest to foreign aggression. The famous Battle of Adwa against Italian invaders happened here The Ridge is a key tourist destination.

Fig. 2.8 the Welqait-Hills (Welqait, Tsegede, Tselemti)

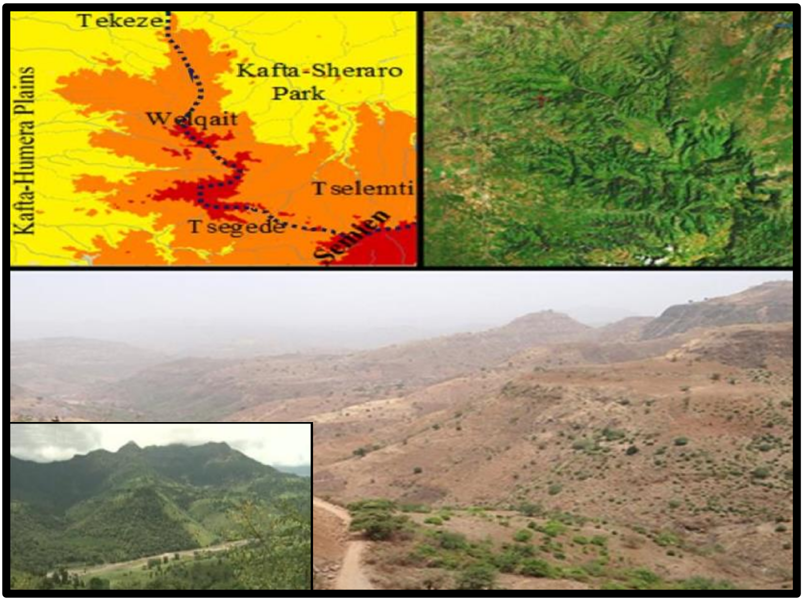
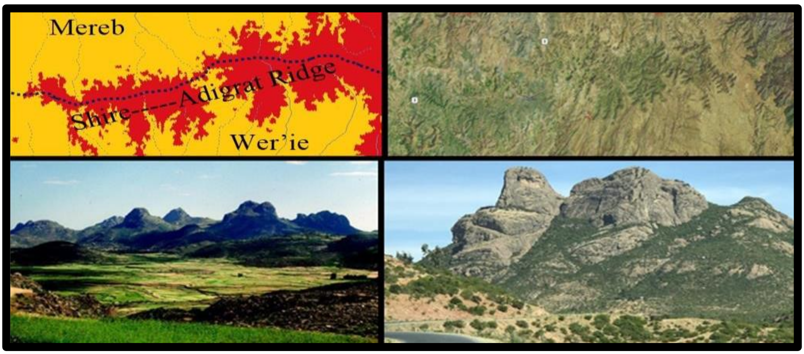


Fig. 2.9 the Shire-Adigrat Ridge (Breathtaking Plugs of Adwa)



The Agame-Massif towers high above the Shire-Adigrat Ridge in the east. The steep ascent to the Massif from the Ridge is marked by the tortuous Mugulat Pass east of Bizet. The massive landscape is the result of the combined thickness of the Paleozoic Enticho Sandstone and the Cenozoic Trap-series lava of the Ashangi Group. The largest part of the Agame-Massif is located in Ganta-Afeshum. Adigrat, the second largest city of Tigray sprawls in a low lying flatland on the eastern foothills of the Massif. The City serves as a strategic node linking the Mekelle-Asmara and the Adigrat-Shire Highway. It is the closest large city of Tigray to the Eritrean Border as well as to the Eritrean Port of Massawa. The implication for investment of this geographic location is obvious. The Agame-Massif is in stark contrast in elevation to the Dalol Depression: the geomorphologic spectacle in the east. From the top of the highest mountain in the Massif Mt. Mugulat (3263m), the elevation falls to 130 meters below sea level at Dalol only in a 70 kilometers distance as 'the crow flies'. The Agame-Massif also possesses close to its southern edge Negash: the second most revered Islamic Shrine after Mecca. The Massif is also well known for its pleasant temperate climate and entrepreneurial society. Fig. 2.8.

The Agame-Massif descends down south to the flat and rolling of Enderta-Tembien Plateau at the Negash serpentine road. The Plateau can be referred to as the "Mesozoic Pie" of Tigray. The Mesozoic rocks, Antalo (Hintalo) Limestone and Agula Shale, cover the entire relief district in a no less than 60 kilometers of radius around Mekelle. Along the northeastern and western edges of the "pie" there are narrow bands of exposures of the Adigrat Sandstone and Enticho Sandstones. In the northwestern edge of the Plateau the Sandstone exposures display the spectacular landscapes of Gere'alta. Fig. 1.10.

Fig. 2.10 the Agame-Massif (Connects three basins)

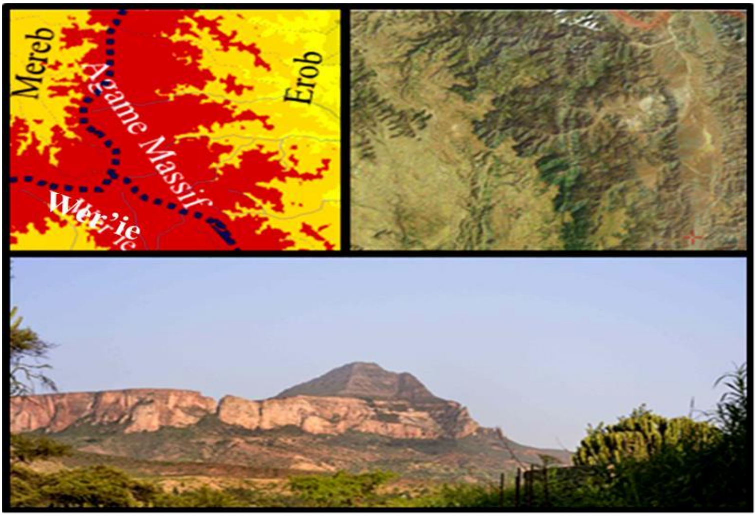
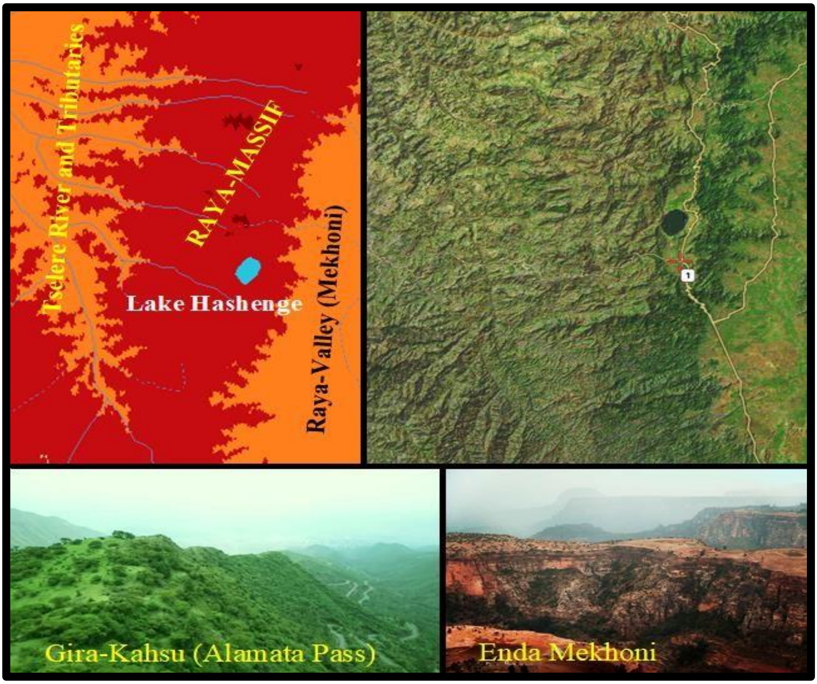


Fig. 2.11 the Enderta-Tembien Plateau

Included in the Enderta-Tembien Plateau is the Awlaelo Plateau in Wuqro Wereda, which is adjacent to the Agame Massif in the north. The general elevation of the rolling Plateau is between 2000 and 2500; but there are peaks that rise to 3000m: Imba Tsion (2917m) in Hawzen, Ekhli Imba (2799m) in Degu'a Tembien, Imba Ar'adom (2756m) in Hintalo Wajirat, and Imba Neway (2388m) in Abergele. The general elevation of the Enderta-Tembien Plateau could also be discerned from the elevation of urban centers located on the Plateau: Mekelle (2254m), Hintalo (2050m), Hawzen (2105m), Hagere Selam (2625m), Wukro (1972m), Hiwane (2479m), Agula (1930m). Hintalo, after which the Mesozoic sedimentary layer is named, is located on the Plateau. It was the Capital of Tigray with the overlordship of *Rae'si* Woldeselasie. The current Capital city is also located on this Plateau.

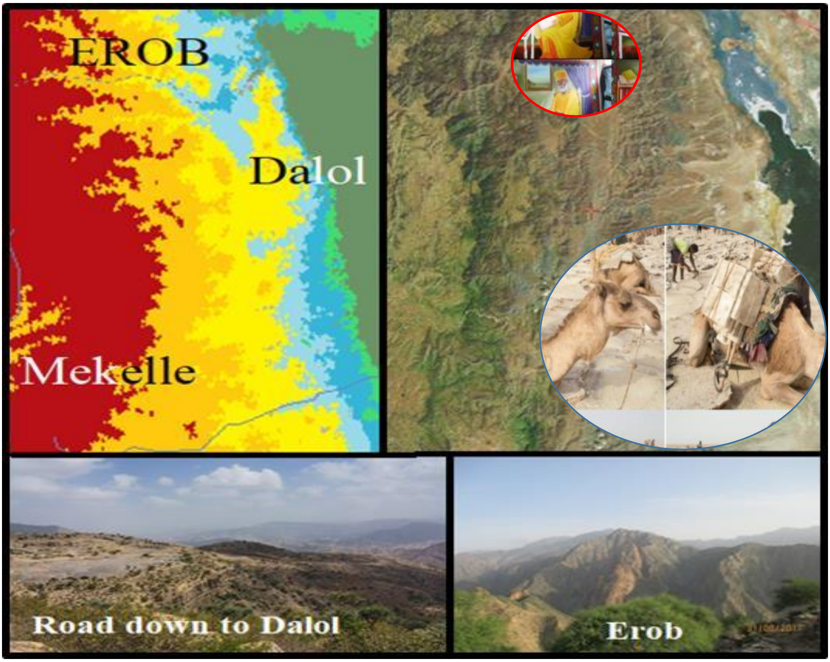
What make the topography of Tigray 'bipolar' are the two high mountain districts in the northeast and south of Tigray separated by a relatively low-lying Plateau. The Enderta-Tembien Plateau rises steeply into the Raya Massif from the edge of the Hiwane Plains. The serpentine road on the slopes of the Alaje heights is where the Raya Massif soars over the adjacent Hintalo-Wejerat. Unlike the Agame Massif the Raya-Massif is made up entirely of Ashangi Group lava of the Trap-series volcanism. The Massif can be referred to as the "Roof of Tigray" on the basis of the fact that the highest mountains in Tigray are located in this terrain district: Tsibet (3939m) in Endamehoni and Emba Alaje (3438m) in Alaje. The major urban centers also reflect the general elevation of the relief district: Adi Shehu (2305m), Maichew (2479m) and Korem (2539m). At the southern edge of the Raya-Massif is found the Gira-Kahsu Pass; a dangerous but breath-taking serpentine road that descends Almata and the Waja Plains. The Massif is also known for the high altitude lake of Hashenege (2409m). Another important landmark located in the Massif is the Hugumburda priority area forest. According to Leul, Sileshi, and Tamirat (2018), key commercial tree species in the forest are: Juniperus procera, Olea eurpaea ssp, Cuspidata, Rus glutinosa, Ficus sur, Hagenia abyssinca, Cassiopeia malosana, and Acacia etbaica. Historically, Alaje, the northernmost portion of the Raya-Massive, is reputed for the victory against Italian forces in the 19th Century and the stiff resistance Woyane movement posed against the oppressive feudal regime of Ethiopia.

Fig. 2.12 the Raya-Massif (the "Roof of Tigray")



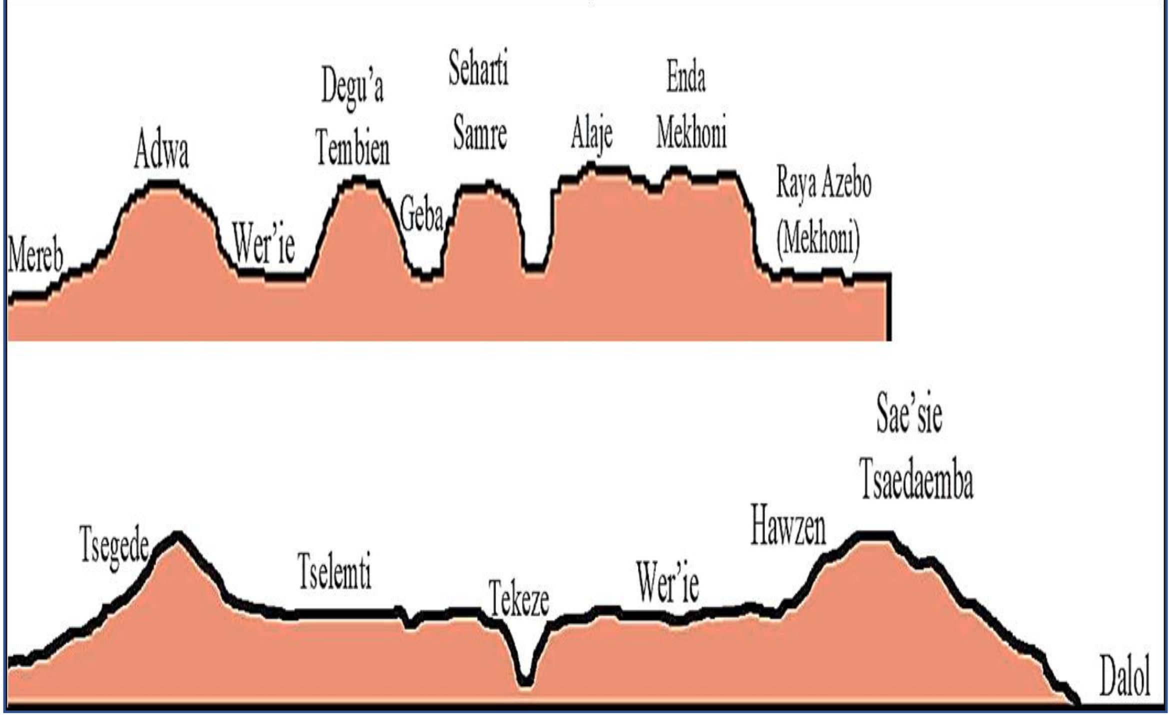
The Great Rift Valley of East Africa extends from the Jordan River Valley to the port of Beira in Mozambique. The Rift Valley has high, medium to low escarpments on its two sides. Although the formation of the Rift system has created the depressions for the Red Sea and the Gulf of Aden its deepest terrestrial rift is found east of Tigray within a distance of less than 100 Kilometers. Here, the contrast in elevation is the greatest. Fig, 2.13.

Fig. 2.13 the Rift-Valley Escarpment (Dolol is closest here)



More than the geological and geomorphological significance the Dalol Depression has its extensive salt flats have been a source of livelihood for thousands in the Tigray side of the Rift Valley Escarpment. For centuries camel caravans to Dalol and back to Enderta, Kilte Awlaelo, and Raya have transported rock salt not only for the local but also for a wider market hundreds of kilometers in radius. Tsegay Berhe Gebrelibanos has done a thorough research on the "Arhotay" cultural history of salt miners and traders and the economic significance of rock-salt from Berahle (Dalol). According to Tsegay (2009) salt from Berahle (Dalol) had extensively interacted with export commodities and other items channeled into regional economies of the Horn of Africa. It also had widespread social impacts. Mekelle was a prominent market in the salt trade. The Escarpment falls within the administrative units of Saes'ie Tsaeda Emba, Erob, and Atsbi Womberta. The highest peak along the Tigray escarpment is the Atsbi Horst (3057m). While Saes'ie Tsaeda Emba has a large area under Paleozoic sedimentary rocks in its northern parts the remaining areas of the Escarpment are dominated by the Precambrian basement rocks: Tsalient, Tembien and Didikama. In Erob, The remnants of the faulted and folded structures of the Precambrian orogeny and the alternating bands of the Tsaliet, Tembien, and Didikama basement rocks have given the landscape an extraordinary architecture. There is still more human than the physical in Erob. The Erob People are extremely resilient communities that have managed to survive and thrive in the extremely rugged and degraded terrain. Erob has been the shelter of Christians since the early years of the faith in Tigray. The monks have built monasteries notably the Mariam Gunda-Gondo, an astounding architectural masterpiece. The Monastery was the center of Deqiqe Estifanos, a movement that advocated very progressive ideas that could have transformed or upturned attitudes of medieval period Ethiopian society. They faced barbaric persecution in the hands of the Church and the Kings (The Ethiopian Herald, 2018).

Fig. 2.14 Cross profile of the terrain of Tigray from Mereb to Mekhoni and Tsegede to Dalol



2.3. Drainage Landforms (dissected topography)

In terrain analysis drainage systems are important components because drainage pattern recognition helps to provide a qualitative description of the terrain for analysis and classification (Zhang and Guilbert, 2012). Relief-landforms are built by the geological processes of rock formation; whereas fluvial-landforms are the outcomes of the geological processes of the demolition of the structures by fluvial erosion. Dissected topography, as the fluvial-land form is alternatively known, is landscape eroded into a network of valleys and interfluves which is influenced by the differences in slope, rock resistance, structure and geologic history of the area (Feldman, Harris, and Fairbridge 1968). The landforms also reflect the successive episodes of uplift, depression, tilting, warping, folding, faulting, and jointing (Zernitz, 1932). Combinations of these geologic controls lead to the formation of identifiable drainage patterns (Drummond and Erkeling, 2014).

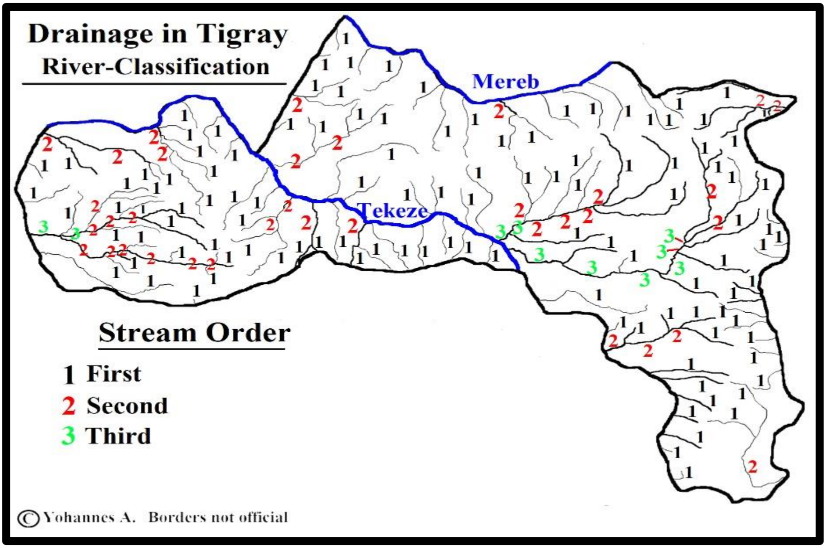
2.3.1. Drainage-landform analysis

In this section, drainage patterns, river classification, and basin hierarchy analysis is done. Except for a small-number of small-size mostly ephemeral streams that flow towards the endorheic Afar Basin, the drainage system in Tigray is almost entirely in the Nile sub-basin of Tekeze-Mereb. As the drainage sub-system in Tigray is in the upper course of the Nile System, the fluvial landforms are more of erosional than depositional. There are relatively small areas of depositional landforms, as alluvial plains, in Humera and Mekhoni. The mix of complex geology and the largely semi-arid climate of Tigray has given rise to a drainage-topography dominated by a network of highly dissected and seasonally dry valleys. As is typical to semi-arid climates the rains that last for no more than two months in summer are characterized by brief and intense showers. This results in flash flooding during the rainy season and low base flow during the dry season. Fig. 2.15.

Fig. 2.15 Mereb River during the rainy and dry seasons (top); Wer'ie and its tributary Tsaliet during the rainy season (bottom)

The brief and torrential rains that are characteristic to the semi-arid climate of Tigray are highly erosive aided by the sparse vegetation cover on the slopes. Besides the geological erosion the happens so gradually that it is almost imperceptible in the human life time, thousands of years of settlement and mismanagement of the land such as over-cultivation, deleterious tillage practices, and the removal of vegetation cover for settlement and the production of timber and firewood have accelerated the formation of gullies and deep rills on the slopes. Fitsum, Pender, and Nega (1999) have determined that half of the highlands of Tigray are degraded. The magnitude of the problem can somehow be estimated from the number and the proportion out of the overall drainage system of ephemeral streams. Streams become ephemeral when the rate of runoff exceeds drastically over the rate of infiltration. Since the latter is responsible for the recharge of local groundwater aquifers the logical outcome of the excessively low level of infiltration becomes low to absent base flow in the valleys during the dry season.

Fig. 2.16 River classification by order in Tigray



Of the total of 80 first order streams in Fig. 2.16, 58 (73%) are ephemeral, meaning that the streams dry up during the long dry season of 9 to 10 months. During the long season of desiccating evaporation and wind, the high rate of runoff during the rainy season lowering the water table, the soils on the stream beds and banks and elsewhere in the watershed, become dry and loose allowing much easier removal of soil. In a study conducted in the Giba, Tanqua, and Tsaliet rivers peak discharge of flash floods has been 50-100 times larger than the preceding base flow (Amanuel et al, 2019).

The upper, middle, and lower Tekeze is joined by ephemerals which are 15 (75%), 29 (90%), and 4 (30%) of total first order streams. It is worth noting that the tributaries of the Tselere River, which joins the Tekeze River from the right bank, have their sources from the more humid Raya-Massif. Here the picture is different from the rest of the Tekeze tributaries. Seventy percent (9:4) of the tributaries of Tselere River are perennial streams. Similarly, the Giba River has 78 percent of its 1st order streams perennial. Extreme situation is observed in the Mereb Basin where all the 1st order tributaries from the left bank (Tigray) are ephemeral streams.

Fig. 2.17 Different features of Giba River

Fig. 2.18 Multiple features of the Tekeze River in Tigray

The Giba River is the longest river in Tigray. The River, which is the largest tributary of the Tekeze River joining it inside Tigray, has five major tributaries: Suluh, Genfel, Agula, Ilala, and May Gabat. The tributaries have their sources in Ganta Afeshum, Atsbi-Womberta, northeast Enderta, and southeast Enderta respectively. Suluh is the headwater of the Giba River having its source in the Agame-Massif. All of the five major tributaries are left-bank tributaries; and four of them rise from the western slopes of the northeastern Rift Valley Escarpment of Tigray.

Giba River is close to Mekelle in the north; and a large reservoir is being built for the City's urban water supply. The dam is built at the confluence of Suluh, Genfel, and Agula tributaries. The reservoir has an originally planned capacity of 350 million m^3 (Gebremedhin and Walraevens, 2013). The tributaries of the Giba River are some of the most erosive with an estimated sediment load of 497– 6543 tons/ km^2/year (Vanmaercke, Amanuel, and Deckers, 2010). Fig. 2.18. The Reservoir behind the Giba dam could be severely silted if proactive soil conservation action are not taken.

Fig. 2.19 Drainage network patterns in Tigray

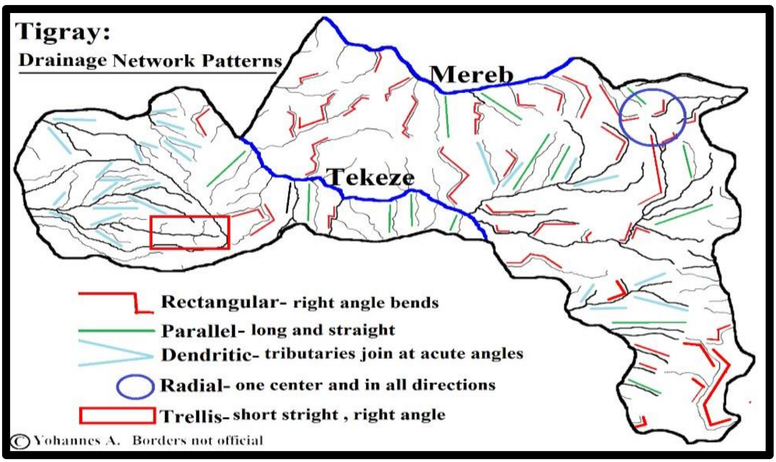
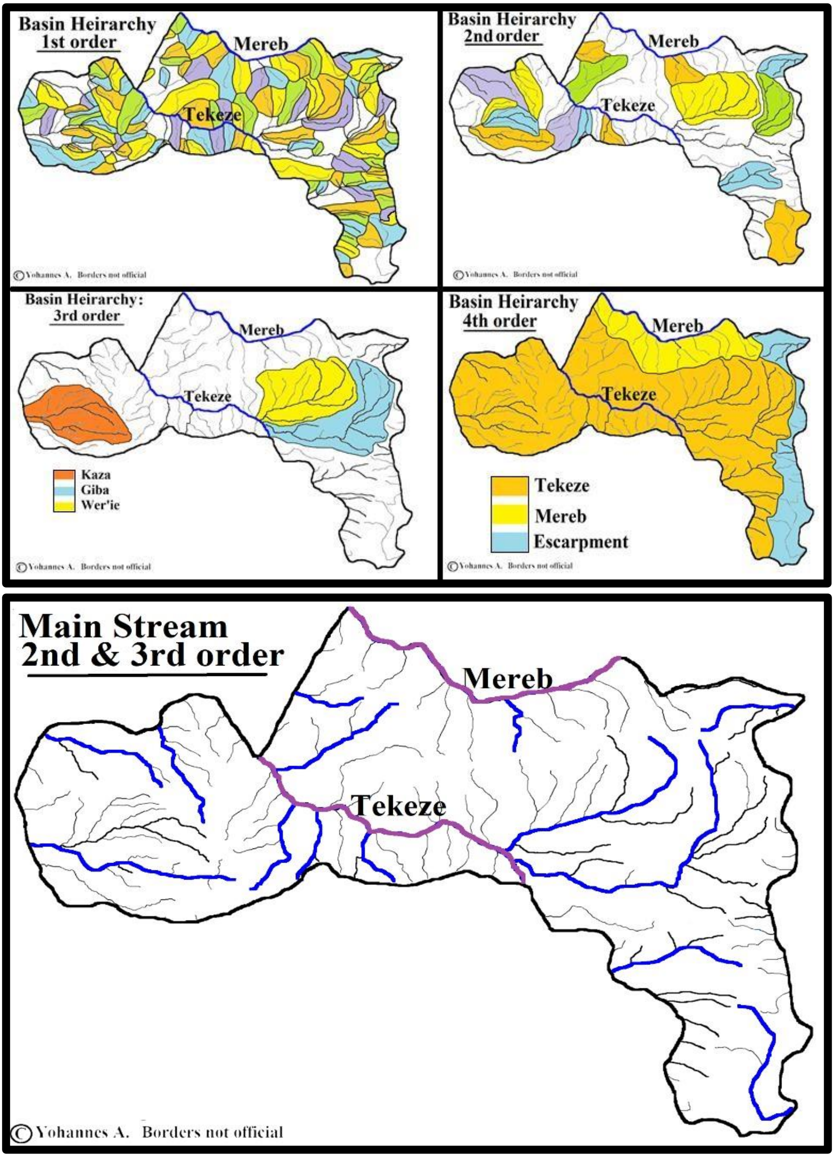


Fig. 2.20 Identified basin hierarchy and main streams in Tigray



The two dominant drainage network patterns in Tigray are the parallel and rectangular patterns. Dendritic patterns also exist largely in Western Tigray and in a few drainage networks in Central and Eastern Tigray. The ubiquity of the angular stream valley networks can be explained with the existence of geologic formations characterized by the high-density of geological contacts and fault lines all over the Precambrian and Mesozoic surfaces. Fig. 2.19. Another aspect of drainage analysis is the identification of basin-hierarchy. It follows from the dominance of first order streams in Tigray that first order basins are dominant. Fig. 2.20 shows that the ratio of first order basins, second order basin, third order basins, and fourth order basins in Tigray is 114:16:3:3 respectively. Main streams are identified using the source-terminal length approach.

2.3.2. Geoanthropology

Geoanthropology is an interdisciplinary approach to the study of the diachronous and synchronous interaction between Earth processes and humanity (MacNeish, 1967). The people of Tigray have suffered a great deal from severe problems of their own making: accelerated fluvio-geomorphic processes. One of the key impacts of land degradation in Tigray is the worsening hydrological drought which is the outcome of the biogeophysical feedback mechanism accelerated by human contribution to the vicious cycle.

The people of Tigray have not been degrading their land with imprudence; the unfortunate geomorphic circumstances were forced on them. Throughout the centuries hundreds of internal conflicts and external wars of aggression have reduced the lives of Tegaru to the level of mere daily concerns of survival. Located as Tigray is close to the Sahel, frontline of the expansion of the Sahara Desert, the increasing frequency, severity, and geographical spread of meteorological drought has complicated the problem and put it beyond the capacity of the unassisted communities. Local governments had been busy with expanding their power and tax-base rather than attending to the widespread land degradation problems the people were facing. The central government had been engrossed in its own malevolent agenda of weakening Tigray politically and economically.

Fig. 2.21 Tigray: victorious over wars and nature with the same hands

The advent of the Tigray People's Liberation Front (TPLF)-led government both at the Center and in Tigray ushered a New Era of self-determination and the combined capacity and willpower to solve the twin age-old problems of land and hydrological degradation. With full participation of the people the Tigray State Government has undertaken one of the most successful cases of land rehabilitation intervention in the world (Mulubrhan et al, 2019). The outcome of the three decades of relentless effort in soil and water conservation has provided potential areas for shallow groundwater development in most of the valley floors (Kifle and Van-Steenbergen, 2015).

Chapter III: Climate and Drought

Climate is the average condition of the atmosphere computed over three decades or more. It is more or less a permanent state of the atmosphere at a particular place. The reference to Humera as warm and dry is what is normally expected. This does not imply that on some days Humera would not experience episodes of chilly weather which forces the normally light t-shirt wearing Humerans to look for warm pullovers. A long and torrential downpour of rainfall may also surprise residents of Humera on some days of the rainy season or even during the dry season. Such negative or positive deviations of the local atmospheric conditions from the climate characteristic to the area are known as weather conditions. Geography as the study of the characteristics of places is focused on climate while the science of meteorology studies the short term variations in the conditions of the atmosphere. This chapter describes the climatic conditions in Tigray as well as the frequent anomalies to the norm in the form of meteorological drought. Climate change in Tigray is also discussed as the subject has become an urgent global and regional issue.

3.1 Temperature conditions in Tigray

It is indicated in Chapter 1 that Tigray is a tropical land as it lies between the Equator and the Tropic of Cancer. This implies that it experiences warm temperature conditions throughout the year. Located between 12^o N-15^o N Tigray gets the overhead sun twice a year in the months of May and August. Compared to areas in the subtropical and temperate latitudes Tigray is too warm throughout the year to experience the markedly different temperature seasons. However, Tigray's location in the tropical latitude is not the only determinant for its temperature conditions. If that were the case all parts of Tigray would experience similar temperature conditions. The spatial distribution of temperature conditions that could have been felt as a result solely of latitudinal location is modified by variations in altitude above mean sea level. Other things remaining the same temperature gets progressively lower from the Equator to the Poles. Similarly, temperature decreases from lower to higher elevations. In what is known as the normal lapse rate temperature decreases 6.5^{o} C in every 1000 meters of rise in altitude. This implies that places located along the same latitude could differ in their temperature conditions if there is a marked difference in elevation.

The difference in the monthly average maximum temperature of Humera and Adigrat, which is 41.7^{o} C and 27^{o} C respectively cannot be explained by the difference in latitudinal location which does not exist. Both stations are located along the 14 ^{o}28'N parallel. The difference between Humera and Adigrat, in the monthly average maximum temperature, can clearly be explained by their elevation difference: 585 and 2457 meters above mean sea level respectively. Additional example can be the difference in latitudinal location between Korem and Alamata which is a mere eight minutes; but the difference in their monthly average maximum temperature is this high: 25.5^{o}C and 35^{o}C respectively. This is attributed to the difference in elevation between the two stations: Korem (2539 meters) and Alamata (1520 meters). Sudan is lowland tropical. It has a great deal of similarity with Humera. El-Gedarif (14^{o}28' N; 634 meters) and Khartoum (15^{o}30' N; 381 meters) experience monthly average maximum temperature of 41^{o}C and 41.9^{o}C respectively.

Table 3.1* Temperature by elevation and latitude in Tigray

Station	Elevation (Meters)	Coordinates (Latitude)	MM	Mm	mM	mm	MM-Mm	mM-mm	MM-mm
Mekelle	2254	13°47'	27	22	18.5	13.8	5	4.7	13.2
Aby'adi	1950	13°62'	31.7	27.8	21.6	17.5	3.9	4.1	14.2
Adigrat	2457	14°28'	27	22	15.9	11.4	5	4.5	15.6
Korem	2539	12°50'	25.5	19.4	14.9	9.7	6.1	5.2	15.8
Humera	585	14°28'	41.7	33	29	20	8.7	9	21.7
Axum	2131	14°13'	29.4	22.3	12.9	6.7	7.1	6.2	22.7
Sheraro	1246	14°40'	39	33	20	15	6	5	24
Shire	1953	14°10'	31.8	23.4	14.4	6.7	8.4	7.7	25.1
Alamata	1520	12°42'	35	27	10.6	3.6	8	7	31.4

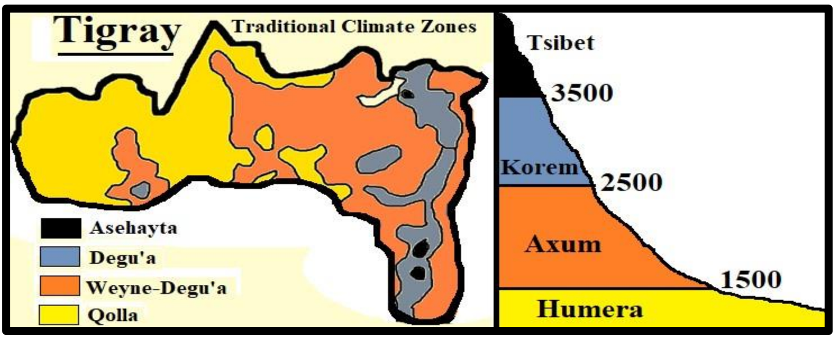
*This table was compiled based on: Data from levoyageur.net, worldweatheronline.com, climate-data.org, and weatherbase

Elevation differences do not explain in which months of the year temperature will be the highest or the lowest. That is for latitudinal location to determine. Since the latitudinal difference between the southern tip and the northern most tip of Tigray is only three degrees the warmest months and the coldest months for all parts of Tigray are April to June. December is the coldest month for most parts of Tigray; but there are a few stations which experience the coldest weather during the month of August. This is due to the cooling effect of cloud cover during the main rainy season, which otherwise would have been a warm month. In Table 3.1 the stations which get highest amount of annual rainfall are where August is reported as the coldest month of the year: Humera, Shire, and Axum. Folk meteorology in Tigray notices how intense the Sun's rays become when the sky is clear during August; it is the month of the second overhead Sun in Tigray.

Another feature of temperature in Tigray that is determined by latitudinal location is the range of temperature expressed as the difference between: 1. the monthly average maximum of the maximum (MM) and the monthly average maximum of the minimum (Mm); 2. The monthly average maximum of the minimum (mM) and the monthly average minimum of the minimum (mm); and 3. The monthly average maximum of the maximum (MM) and the monthly average minimum of the minimum (mm). Table 3.1. The ranges of temperature between the highest maximum month and the lowest maximum month for Humera, Shire, and Alamata are the highest with 8.7^{o} C, 8.4^{o}C, and 8.0^{o} C respectively. The lowest is the range for Aby'adi (3.9^{o}C); Mekelle and Adigrat following with 5^{o}C each. This shows how high the average maximum can rise during the hottest month and how low the average maximum can go during the coldest month of the year.

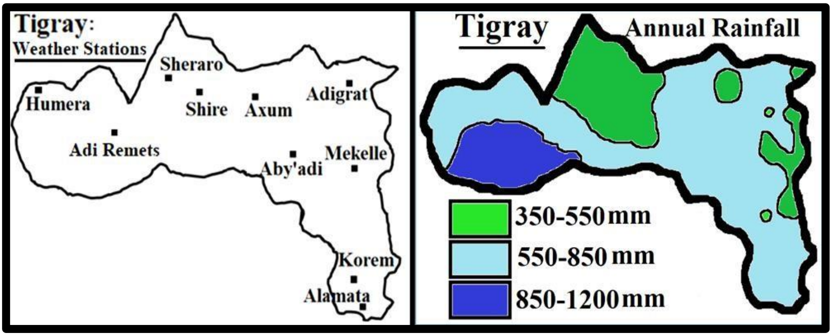
How high the average monthly minimum is and how low the average monthly minimum goes is another expression of the range of temperature experienced annually. The difference between the highs and lows is the highest for Humera (9^{o} C), Shire (7.7^{o}C), and Axum (6.2^{o}C). The lowest values are observed in Aby'adi (4.1^{o}C), Adigrat (4.5^{o}C), and Mekelle (4.7^{o}C). The range between the two extremes is the most important indicator of the annual variation of temperature in a particular area; this is the difference between the highest monthly average maximum and the lowest monthly average minimum. The highest range of temperature between the two extreme months of the year is recorded in Alamata (31.4^{o}C), Shire (25.1^{o}C), and Sheraro (24^{o}C); whereas the lowest values are for Mekelle (13.2^{o}C) and Aby'adi (14.2^{o}C). Associated with the range of temperature is the suitability for human habitation. Other determinants remaining constant the lower the range of temperature the higher the human convenience for work and residence.

Fig. 3.1 Traditional elevation-temperature zones



The negative correlation between elevation and temperature distributions has been framed in the traditional elevation-cum-temperature classification scheme: Qolla, Weyne-Degu'a, Degu'a, and Asehayta. The traditional climate-zones are listed by the order from lowest to the highest elevation matched with the hottest to the coldest respectively. Neither there is a convention nor a consensus about the exact altitudinal ranges for each of the traditional climatic zones. Here, the more common altitudinal boundaries are used in the compilation of Fig. 3.1.

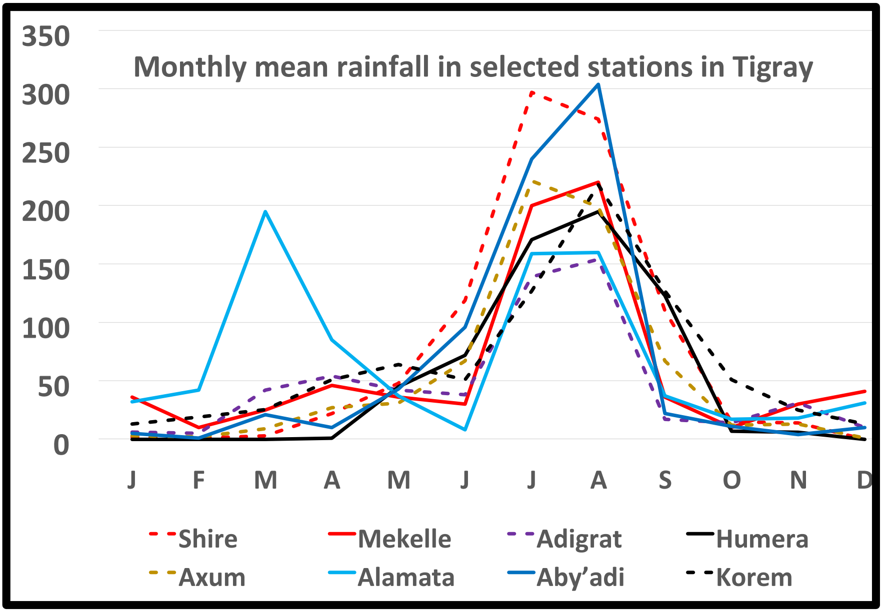
Fig. 3.2 Location of selected meteorological stations, Tigray

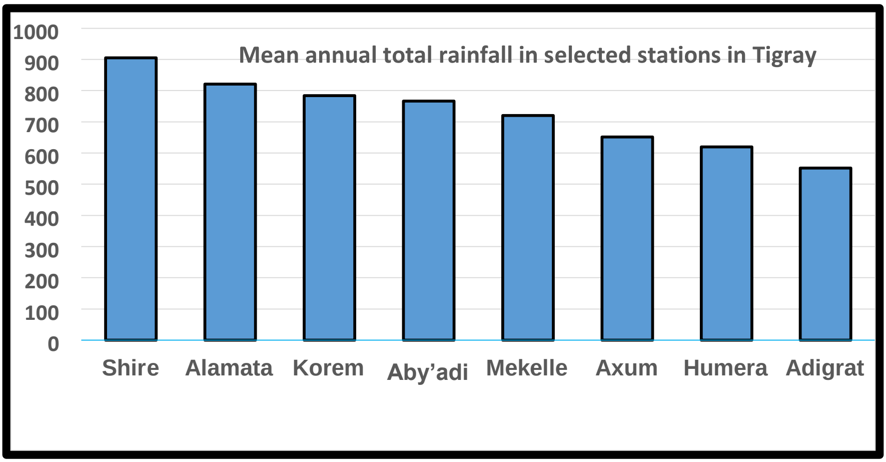


3.2 <u>Rainfall patterns in Tigray</u>

Except for the southern administrative zone Tigray gets all of its rain during *Kremti* (Northern Hemisphere Summer). Southern Tigray gets additional rain during what is known as the season of “little rains” in *Tsedia* (Northern Hemisphere Spring). Fig 3.3 shows that the average annual total rainfall, in most parts of Tigray, does not exceed 1000mm. The temporal distribution in all stations peaks in July and August. The nature of spatiotemporal distribution of rainfall in Tigray can be understood if the global and regional patterns of rain-causing air-circulation is described. Rain is brought to Tigray carried by the prevailing winds known as Southwesterlies. In Africa these global winds blow from the high pressure in southern Atlantic Ocean to the destination low pressure cell in the Arabian Desert. Winds normally blow from high to low pressure.

Fig. 3.3* Monthly mean rainfall in selected stations in Tigray





*The charts are compiled based on: Data from levoyageur.net, worldweatheronline.com, climate-data.org, and weatherbase

The Southwesterlies, heavily laden with moisture picked from the Gulf of Guinea in Sothern Atlantic and adding to its load of moisture from the humid Congo Basin, blows towards the Arabian low pressure cell. Between the Gulf of Guinea and the Arabian Desert lies the extensive mountainous regions of western Ethiopia which acts as a barrier on the path of the moisture-laden Southwesterlies forcing the prevailing winds to shed most of their moisture on the highland region. Exhausted of their moisture after the orographic rainfall on the western highlands of Ethiopia the dry Southwesterlies pass on to the Danakil Rift and the Arabian Desert rendering them rainless. En route, the Southwesterlies cross the Tigray Highlands.

Fig. 3.4 Regional air circulation causing *kremti* rain in Tigray

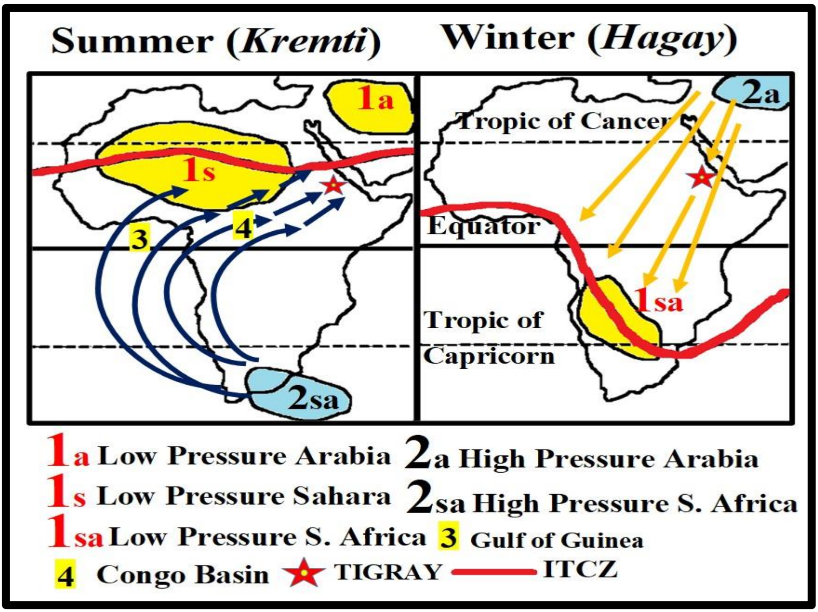
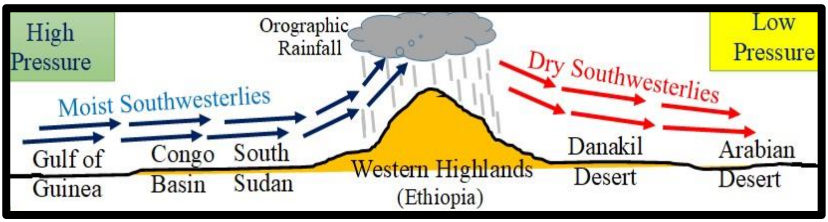


Fig. 3.4 depicts the pattern of the circulation of air that results in the rainy season in Tigray in summer and the dry season in autumn and winter. The position of the Inter Tropical Convergence Zone (ITCZ)

and the low pressure and high pressure cells are also indicated. A low pressure cell develops with greater atmospheric heating. When during the Northern Hemisphere summer the higher angle of the sun's rays prevails, the ITCZ which is a meteorological frontline onto which the Southwesterly winds from the high pressure in Southern Atlantic and the Northeastern Trade Winds from the high pressure in western-central Asia converge. Wherever the atmospheric pressure becomes much lower locally along the ITCZ more intense low pressure cells are created which divert the wind direction towards them. When the ITCZ comes close or overlaps with the Tropic of Cancer during the Northern Hemisphere summer the greater heat in the continental interiors creates low pressure cells in the middle of the Sahara Desert and the Arabian Peninsula.

Fig. 3.5 Orographic rainfall from the Southwesterlies in Tigray



The Southwesterlies emanate from the high pressure cell in the vicinity of South Africa, are diverted to the low pressure cells in the Sahara and Arabia. The winds pick huge quantities of moisture from the Gulf of Guinea and the Congo Basin and reach the western highlands of Ethiopia on their way to the Arabian low pressure cell. Fig. 3.5 shows how the elevated western highlands of Ethiopia condense the moisture the Southwesterlies carry that was naturally destined to reach the Arabian Peninsula.

Fig. 3.6 Distribution of rainfall in the western highlands

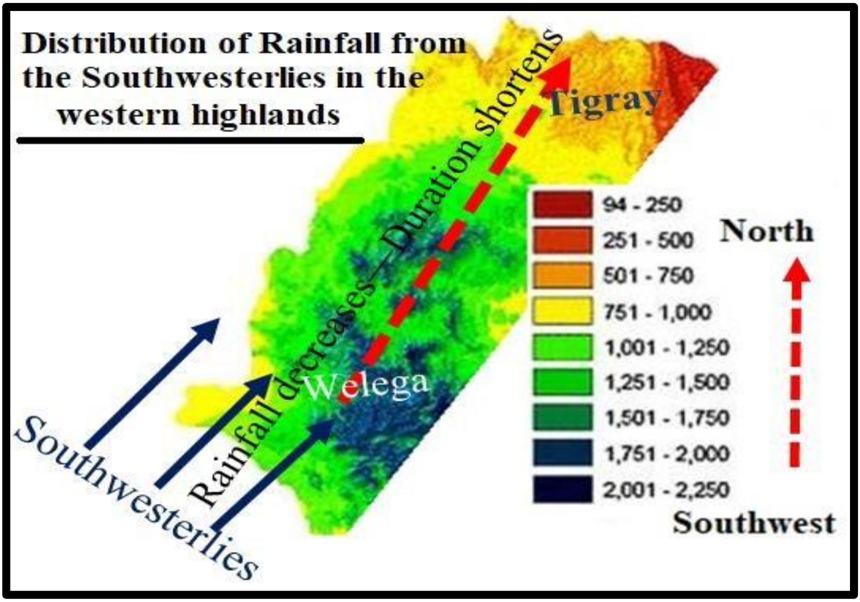
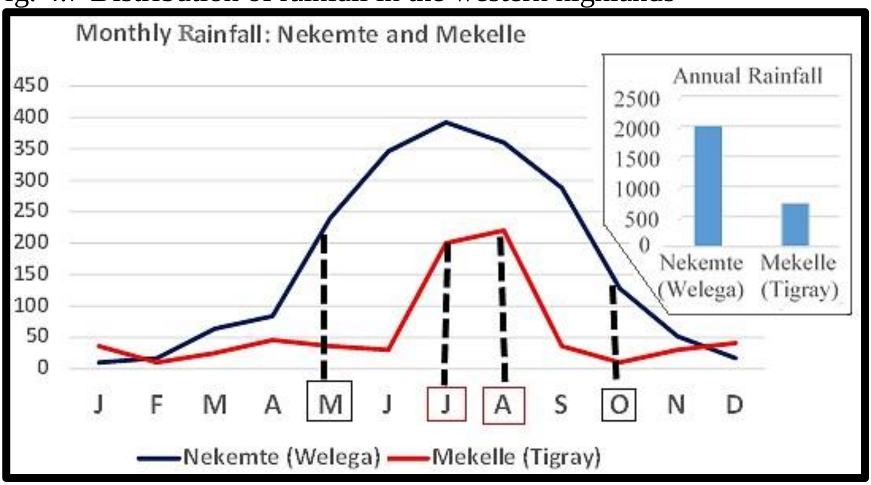
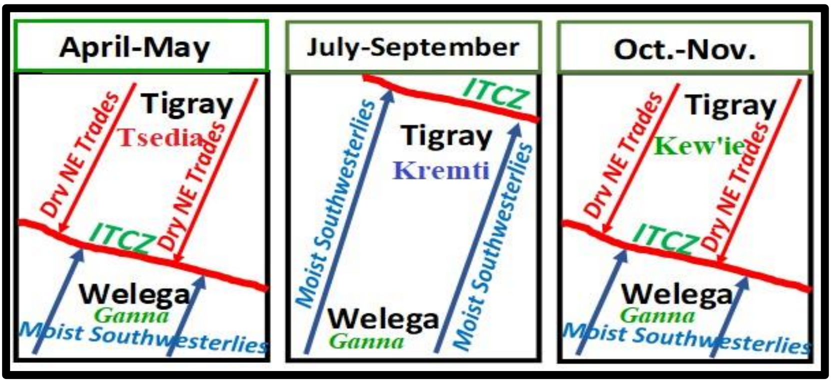


Fig. 4.7 Distribution of rainfall in the western highlands



The northernmost edge of the western highlands are the Highlands of Tigray. It is the circulation of air that takes place during summer that is responsible for the main rainy season in Tigray. Fig. 3.6. The total amount of rainfall in the western highlands progressively decreases from the southernmost part of the highland region (Welega) to its northernmost part (Tigray). This happens because the direction of advance of the moist Southwesterlies is from Welega towards Tigray. The ITCZ (belt of low pressure), into which the moist Southwesterlies are drawn from a high pressure system, advances and retreats only within the Tropical zone between the Tropic of Cancer and the Tropics of Capricorn. The ITCZ follows the direct rays of the Sun as it moves back and forth within the Tropics.

Fig. 3.8 ITCZ: Length of the rainy season in Welega and Tigray



When the Sun is overhead over the Equator during the Equinox (March 23rd) the ITCZ will be located closer to the Equator, far south beyond the borders of the western highlands. As the direct Sun moves towards the Tropic of Cancer the ITCZ also moves northwards pulling with it the moist Southwesterlies. First to get rainfall from the Southwesterlies are the southern parts of the western highlands (Welega). Here the rainy season begins as early as April-May. Fig. 3.7. With the northward migration of the ITCZ, following the position of the direct sun the Southwesterlies reach Tigray late in July. Until then Tigray will remain under the influence of the dry Northeastern Trade Winds from the high pressure area in western Asia, which blow southwestwards to converge with the Southwesterlies at the ITCZ. While the rainy season is ongoing in Welega Tigray remains dry. Tigray will have only two months (July and August) of peak rainy season. Fig. 3.7.

The ITCZ begins its southwards migration because on September 21st the Sun will be overhead over the Equator. By this month the rainy season in Tigray has ended because the ITCZ has gone beyond its southern borders and no more draws the moist Southwesterlies to Tigray. The ITCZ in its southern position draws the dry NE trades from the dry continental interior of western Asia. Tigray will experience the *Kew'ie* (autumn) season, which is a season of harvest of the summer crops. During the transition from *Kew'ie* to *Hagay* (winter) season Tigray gets limited rain from the moisture picked from the Red Sea by the NE-trades. Most of this moisture is dropped on the highlands in Eritrea facing the Red Sea. The limited rain reaching Tigray is the small leftover. In Fig. 3.7 s the two ends of the red curve for Mekelle/Tigray (January and December) show a slight rise over those for Nekemte/Welega.

The Map on the right side of Fig. 3.4 shows the position of the ITCZ and the low pressure cell in southern Africa. This happens when the sun is overhead in the Southern Hemisphere on December 22nd. This marks the beginning of the winter season in the Northern Hemisphere. Now the opposite of the air circulation that takes place during summer (*Kremti*) prevails. The low pressure cell in Arabia (western Asia) in summer changes to high pressure cell; and the high pressure cell in southern Africa changes into low pressure cell.

The Southwesterlies are limited to the southern Atlantic, while the NE Trades dominate the northeastern and central Africa as they blow at a high speed from the high pressure in western Asia to the low pressure cell in southern Africa. The entire Tigray comes under the influence of the dry NE-Trade Winds during the *Hagay* (winter) season. The wind farm at Ashegoda, near Mekelle benefit from the high velocity NE-Trade winds.

Fig. 3.9 Ashegoda wind farm near Mekelle

In the following season, as the overhead Sun is over the Equator, the ITCZ is located half way between its summer and winter position; somewhere across South Sudan. This position attracts moderately moist winds from the Indian Ocean, Arabian Sea and the Gulf of Aden. En route the east-facing western highlands get some rainfall, which in Tigray is known as *Tsedia* (spring). Only Southern Tigray gets the 'small rains' of this season. Fig. shows the peak for Alamata (Southern Tigray) in the month of March.

3.3 Drought in Tigray

3.3.1. Introduction to drought

In climate there are predictable patterns that we get used to and take for granted: rain in the summer and dry in the winter. The established routine of preparing the soil for sowing seeds in June, weeding in July, protecting maturing crops through to the end of the rainy season, are some of the things farmers do with certainty year in year out. Nevertheless, in some parts of the world farmers are surprised by delayed onset of rain, dry spells lasting for a week or so, to a devastating drought lasting for a few years. Although the atmospheric system is more or less predictable, there are anomalies in some of the elements of climate, more commonly rainfall. In some interval the expected rain-causing pattern of air circulation changes as a result of the phenomena which came to be known as "El Niño Southern Oscillation" (ENSO).

The ENSO is the abnormal warming of the Pacific Ocean the effect on the air circulation of which reverberates throughout the Globe. Few extreme natural events are as environmentally, economically and socially disruptive as droughts (Carrão and Barbosa, 2016). In Africa 70% of the Continent is affected by drought; and by 2030, about 700 million people will be forced to leave their homes because of drought globally (Padma, 2019). The United Nations Convention for Combating Desertification (UNCCD) has provided three indicators for identifying drought risk: drought hazard (proportion of land area exposed), the proportion of people exposed, and vulnerability (the degree of risk to people and ecosystems) (Padma, 2019). The US Drought Monitoring system (USDM), identifies levels of drought as: abnormally dry, moderate drought, severe drought, extreme drought, and exceptional drought (NIDIS, 2020). This serves as framework for measurement.

In qualitative terms drought is defined as a deficit of water relative to normal conditions; but providing a quantitative equivalent to this definition is impractical, Lloyd-Hughes (2014) asserts, because the climatological phenomena are interlaced with human influences. Hence, the assessment of drought hazards using various indexes is not as straight forward as it may appear to be. In their assessment of drought risk in Tigray, Amare, Ayoade, and Bello (2019), have demonstrated the importance of integrating socioeconomic and climate data for comprehensive drought risk characterization, which can be used as an input for drought management planning.

According to AKLDP (2015), there are uncertainties around El Niño-specific impacts on the main kremti rains. Of the nine episodes of El Niño only four resulted in severe and extended drought conditions. This implies that the processes of drought, land degradation, and desertification are so intricately interwoven that the magnitude of occurrence of El Niño episodes do not fully explain the severity, frequency and duration of drought. Land degradation is the biological and economic productivity loss of land. Any tendency for plant cover to decrease would be reinforced by a decrease in rainfall and in a positive biogeophysical feedback mechanism initiate or perpetuate drought (Charney, Stone, and Quirk, 1975).

3.3.2. Drought in Tigray

Drought is unfortunately a familiar event in Tigray Goldman (2016) distressingly reflects. Drought induced famines and pestilence in Tigray are reported from as far back as 1535 A.D. and 1634 A.D. (Pankhurst, 1972; Stenhouse, 2003). The 1958 drought in Tigray remained obscure until Mesfin (1986), Bahru (1991), and Gill (2010) exposed it for claiming over 100,000 lives because Emperor Haile Selassie refused to send basic emergency food aid. The cataclysmic 1973-74 famine in Tigray was caused primarily by a prolonged and withering drought. About 50,000 to 100,000 people died as a result; and Emperor Haile Selassie this time said he was unaware of the situation (Mohr, 1974).

The latest and the severest blow to date to the social and economic integrity of Tigray was the 1983-85 drought induced famine. It had a death toll of 1.2 million, leaving 400,000 refugees (Dawit, 1989; Gill, 2010). The majority of the dead were from Tigray (de Waal 1991). The study conducted by Cultural Survival among the Tegaru famine victims in Eastern Sudan revealed that the famine triggered by drought was aggravated by the brutality of Ethiopian troops and the "Hunger as a weapon of war" policy of the Military Government. Drought was found to be a convenient excuse to remove the farming population from Tigray to resettlement areas in southern Ethiopia with the goal of depleting the support base of the TPLF-led rebellion in Tigray (Clay and Holcomb, 1985). This particular drought was so severe that it devastated livelihoods in an already war torn Region, and hundreds of thousands flocked to neighboring Sudan, in a heart breaking long human caravans of emaciated men, women and children. Ruiz (1990) described the tragedy as follows:

> *"Hundreds of thousands made their way to refugee camps in Sudan or to makeshift feeding centers for famine victims within Ethiopia. Many of those who died succumbed during that arduous trek, others died when they reached the camps, either because they were too week to eat or from one of the many epidemics that swept through the camps."*

Drought in Tigray has always been increasingly more severe and more frequent with a return period as short as 2-4 years (Araya, 2011). Furthermore, the risk from drought hazard is higher, given Tigray's higher agrarian population densities and rain-dependent livelihoods, than other drought-prone areas elsewhere in the Horn of Africa. In their analysis of the spatial patterns of drought risk in Tigray Region Amare, Ayoade, and Bello (2019) found out that about 44.1% of the districts in Tigray are in the high to very high drought risk levels, without significant variation in drought risk between them. The pattern of distribution also reveals high and very high drought risk levels largely clustered in the western, eastern and southern zones of Tigray.

Fig. 3.10 Drought and its humanitarian consequences in Tigray

Drought is projected to be worsened in the future due to climate change when warmer temperatures enhance evaporation from soil making periods with low precipitation drier. Through a positive feedback very dry soils and diminished plant cover can further suppress rainfall in already dry areas (C2ES, 2020; Charney, Stone, and Quirk, 1975). Climate change projections are made by Biniyam et al, (2021) to confirm the relationship between climate change and drought in Tigray. The result showed that the average annual minimum temperature will increase by about 0.8-2.9°C; the mean annual maximum temperature will increase by 0.9-3.75 °C.; and the average annual temperature will increase by 3.5-13.4 %. Following from the findings extreme drought events are projected in the future (2018-2099): more than 72% of study area will be affected by extreme drought, 22.3% by severe drought and 5.57% by moderate drought.

In the Southern zone of Tigray there are evidences of climate change according to the research conducted by Misgina and Simhadri (2015): Annual rainfall showed no change across the region, but seasonal rainfalls have exhibited significant trends of changes in the last three decades. The study confirmed that rainfall in lowlands increased significantly by about 106mm/decade, whereas highlands experienced no significant change. Besides, when the highlands lose a significant amount of (35mm/decade), lowlands didn't. The critical problem in Southern Tigray is the rains in *Tsedia* have been failing for many years now. The "little rains" in spring seem to be history.

Chapter IV: Human Geography

Geography is the description and explanation of the distribution of physical and human phenomena on the surface of the Earth. In the preceding chapters the physical geography of Tigray is discussed in some detail. Human geography is the application of spatial analysis of the vast array of the distribution of humans and their activities on the surface of the Earth. In this chapter no attempt is made to cover all aspects of human geography. Rural geography and urban geography, the two branches of human geography, are considered sufficient to provide a good picture of the whats and the whys of human habitation in Tigray.

4.1. Rural Geography

About 80 percent of the total population of Tigray live in rural areas. Since the main occupation of the overwhelming majority of the rural population is agriculture the analysis of rural geography for Tigray is focused on its agricultural geography. Furthermore, in view of the fact that most of the people are engaged in crop production rather than in animal husbandry the different features of the geography of crop production is given the broadest coverage.

Elevations in Tigray range from 500 to 3000 meters. This suggests different agro-ecological zones with their own characteristic crop production. Allied with the agro-ecology are local histories and traditions that can explain why some crops are more commonly grown in some than in others. Tigray is not a recent agricultural settlement. The people are an agrarian society that tilled the land since antiquity. As the population and repopulation of Tigray is traced back to the days of the Middle-Eastern civilizations agriculture in the highlands of Tigray must have been one of earliest recipients of the Mesopotamian inventions and innovations in the cultivation of the land and the rearing of animals. Axum, the precursor of Tigray, was not only a Red Sea trading power but also a prosperous agricultural region. There is a huge diversity of the crops grown in Tigray. There are a large variety of temporary crops (cereals, pulses, oilseeds, and vegetables) and permanent crops (fruits trees, hops, wild prickly pear); but quantitative analysis, displayed on charts and choropleth maps, is made for those which are deemed dominant.

Central Statistical Agency agricultural land use data for 2001 is used in the analysis of the geography of crop production in Tigray as more recent data are partial or unavailable for all weredas. Weredas (districts) are taken as the lowest spatial unit for the analysis. It is the best level for spatial analysis of crop production in Tigray because *tabia* level data is not only unavailable but also an unnecessary detail. The analysis could be a support for agricultural extension planning because wereda is the level in the administrative hierarchy that is selected for government agricultural support programs.

As an introduction to the agricultural geography of Tigray a background of the relationship between land and people is represented with the help of computed and mapped densities. Crude density in this context is the rural population in every km^2 of the area of a particular wereda; while rural or agricultural density is rural population in every km^2 of cultivated land in the wereda. Fig. 4.2.

Fig. 4.1 Location map of weredas in Tigray

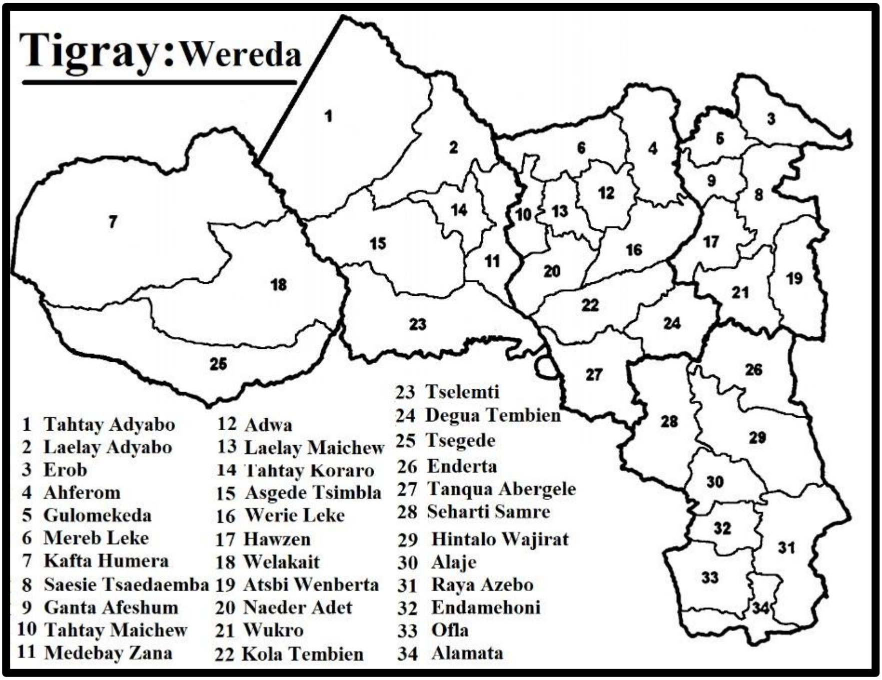
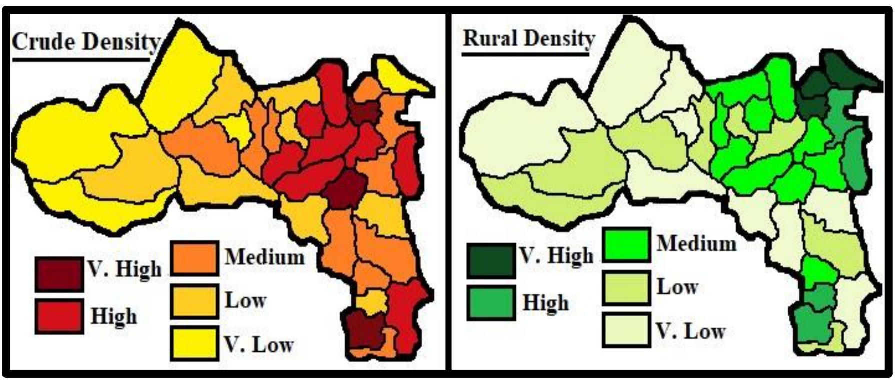


Fig. 4.2 Tigray: Crude rural density and rural (agricultural) density



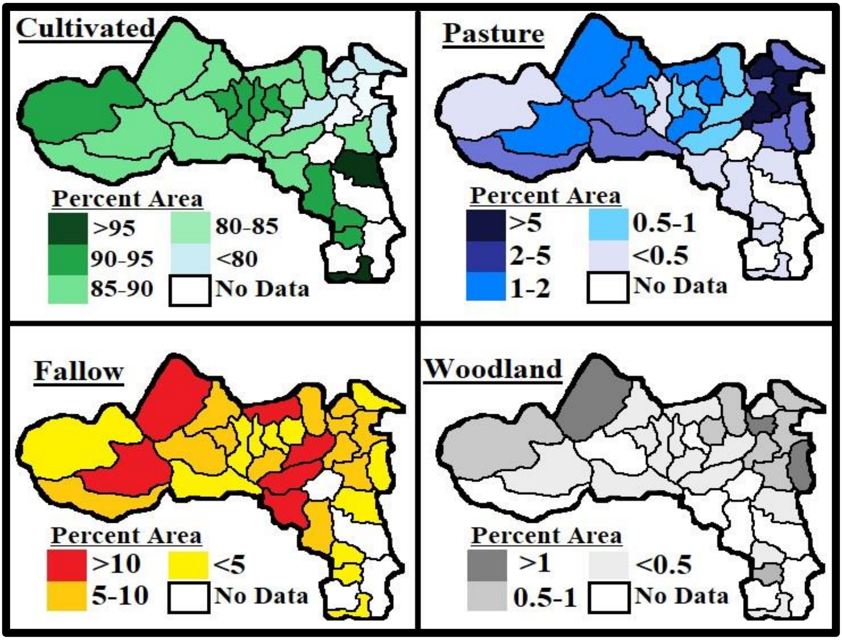
Crude density is the total population divided by the total area. In this particular context of rural geography the total population taken is the rural population (excluding urban population). This can give a general impression about population distribution in a particular geographical unit. However people are not evenly spaced as the measure of density suggests. In real life there could be very high concentration of people in one locality while other places remain vacant or sparsely settled. In rural areas, where crop production is the mainstay of the economy, a measure of population density that takes into account the cultivated land on which people actually make a living, is closer to the truth as a measure of the distribution of population. Rural (agricultural density) density is computed by dividing rural population by the cultivated area in km^2 (converted from hectares to facilitate comparison with crude density).

The two population density maps in Fig. 4.2 compare the two density distributions: crude rural density and rural-agricultural density. Clear spatial clustering is observed where the northeastern-third of Tigray is highest density cluster and the western-third is a low density cluster. Elevation of land as a factor determining the suitability for agrarian population concentration and sparseness is major explaining variable. Another, but a smaller cluster of density is located in the southern-third of Tigray. On a birds-eye-view the two distributions appear to have striking similarity in the relative distribution. However, the figures for agricultural density are 10 to 25 fold greater than the rural crude densities. In Erob wereda it even goes to as high as over 40 fold. The proportion of cultivated land at wereda level in Tigray ranges 7-15% of the total land area. Erob wereda is an extreme case of very high agricultural density, which can be explained by its extremely rugged Precambrian topography.

4.1.1. Land-use and land-cover in Tigray

The land use-land cover maps in Fig. 4.3 are compiled based on the percentages reported in the Agricultural Survey of 2001 by the Central Statistical Agency of Ethiopia. Land use-land cover could not be available for the weredas left unshaded on the maps.

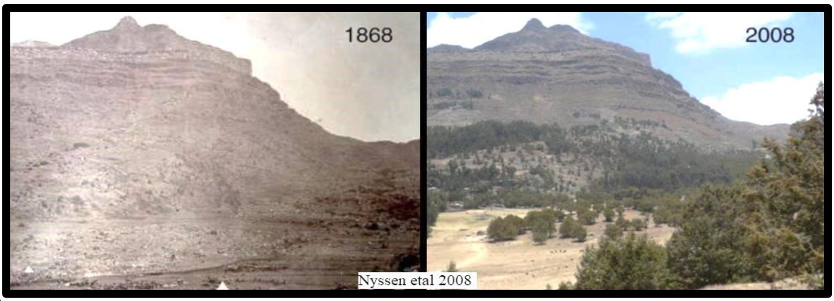
Fig. 4.3 Tigray: Land use-land cover



The share of cultivated land of the total land use–land cover varies from as high as over 95% in Enderta and Alamata to less than 80% in the weredas clustered in northeastern Tigray. The share of cultivated land is so high in Tigray that the figures for only two weredas (Saeseie Tsaedaemba and Hawzen) fall slightly below 80%. The weredas in the vicinity of Axum form a cluster of high proportion of cultivated land. This could possibly be attributed to high population density and historical factors. One of the traditional agricultural practices that help boost crop productivity is fallowing. Leaving the land to restore its fertility for a season or two is a practice which is becoming less and less affordable in view of the rising demand for food crops and industrial raw materials. The rapid increase in population and the rise in the living standard of the population necessitates the continuous cultivation of the land in order to meet the market demand for crops. In Fig, 5.3 fallow land over 10% is in the *Kolla* weredas of Abergele, Kolla Tembien, Weri Leke, Mereb Leke, Tahtay Adiabo and Welqait. The weredas are so less densely populated that fallowing become a greater possibility than it is elsewhere. In Laelay Maychew, Tahtay Maichew, Medebay Zana, and Adwa the low share of fallowing of the total land use could be explained by the centuries of agricultural settlement in the area where little land can be spared for fallowing. Erob, Atsbi Womberta, Alaje and Endamehoni are also low in fallowing due to the high and rugged topography that allows limited availability of land for cultivation in the valley bottoms. Enderta wereda is the immediate supplier of marketable crops to Mekelle City. This may have created a pressure on the supply system in which leaving land fallow may not be rewarding in the short-term.

Pasture land for open grazing has for several decades now become a luxury for the highland agrarian societies of Tigray. The pasture candle is burning on both sides in the sense that frequent drought is lowing the high groundwater table required to maintain a permanent grassland for a pasture. At the same time grasslands are being encroached into disappearance by conversion into cultivated land. In our lifetimes we have seen rich pasturelands turning into dusty plains. The extensive '*Sewhi Ilala',* lying in the *Gembela Plains* of the northern outskirts of Mekelle City, was where almost the entire cattle population of Mekelle grazed in the 1960s. Now no trace of it can be seen. In the rural areas elsewhere grazing lands have become the final frontiers of the expansion of cultivation. With the advent of home-feeding of the grazing livestock pastures have been encroached for cultivation without any restriction. Adding extensively to the reduced availability of pasturelands is the widespread area enclosure which included valley and hill-slope pastures. The mammoth programme of soil and water conservation in Tigray has imposed strict regulations on the use of open grazing on the slopes. Farmers have become accustomed to the ‘Cut and carry’ approach to domestic animal feeding allowing the restoration of not only former grasslands but also the rehabilitation of the extremely depleted woodlands. Fig. 4.4.

Fig. 4.4 Tigray: Environmental restoration after 140 years



All over Tigray, the growing of irrigated crops in valley bottoms has accelerated the conversion of pastures because the latter are more common in valley bottoms where the water table is high enough to support a perennial growth of grass. Fig 4.3 shows the northeastern weredas of Tigray in which the Agame massif is located have got a relatively higher share of pasture land above 5%. The cool temperate highland weredas may have maintained the pasturelands probably due to the lower rate of evaporation which is a serious problem in lowland grazing lands.

The problem of pasture is associated with the 'path dependency' in the age-old practices of rearing large stock farm animals. The stock includes cows, oxen and pack animals. Large stock is reared to satisfy the farm households' as well as urban markets' demand for beef, milk and milk products. Earning income from the sale of live animals, to slaughter houses routinely and individual households occasionally during holidays, is also another motive for raising large stock. However, rearing oxen that serve as traction power in land-tillage and for threshing harvest is most desirable among the traditional subsistence farming communities.

Fig. 4.5 Tigray: Well-known Cattle Breeds; Work Oxen

Rearing large stock requires a lot of water and fodder. This is no more a possibility in Tigray as the pastures are shrinking and the water resource is dwindling. The 'business as usual' in animal farming of raising large stock is no more a sustainable practice. Path dependency is a tendency for what started in the past to persist because of resistance to change. There are several reasons why 'comfortable old shoes' are preferred to the new ones. As 'old habits die hard' the customs and values associated with the old ways do not change readily. Certain ways of doing things can create heavy disincentives for change because so much is already invested in the existing ways that the positive feedback or the self-reinforcing process tends to perpetuate them (Stuteville and Jumara, 2010). The financial cost and the inconvenience of adopting new ways has always been a challenge to societies; but some established public attitudes are more potent impediments to the change to alternative pathways for sustainability.

In Tigray food habits that glorify beef and mutton consumption, raw or roasted, has always caused the market price for large stock to skyrocket. Notwithstanding the sustainability problems that arise from environmental degradation due to increase in the production of large stock to meet the market demand, farmers are motivated to walk on the beaten track and perpetuate the deleterious status quo. Large stock as status symbols in rural societies is still another stubborn cultural value that forms a stumbling block for the identification of novel and sustainable pathways in the rural settings. Unavoidable changes of climate in which a more widespread exposure, extended duration, and higher frequency and severity of drought, with all its biogeophysical feedback implications, will urgently need action.

The 'pathways' approach is a social, technological, and environmental (STEP) process that explores alternative pathways to sustainability, in various environmental and natural resource management contexts, with the aim of resolving sustainable development dilemmas (Beland, 2015). Low-tech climate-based subsistence livelihoods are not sustainable. In Tigray where environmental constraints pose enormous challenge for sustaining even the most basic of subsistence, leave alone a vibrant economy, the identification of alternative pathways seems to be long overdue. Of course, there are a few signs of a shift to more environmentally sustainable and even more lucrative economic activities.

Fig. 4.6 An alternative pathway: bee-keeping in Tigray

The widespread adoption of bee-keeping as an alternative livelihood or as a backup for the mainstream subsistence economy in Tigray can be considered as a great beginning. Be-keeping is a high value production per land area needed for its operation. It does not need a separate cleared land; it can be done in areas that cannot be used for cultivation and in area-enclosure slopes. The side benefit of locating bee-hives in area-enclosures is the benefit of a more enhanced pollination that may accelerate the process of ecological successions. The bee-keeping economy can be a significant employer of youth and women. Value can be added by processing and packaging honey for export. The ASPIRE Programme funded by The Netherlands has been supporting bee-keepers in Ahferom, Weri Leke, Kolla Tembien, Degua Tembien, Seharti Samre, Enderta, Atsbi Womberta, and Wukro (Kilite Awlaelo) with technology adoption and training.

Another area for alternative livelihoods is the harvesting and processing of Prickly Pear Cactus in the Eastern and Southern Zones of Tigray. The thorny succulent plant is a xerophyte that can grow in semiarid marginal lands. This makes it an environmentally friendly economic good. The beautiful and tasty wild fruit is a popular supplemental food stuff in the northeastern third of Tigray. In recent years the fruit is gaining popularity in the urban markets of many larger cities inside and outside Tigray. Katherine Zeratsky of Mayo Clinic listed the health benefits of the Prickly Pear fruit:

treats diabetes, high cholesterol, obesity, and hangovers; decreases blood sugar levels; and possesses anti-viral and anti-inflammatory properties. The fruit is rich in fiber, antioxidants, and carotenoids. It is eaten whole boiled or grilled and also in the forms of juice and jam. These benefits of Prickly Pear can help its commercialization and serve as a major alternative employer in localities where it grows wild. It is also possible to cultivate it in areas devoted for soil and water conservation.

Fig. 4.7 An alternative pathway: Prickly Pear Cactus in Tigray

In Raya the Cactus plant is used more as cattle feed than a part of the diet. Greater food security from crop production in the Zone may be taken as an explanation. Sometimes interventions aimed at alternative livelihoods may go wrong if through cause-effect studies are not made. This is what happened to the good intentions of helping famers in Raya, to use Cactus as a supplemental income source other than its service as cattle feed. According to Tesfay (2015) Carmine Cochineal was introduced in Southern Tigray to add value to existing cactus pear vegetation and created employment opportunity for the locals who started exporting dried cochineal to Mexico and Germany bringing in foreign currency. Conflict of interest arose in the communal lands where cactus pear grows and the programme was halted. Unfortunately, the insect became a full-fledged invasive pest in Hintalo Wejerat, Raya Azebo, Endamehoni and Enderta, and controlling it was not successful. Intervention without caring to investigate the most critical element of tenure is sheer negligence.

Fig. 4.8 Tigray: Use of woodland products in construction

From Fig. 5.3 it is clear that the share of woodlands in Tigray out of the total land-use land-cover is negligible. It does not mean it was like that in the past as well. Although frequent drought and locust invasions have wilted and defoliated tree stands to the extent that recovery was made impossible the human factor to the dwindling of woodlands is more prominent. For thousands of years woodland products have been used for making agricultural implements, firewood, and for house construction. As population increased rapidly the demand for firewood and construction material rose simultaneous. The traditional stone houses in Tigray have ceilings heavily reinforced with large logs. This is needed to prevent the heavy earthen roof from collapsing. It is not difficult to imagine how many trees are logged to build a single *Hidmo*. Fig. 4.8.

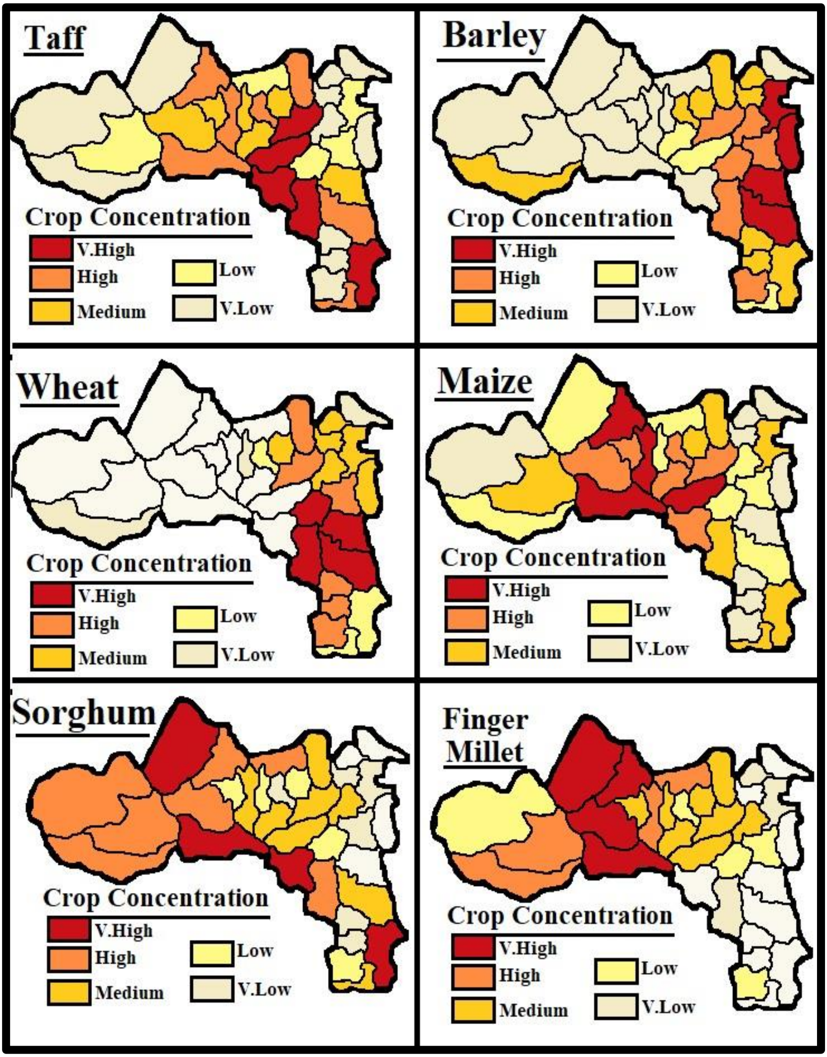
In addition to the local demographic and economic causes of woodland destruction the geopolitical location of Tigray vis-a-vis external wars of aggression has also contributed to the depletion of the woodlands. For more than a century Tigray has been the thoroughfare for attack and defense. The armies from overseas and from Ethiopia depended on the existing woodland products for firewood and other purposes. Internecine conflicts and protracted wars of rebellion have had their adverse impacts on the woodland cover. Restoration of the woodland cover and the maintenance of its ecological integrity requires lasting peace and prudent planning.

Fig. 4.9 Tigray: Forest remnants and what is done to them in Tigray

4.1.2. Cropping patterns in Tigray

Even distribution of the types of crops in a geographical region, which is characterized by altitudinal and climatic diversity is not possible. It is expected that the growing of particular types of climate-dependent crops would be concentrated in some weredas than in others. The geographic differentiation of crop production is expressed in what is known in agricultural geography as "crop concentration" (Murugesan et al 2018). The crop concentration index is computed from the area of land under a particular crop for each wereda. CSA agricultural land use data for 2001 is used in the analysis of cropping patterns.

Fig. 4.9 Tigray: Concentration of cereals in Tigray



More recent data is not available or is inadequate. This is not a serious weakness though. Since crop concentration patterns don’t change significantly in a matter of two decades the results of the index from 2001 data can be considered as valid as a more recent data could be. Weredas (districts) are taken as the lowest spatial unit for the analysis. It is the best level for the analysis of cropping patterns in view of the agricultural extension programmes which are organized at that administrative level. The results of crop concentration index have the advantage of facilitating crop zonation for crop-specific planning and extension assistance.

The index of crop concentration was computed for six cereals, five pulses, and three oil seeds. The 14 crops selected jointly account for 98.8% of the area under temporary crops in Tigray. Separately, the six cereals selected cover 99.9% of the area under all cereals; the five pulses selected make up 93.3% of the land under pulses; and it is 99.7% for the oil seeds. The computed concentration indices for each crop are ranked and cutoff points decided to classify and map as: Very High, High, Medium, Low, and Very Low concentration. The values are not displayed for the ease of reading the distribution.

The six cereal crops are not equally important in terms of their share of the total cereal land in Tigray. Taff and Sorghum, two cereals that are grown in two different agro-ecologies account for 50% of the area cultivated with cereals. The rest of the cereals share the remaining 50% almost equally.

Taff is a staple food in the mid-elevation areas of Tigray. It has an increasingly higher market demand causing its price to sky rocket. Tigray does not produce enough Taff to satisfy the rising urban demand; hence, it is obliged to depend on other markets outside Tigray for the supply. Such unreliable dependence has made it vulnerable to market shortfalls and blockades. People are so used to the taste for the pancake (*Enjera)* made from taff that the price elasticity of demand for the cereal is very low. Unable to change their food habits to crops with better local availability most people spend a large portion of their income on the purchase of Taff. This typifies the link between food habits and food security. Highest concentration of taff is found in the Weri and Tekeze valley weredas of Wei Leke, Kolla Tembien, Abergele, and Saharti Samre. Taff concentration is lowest in the highest and lowest extreme elevations of Tigray.

Maize (*Efun, Meshelahri*) displays a similar distribution with the very high, high and medium concentrations in the mid-elevations in the middle portion of Tigray. There is a clear clustering in the areas of concentration of barley, wheat, sorghum, and finger millet: barley and wheat in the high elevation east and sorghum and finger millet in the lowland west. The overall picture of the concentration of cereals in Tigray is: 1. Cool climate cereals: barley and wheat in the highland weredas in the east; 2. Warm climate cereals: sorghum and finger millet in the lowland west; and 3. Temperate-land cereals, taff and maize in the mid-elevation central region of Tigray.

Although taff is in high demand in the market wheat and barley have managed to be central to the traditions in Enderta and Agame respectively. Wheat (*sinday, sirnay*) for many centuries now has become synonymous with the name of the 'Seb'aa-Enderta' folks. The wheat culture of Enderta has introduced '*Hmbasha*" and "*Hbeshsti*", two different styles of baking wheat-bread, to the world. There are many traditional varieties of wheat in Enderta, most of which have gone out of cultivation, in recent years, because of the introduction of exotic varieties of wheat as part of the foreign funded food security programmes. Hybrid seeds are having the upper hand too. Some of the native varieties of wheat in Enderta and Awlaelo are: *Chira-Feres, Shehan, Albado, Ayqurtem, Felasito, Enguta, Kinkina, Desalegn, Tselim-Senaday.* (Rahwa-Facebook).

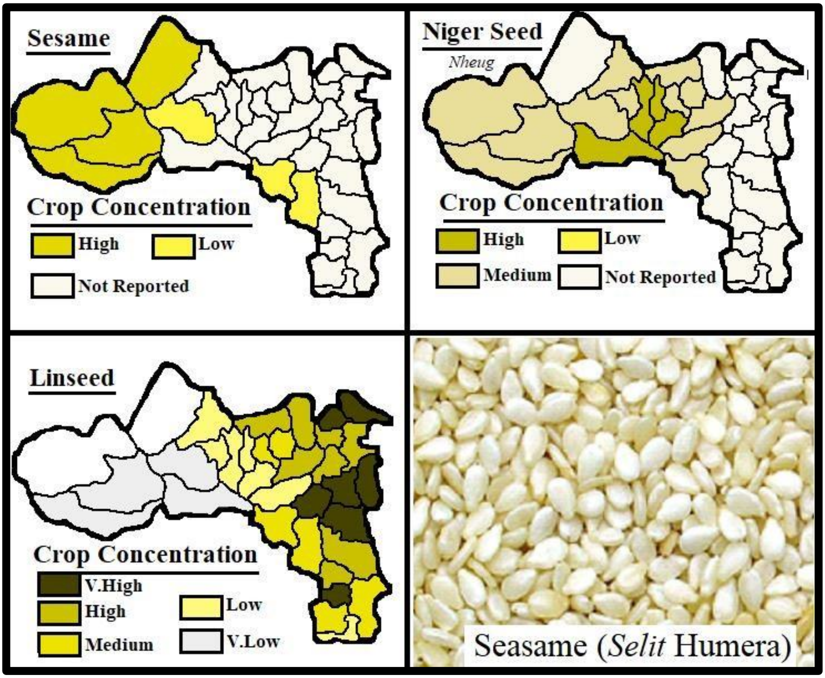
Fig. 4.10 Wheat-bread in Enderta and Barley-*Tihlo* in Agame

Oats (*Ares*) are temperate climate cereals. They are reputed to be effective for reducing cholesterol in the human body. In Tigray oats account for only 0.1% of the total land area under cereals. What makes it unique is not its tiny share of the area cultivated but it's very high geographical concentration. About 60% of the oats cultivated in Tigray is in Enderta. Traditionally, oats is removed from its husk and lightly roasted into a snack known as: *Fintsah*. In the Agame Mountains and barley is not just a staple cereal diet; it is central to the identity of the Agame people. This comes in the form of the unique dish known as *Tihlo.* Fig. 4.10. Outside the Agame region *Tihlo* is introduced to culinary enthusiast all over the world. The balls, rolled from moistened barley flour, are picked by a special stick similar to the Far Eastern chopstick. Sorghum is the theme for traditional songs and the most important part of the diet of the lowlanders. Pancake of baked sorghum flour mixed with milk is a delicacy for the locals and guests alike in Sheraro and Humera. *Wedi Aker* is the most popular local variety of sorghum.

Fig. 4.11 The pervasive *siwa* culture in Tigray: Rural folks in a market *enda-siwa* (top-left); typical earthenware *wancha* (top-right); Professor Jan Nyssen, enjoying traditional meal and a cup of siwa in rural Tigray.

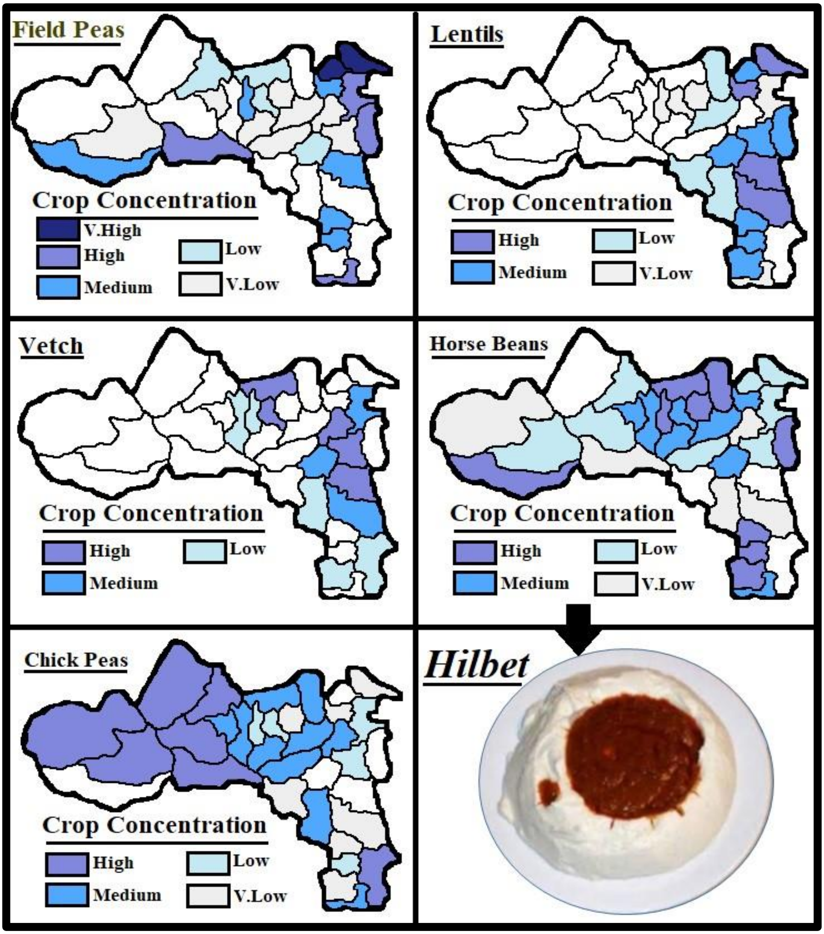
Cereal growing culture in Tigray is not only a staple food growing system but also a widespread brewing tradition. *Siwa,* name of the locally brewed beer, is inseparably woven into the social fabric of Tigray. Although local beer-pubs (*Enda-Siwa*) are ubiquitous all over Tigray no festivities, ceremonies, occasions, church services, farming activities, markets, and even battle fields go without pots of *siwa* around the corner. To most people the pleasure derived from socializing with a *wancha* of *siwa*, skillfully balanced in the hand as it is customarily filled to the brim, is what they value most. *Siwa* is mildly alcoholic but also a nutritious beverage. It is believed to have antiseptic properties; that is why most rural folks drink *siwa* in place of water the quality of which is uncertain. There are at least two brews of *siwa:* the thicker, more syrupy and darker *Duqua* and the more translucent and honey-yellow color *Tseray. Siwa* is brewed from barley (*sigem*) in the highlands and from sorghum, finger millet, and maize in the lowlands. The latter cereals are also commonly used for brewing *siwa* in the highlands as barley becomes increasingly hard to come by.

Fig. 4.12 Concentration of cereals in Tigray



In Fig. 4.12 the concentration of oilseeds in Tigray shows vivid spatial clustering. Sesame (*Selit*) is a western lowland phenomena, while linseed (*Entatie*) is a highland crop in the eastern half of Tigray. Niger seed (*Nhiug)* is a mid-elevation crop cultivated more widely in the central portion of Tigray from Mereb to Tekeze.

Fig. 4.13 Concentration of cereals in Tigray



The dish of a typical meal in Tigray has of two basic components: *Enjera* and *Tsebhi*. The former is a pancake baked from the flour of any of the cereals: taff, barley, wheat, maize, sorghum, and finger millet. The latter is cooked from processed and milled pulses. Oil seeds are included as cooking oil or their powdered form directly mixed into the broth or sauce prepared from pulses. Some of the oil seeds like linseed and niger seed may be consumed directly after grinding or pounding them. In Tigray, as it is elsewhere in the other adjoining regions it is not easy to determine which of the two the main meal is. In practice, the pancake prepared from cereals is used as spoon or fork to convey the broth to the mouth of the diner. This is the irony in food security. Are people spending so much on "spoons" when the main meals are pulses?

Fig. 4.14 Pancakes (Enjerra) baked from the flour of the six cereals

Results of the crop concentration index for pulses in Fig. 4.13 reveal a sub-regional clustering of the crops. Vetch (*Sebere)* and lentils (*Birsin*) are more concentrated in the highlands in the east; and chickpeas (*Shimbra)* are highly concentrated in the lowland west. Field peas (*Ayni Ater*), however, do not display a similarly distinct sub-regional clustering. Field peas, vetch, and chick peas are prepared into a popular broth known as *Shiro.* It is by far the most commonly consumed during fasting days and seasons by the Orthodox Christian faithful. It is so popular that there are specialized restaurants selling a variety of dishes of the broth. Horse beans are similar in the geographical patterns of crop concentration to field peas; but the pulse has a special place in the food menu of the Adwa-Axum areas. A special sugar-white paste is prepared from horse bean powder known as *Hilbet.* Fig. 4.13. The paste, which is consumed with specially prepared red-source and *Enjerra,* is a prestigious meal during the fasting season. Preparing the paste is extremely laborious; but its flavor is rewarding in the end.

Fig. 5.14 Ashenda Tigray: Festival of girls by the end of the rains

Cultivation of crops is the most celebrated of all economic activities in the rural areas of Tigray. The three-days of outdoor festivity with traditional songs and dance is transformed into a religious ceremony; but it must have longer historical roots. What happens in the festivities and the fact that it happens when the rainy season is almost over hints an ancient tradition of celebrating the end of the "dark" season and the beginning of sunny days. Fig. 4.14.

4.2. Urban Geography

Urbanization is the future of our Planet. It is broadly defined as the increasing proportion of people living in urban areas (OECD, 2003).The process manifests itself both by the increase in the number of new urban centers and increase in population sizes of the existing centers (Tsegay, 2010). According to Baqui (2009) world urban population by 2030 is projected to be 5 billion. This trend of urbanization is not the same in developing and developed countries. In the 80 years considered the change is higher in developing countries (38%) than the developed countries (28%). Although a vast potential exists for the urban systems of developing countries there is a need to recognize that rapid and often unplanned urbanization could bring risks of profound social instability, a potential for water crisis, and devastating spread of disease (Scott, 2015 and Faraji, et al 2016).

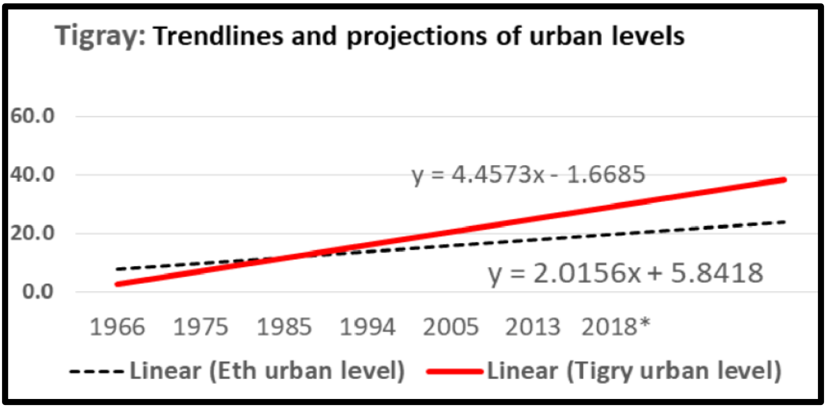
The Demographic Yearbook for 2005 has compiled the various population thresholds used in different countries to distinguish an urban from a rural settlement. The population cut-off points range from 200 to 50,000; and one example from each are given here: Norway (200), Albania (400), Canada (1000), Equatorial Guinea (1500), Ethiopia (2000), USA (2500), India (5000), Malaysia (10,000), Turkey (20000), and Japan (50,000). Typical to the urbanization in developing countries is urban primacy: “macrocephalic urbanization”. Primate cities, defined as the largest cities twice or more in population size than the next cities in the rank order, are characterized by outsized significance in relation to the other cities (Leimenstoll, 2014). A few examples of primate cities are: Bangkok (30 times), Lima-Peru (13 times), and Addis Ababa (12 times). Urban primacy is often the outcome of agglomeration economies where firms and people locate near one another in cities and industrial clusters initially to enjoy the benefits of transport cost savings (Glaeser, 2010). Infrastructure, services, skill, and capital attract investment, leading cumulatively to the largest cities growing much faster than the smaller ones.

4.2.1. Checkered history of urbanization in Tigray

Tigray is the cradle of urbanization in the Horn of Africa embodied in the glorious trading civilization of Axum. The Kingdom of Axum, lasting from around 100A.D. to 940 A.D., was one of the greatest empires to ever exist in Africa (Kennedy, 2016). For many centuries after the gradual collapse of the Axumite urban system whatever urban centers existed were not active hubs of production and trade, but largely served as administrative and campaign centers for the frequently shifting power relationships between local and regional lords and overlords. The urban settlements of this era did not enjoy the kind of functional relationship the network of Axumite cities and towns have had. Rather, they symbolized the politically induced parochialism among the people of Tigray. On top of this, many of the larger urban centers of Tigray served as campaign headquarters for the repeated aggression by Italians. The long period of Italian military campaign had grave implications for the variability of the urban centers in Tigray as leaders of the local and regional economies.

When a unified regional administration was installed by the government of the last Emperor, towns in Tigray became administrative centers of the hierarchies from a governorate general at Mekelle to wereda levels. The urban centers at all levels were not economic centers of any significance. In fact, four of the historically significant urban centers hosted military camps. The main goal of the large garrisons in Adwa (Adi-Abun), Adigrat (Welwalo), Mekelle (Quiha) and Maichew was to use the urban centers as instruments to maintain subordination of the people and the local lords to the throne rather than facilitate the growth of the urban centers as flourishing economic units. They were also used as centers for assimilation through intermarriages. Aggravating the predicament of the urban centers of Tigray was the recurring drought which had been turning the towns into relief camps. It was in this situation that the urban centers of Tigray received the rule of the Military; which did worse by converting the entire Tigray into a virtual battle ground.

Fig. 4.15 Rapid urbanization in Tigray



4.2.2. <u>Trends of urbanization in Tigray</u>

The 17 years rebellion in Tigray ended not only the two decades of military rule, but also the centuries of persistent degradation of the livelihoods of the people of Tigray. The peace and stability that Tigray experienced in the last three decades has been having huge implications for the growth of urban centers. From 14.9 % level of urbanization in 1994 it more than doubled to 34.4% in 2018. This is not only a drastic change on its own, but also the level exceeded the average for Ethiopia since 1994. The gap between Tigray and Ethiopia is projected to widen. The timing of the rapid rise in urbanization in Tigray coincides with the end of violence and the beginning of decades of peace unprecedented in its history. Fig.4.15.

In this section a quantitative analysis of the trend of urbanization in Tigray is done for the years from 1966 to 2013. The analytical study of urban settlements with respect to their size has great significance for regional development and urban planning (Naqshbandi, Fayaz, and Bhat 2016). The analysis is based on decadal urban population data from the statistical abstracts in the Central Statistical Agency. The latest population data (2018) for all urban centers of Tigray was available from the Bureau of Urban Development of Tigray. The decadal population data extracted from the statistical abstracts was not restricted to the pre-1991 Tigray. In order to include Alamata, Korem, and Humera in the analysis the pre-regional state abstracts had to be referred to in the tables for the urban centers in Gondar and Wello provinces.

Fig. 4.16 Family reunion: Alamata, Korem, and Humera of Tigray

There is an understandable limitation to the dataset used for the analysis. The Statistical Abstracts published annually by the Central Statistical Agency of Ethiopia base their reports on population size estimates and projections from the Censuses 1984. 1994, and 2007. There is no way to verify the accuracy of the estimates. The entire work depends on the assumption that the estimates are close enough to the ground-truth. In the statistical abstracts that were issued during military rule some urban centers in Tigray appear in one issue and disappear in another. It was only for the major towns of Tigray that data was consistently available without a break from 1966 to 2018. The cutoff point for determining an urban settlement in Tigray is 2000 or more people. This was used from the beginning (1966) until 1994.Two decadal issues (1994 and 2005) of the abstract disregarded the cutoff point and included settlements with even less than 300 as urban centers. To maintain consistency only urban centers with populations 2000 and above were selected.

4.2.3. Patterns of spatial distribution of urbanization in Tigray

Urban population distribution at any spatial scale is not even. This also holds true for Tigray. Here, the spatial share in percentages of the total urban population of the Tigray, computed for 2018, is done for the Six Zones, Mekelle, and Eleven other major towns. The three categories (Major towns, Mekelle, and the Zones) are mutually exclusive. The share of the zones does not include the share of the major towns located in the territory of the zonal administrative units. The sum of the percentage shares of the total urban population of the Zones is less than half of the total (48%). The remaining more than half of the share is taken by 12 urban centers including Mekelle.

The highest share at Zonal level is for Ma'ekelay, which is 11% followed by Me'erab 9.7% and Semien-M'erab 8.9%. The lowest percentage share of the total urban population is in Debub-M'braq (4.8%). This is probably due to the overshadowing effect of the rapid urban growth of Mekelle, which is located in this Zone. Mekelle, a single urban center alone hosts 20% of the total urban population of Tigray. The only significant other town in Debub-M'braq (Quiha) has already been swallowed by Mekelle. Fig. 4. 17.

Fig. 4.17 Distribution of urban population in zones and urban centers

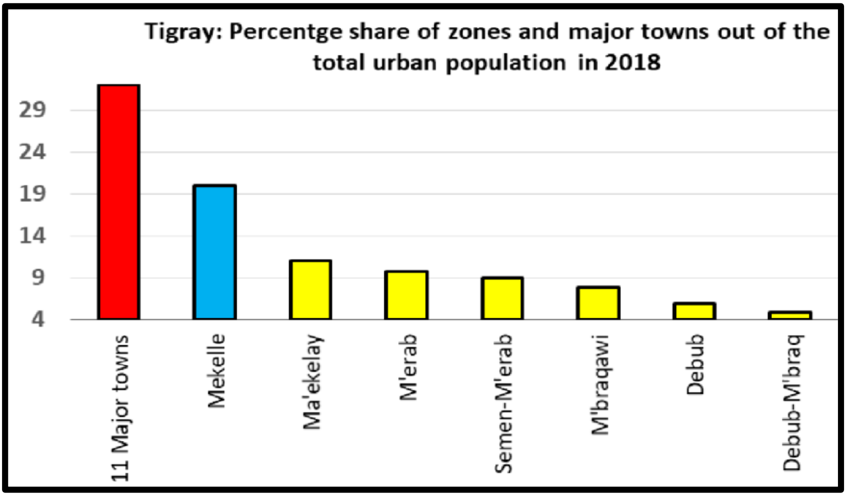
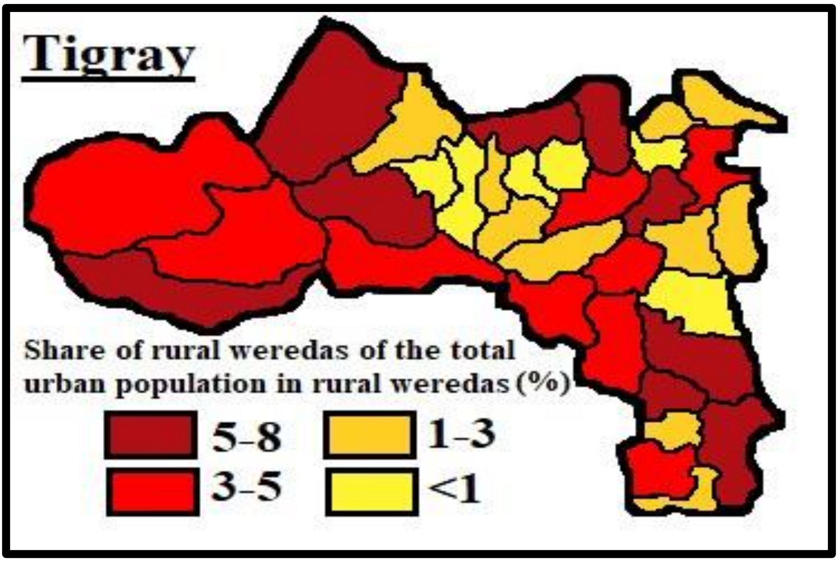


Fig. 4.18 Distribution of wereda urban population



For a better visualization the shares of the remaining urban population of Tigray (48%) of the rural weredas are depicted by a choropleth map. The location of the weredas with the highest shares (5-8%) of urban population do not display geographical concentrations to any significant degree. Although to a lesser extent, the medium levels also have a similar spatial spread. However, the low and lowest levels are more concentrated in the eastern and central weredas. Fig. 5.18.

4.2.4. Size category distribution of urban centers in Tigray

Size category distribution on a time dimension is a very useful analytical tool to understand urban systems. For various historical, economic, political and social reasons urban growth may occur differentially in the smaller, medium and larger urban centers through time. The six size-categories are decided upon by simple eye-balling of the population figures of the ranked list of all urban centers of Tigray in 1966, 1975, 1985, 1994, 2005, 2013, and 2018.

By the mid-sixties (during the Monarchy), about half of the urban centers of Tigray had less than 5000 people. None of the urban centers had a population exceeding 50,000. The largest town, Mekelle, was only 23,000. Even a decade later, by 1975, the situation didn’t change to any degree of significance. The towns with less than 5000 were still 50% of the 21 urban centers that existed in that year. Mekelle was the only urban center in the medium category (20,000-50,000). By 1975, only Adwa joined this category. In 1985 one urban center jumped into the next higher category (50,000-100,000), which had no occupants before. That urban center was Mekelle with a 100% increase in population in just ten years.

The trend by 1985 included some unusual changes where Adwa dropped back and the category (20,000-50,000) was left vacant.

While the category <5000 still maintained its 50% share. The towns in the category (10,000-20,000) increased from four to nine; a 100% increase. In this year 97% of the urban centers of Tigray belonged to categories having < 20,000 people. After 1994, which coincides with the end of the rebellion most of the categories have been increasing, though with some fluctuations.

Table 5.1 Size-categories of urban centers in Tigray 1966-2018

Size Categories	1966	1975	1985	1994	2005	2013	2018
<5000	9	10	14	17	19	12	43
5000-10000	5	5	6	10	13	18	41
10000-20000	2	4	9	4	7	15	6
20000-50000	1	2	0	5	8	7	23
50000-100000	0	0	1	1	1	4	6
100000+	0	0	0	0	1	1	1
No. of Towns	17	21	30	37	49	57	120

By 2018, six urban centers reached the 50,000-100,000 level, which was occupied only by Mekelle in 1985. By 2018, Mekelle has singly risen to a much higher category level, which none of the urban centers in the lower categories can reach in the foreseeable future.

As Mekelle's population skyrockets, still 43% of the urban enters of Tigray are in the categories under 10,000.

4.2.5. Growth fluctuations among the major urban centers in Tigray

In 2018 twelve out of the 120 urban centers in Tigray accounted for 50% of the urban population, while they constituted only 10% of the total number of urban centers. The selection of the 11 urban center from the ranked continuum of 120 is based on their status as "urban-weredas". Such administrative status is equivalent to "rural-weredas" in administrative terms although not necessarily in population size. Percentage changes of population are computed and tabulated for the 11 major urban centers in the end years of the five decades. The growth rates of the urban centers can be compared from two perspectives: all urban centers in one decade and a single urban center in all decades. Table 4.2 and Fig. 4.19.

Table 4.2 Growth rates of selected urban centers, Tigray 1966-2018

Urban Centers	1966-75	1975-85	1985-94	1994-2005	2005-2013	2013-2018	1966-2018
Abiyiaddi	89.5	33.9	-28.3	129.7	18.1	25.1	517.6
Adigrat	59.3	36.3	121.7	66.7	22.6	26.5	1144.9
Adwa	70.4	-33.6	70.9	66.4	31.8	24.7	429.2
Alamata	69.0	103.9	80.8	66.6	1.1	25.1	1213.2
Axum	25.6	7.7	47.4	68.7	29.4	24.9	443.4
Endaselasie	49.2	26.7	89.6	66.3	49.4	24.8	1011.6
Humera	78.5	126.8	32.5	68.2	18.2	25.5	1239.0
Korem	1.9	41.3	75.0	66.0	-20.2	24.7	316.4
Maychew	23.3	46.2	34.2	66.3	-5.4	24.9	375.4
Mekelle	60.0	76.5	51.7	66.8	77.2	25.1	1484.3
Wukro	38.9	66.9	21.3	66.4	46.8	24.9	757.5

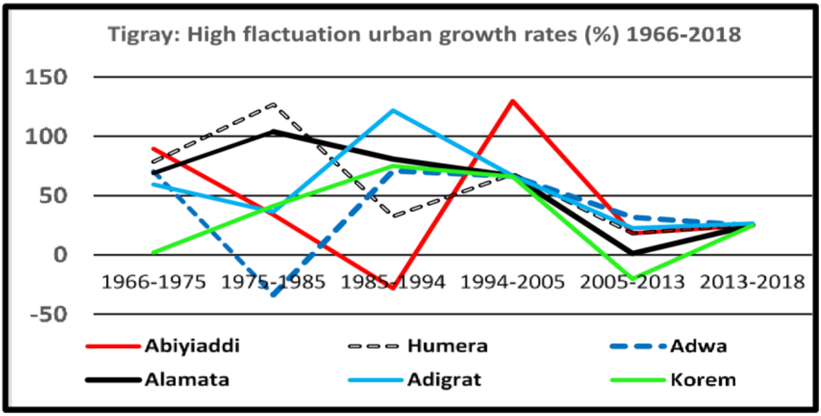
i) <u>Growth rates 1966-1975</u>

This decade was characterized by public disillusionment with the Monarchy, devastating drought in northern Ethiopia and establishment of a military dictatorship. Aby'adi experienced the highest growth rate followed by Humera. The lowest growth rates were in Korem, Maychew, and Axum in that order.

ii) <u>Growth rates 1975-1985</u>

The following decade were years of uncertainty due to the demise of the Monarchy and the consolidation of military rule. The implications to urban development was huge as the urban land proclamation and confiscation of firms further complicated the already existing problems. The intensification of TPLF-led struggle and the liberation war in Eritrea converted Tigray into an arena of war. The highest growth rates occurred in Humera, close to 130% followed by Alamata (104%). The most drastically declined urban center at this time was Adwa, which experiences a significant negative growth.

Fig. 4.19 Growth rates of selected high fluctuation urban centers



iii) <u>Growth rates 1985-1994</u>

The political uncertainty that prevailed in the previous decade intensified in the first half of this decade. The war in Eritrea and Tigray reached its climax. In the second half of the decade it was the end of war and the beginning of peace, stability, and rehabilitation in Tigray. This time it was the turn of Adigrat with 122% growth rate excelling all others. Endaselassie, Alamata, and Korem followed with 90%, 81% and 75% respectively. Adwa, which had plunged far down in the previous decade, registered a 71% positive growth. This time it was Aby'adi that took Adwa's place with a significant negative rate of -28%. Fig. 4.19.

iv) <u>Growth rates 1994-2005</u>

This was a decade of relative peace, prosperity, and urban boom; the war had ended in the previous decade. Ten of the major urban centers experienced a positive growth rate exceeding 65%. A very interesting aspect of the growth rates of these urban centers is that there was little variation in their growth rate: for all ten of them it ranged from 66% to 69%. Aby'adi which had declined the previous decade with very low negative growth rate had attained the highest positive growth rate of 130%.

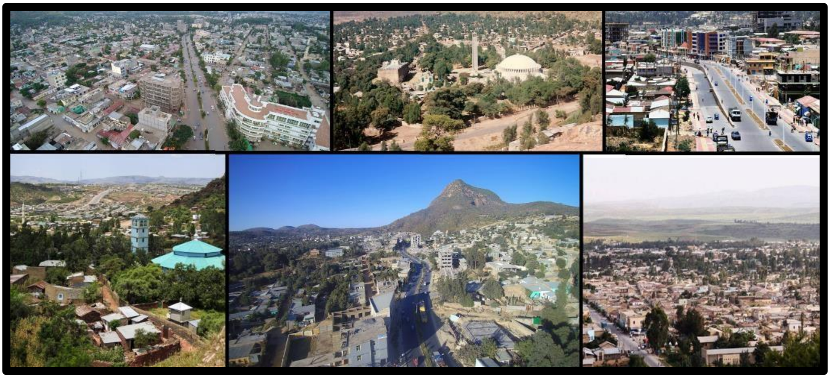
v) Growth rates 2005-2013 and 2013-18

As EPRDF rule continued to register economic growth and extensive infrastructural development in the 2005-2013 decade the rates of growth have been not as dramatic as in the previous. While Mekelle alone rose to as high as 77% growth rate, seven urban centers (Endaselassie, Wukro, Adwa, Axum, Adigrat, Humera, and Aby'adi grew only by 50% to 18 %. Korem, which had experienced high enough growth rates, in the previous two decades, went precipitously down by -20%. Maychew, which historically has not been a "big grower", also declined by -5% followed by Alamata with only 1% growth. The last half of the decade (2013-2018) did not reveal any high enough growth rate and also variations in the rates. All urban centers, including Mekelle, got growth rates ranging from 24% to 27%. This must have been the decade of primacy of Mekelle City.

vi) Overall growth rates 1966-2018

The decadal growth rates of the populations of the major urban centers have shown a great deal of fluctuations. This can be summed up by the growth rates computed for the five decades, from 1966 to 2018. Four urban centers (Endaselassie, Adigrat, Alamata, Humera, and Mekelle) experienced very high growth rates ranging from 1000% to 1500%. The rest (Korem, Maychew, Adwa, Axum, and Aby'adi), grew more slowly by percentages ranging from 300% to 518%. Wukro has an intermediate value of 757.5%.

Fig. 4.20 Major Cities in Tigray: Shire, Axum, and Adigrat (Top); Abyi'adi, Adwa, and Wukro (Bottom)

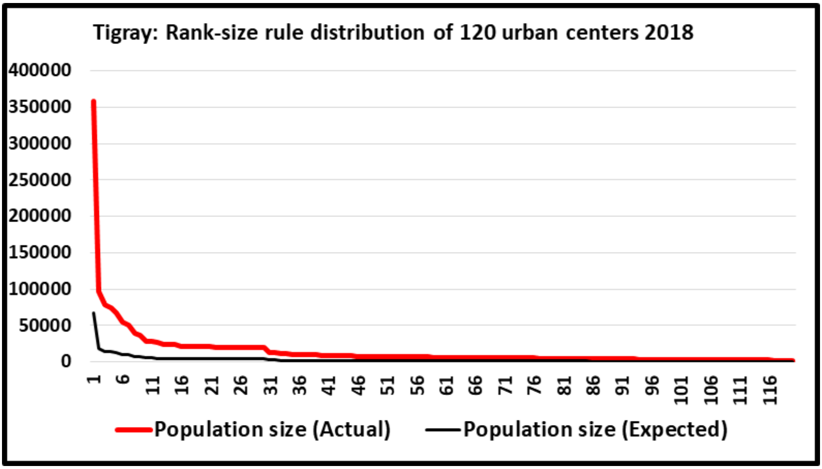


4.2.6. Urban Primacy in Tigray

The most economically, administratively, and technically sound size distribution of an urban system in any region is some semblance of balance of the size hierarchy between small, medium, large and very large urban centers. This provides a solid ground for sustainable regional development where rural to urban and urban to urban interactions are based on mutual benefits. However, this is not the reality in the urban growth patterns of developing countries. There is a tendency for one urban center, usually the political capital, to be larger than the other urban centers by more than one fold. Such imbalance in the growth of urban centers is referred to as 'urban primacy' and defined as: the largest city being twice or more in population size than the next city in the rank order.

Rank-size-rule measures the degree of primacy in urban systems, and is a very useful tool in the analysis of urban-size relationships (Ettlinger, 1984). Rank-size-rule is computed and a chart compiled for the 120 urban centers of Tigray in 2018, in order to graphically illustrate what is already described by Tesfay (2017) as the "hyper-urbanization" of Mekelle, the capital city of Tigray. The computed difference between the actual and expected is quite high; the actual is 437% higher than the expected. This can be clearly discerned graphically from the difference between the black colored curve (expected) and the red-colored curve (actual) shown in Fig.5.20. The difference between the expected and the actual values is much enhanced because it is drastically influenced by the high value for Mekelle. The expected level of primacy of Mekelle and the actual primacy remains to be 3.7 times the next urban center in the rank order. Actual population of Mekelle in 2018 is 358,529 but the expected is 66,765. It has an excess of 291,764 people for the ideal size in the rank-size rule to be attained.

Fig. 4.21 Growth rates of selected high fluctuation urban centers

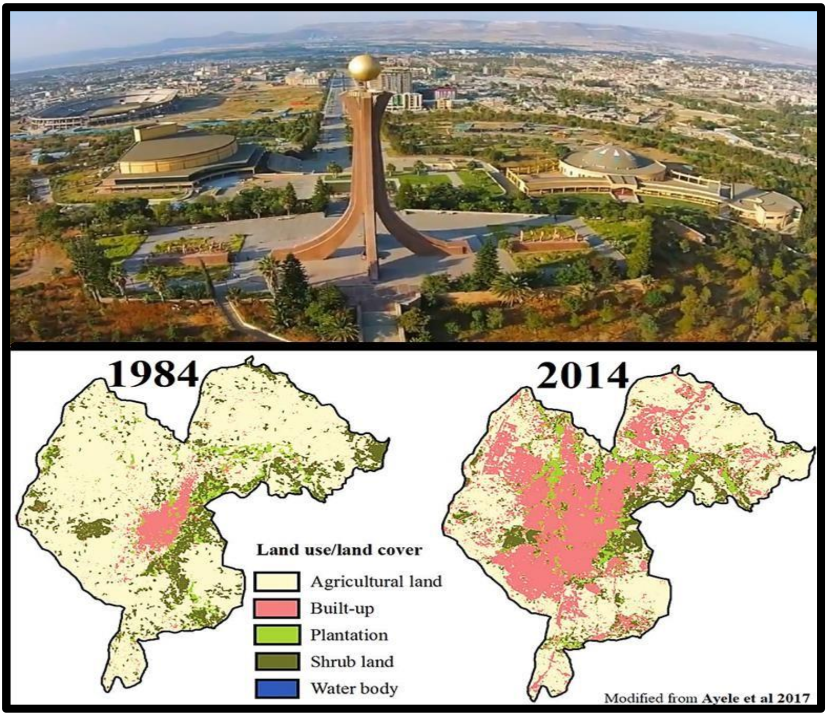


Although the rapid trend of urbanization in Tigray could be considered as a blessing in contrast to the several centuries of debilitation, the fact that the process is by and large spontaneous and lacks foresight is a sufficient reason for grave concern. The euphoria arising from the fact that Mekelle has become the second largest city in Ethiopia should be replaced by sustainability thinking about the future of urbanization in Tigray. There are adverse economic and social implications of the high level of primacy of the urbanization of Tigray. Although some like Cities Alliance (2016) paint a less bleak picture of Mekelle and put the City at the top in Ethiopia in terms of health and educational service provision, most others see the excessive growth of Mekelle in a different light.

High level of urban primacy in Tigray has not come without costs. Due to the economies of scale it enjoys the Primate city is sucking in investment, human, financial, and material resources from all over Tigray. The positive feedback further enhancing its primacy is increasingly weakening the towns far below in the rank order. The initial advantage from the agglomeration economies for the primate city would in the course of time turn into a damaging diseconomies. Cities Alliance (2016) that saw positive development in the urbanization of Mekelle, as compared to other cities, has its doubts about the ability of the City's sewage, solid waste disposal, and water supply infrastructure to sustain its fast growth into the future. Tesfay (2017) also listed down the possible consequences of over-urbanization in Mekelle as: displacement of farmers, food insecurity, water scarcity, housing shortages, high cost of living, crime, conflict, environmental degradation, and health problems.

The urban primacy of Mekelle is twined with another critical problem of low density growth. Urban sprawl is voraciously eating into the fertile farmlands along the urban-rural interface. This is making the lives of the residents of the rural-urban fringe extremely miserable. The eviction of farming families from their lands without sufficient compensation and/or well-planned alternative livelihoods is rooted in the urban bias of development theories which disregard the harmonious rural-urban economic and social linkages critically needed to ensure sustainable urban development. Lynch (2018) asserted that urban-based industrialization policies can have an adverse impact on the development of rural areas.

Fig. 4.22 Growth rates of selected high fluctuation urban centers



Haile (2019), in his Tigrai Online commentary, has given a sobering account of the modus-operandi of eviction from fertile lands in the rural fringes of Mekelle: The local government pays compensation as low as “three birr per m^2, while selling it to bidders at 30,000 birr for every m^2” Haile Tessema has also related the eviction to a growing social crisis including unemployment, underemployment, alcoholism, substance abuse and rise in criminal activities. Although high officials down to the rank-and-file in the bureaucracy are using the opportunity to amass wealth the government of Tigray seems to have been trapped between the social and economic problems created by the unjust eviction and the housing needs of the residents of Mekelle and the demand for land by investors. As it is true all over the world, urban residents and investors are more vocal than the rural poor; the former are more enabled to defend their interests than are the latter.

At least three research reports have been published that have investigated the speed and extent of the urban sprawl of Mekelle. According to Zemenfes, Melesse, and Yiadom (2014), in 1964 the share of built up area was 7%, cultivated land 66%, and forest and grassland, 27%; by 2005 the built up area reached 74%. In only four decades the built up area expanded over tenfold at the expense of the cultivated land, forest and grassland. In another research report by Ayele et al (2017), for the period between 1984 and 2014, the built up area increased from 19% and 88%. Based on this trend it is projected that the built up area will double by 2035. Emphasizing on the legal aspect of the land eviction Shishay (2011) considered the actions as violations of Articles 40 (4 and 8) and 44 (2) of the Constitution. Due to the urban expansion process 81.4 hectares of farmlands has been converted to urban land use from the selected 90 sample farm households. Out of these 45% were evicted with a maximum of 3000 birr, and 48% were expropriated without legal compensation.

The water supply challenges Mekelle City is facing is well documented by Daniel (2020). The City now depends for its water supply on 30 boreholes with productivity of more than 25,000 m^3 a day; over 700 unmonitored private wells; Gereb Segen reservoir with storage capacity of more than 12 M m^3 and treatment capacity of 15,000 m^3 per day. As the daily demand is more than 71,000 m^3 a new reservoir is under construction at Gereb Gheba with treatment capacity of 228,000 m^3 per day. It is apparent from the treatment capacity figure that the prospective supply source can satisfy three times the current demand. However, taking into consideration the rapid rate of population growth and the expansion of investment in the City, and at the same time the shifts to extravagant water consumption life styles gathering momentum, it is hard to be optimistic about sustainability of water supply sources to adequately meet the steeply rising demand.

The Mekelle water supply system seems to have been locked in an endless race with demand. The system is technically and philosophically geared towards matching every demand with supply. In view of the fact that the system of supply is fully manned by engineers enquiry into the demand side of the water equation is not a customary practice. Trying to match every demand with supply is never attained at any point in time. The likelihood is that the gap will increasingly get wider as the system of supply fails to match the demand not only because of the rising demand but also because of the failure of the supply system. The latter could arise from the shortage of finance and technical skills to harness increasing more distant and much deeper sources of water. The increased frequency of drought and the natural depletion of water resources and the pollution of surface or groundwater could reduce the total availability of water.

Side by side with looking for new sources of supply the way water is used and abused has to be addressed. A significant part of the solution where the demand side of the equation can be regulated is the conservation of water, which must pervade the cultural value systems. The adoption of western lifestyles related to the utilization of water must be contextual to the local availability of water. At least as far as water is concerned people have to be able to live by their means not by their whims.

Whatever the balance of the curses and blessings of urbanization in Tigray is, nothing else should take the place of proactive decision to prepare the urban phenomena for 20 to 50 years into the future. Proactive planning and management of the urban system in Tigray requires information about the spatial-temporal status of the process of urbanization.

4.2.7. Points to ponder

Future regional development of Tigray is expected to be pivoted in urban-industrial approach to sustainable development. Sustainable industrial and service-based development is not possible without well planned urban system at all levels of the hierarchy. The rough ride of urbanization in Tigray before 1991 and the rapid but largely spontaneous growth after that, must be systematically corrected. No more time should be wasted to curb the "hyper-growth" of Mekelle City and do justice to the urban system by systematically redistributing economic resources, population, and infrastructure to the medium sized urban centers. The medium-sized urban centers would do the same for the smaller urban centers. Efficient and cheaper transportation connecting all level of the hierarchy would hit at the very foundation of urban primacy.

In this concluding paragraph it is deemed worthwhile to summarize the recommendations forwarded for debate by Haile (2019): using barren lands for locating industries; paying compensations for evictions from farmlands according to the market value of the land, adopting high density residential development in the form of high rise buildings, disperse higher learning institutions and industrial investment to all over Tigray; introduce attractive incentive systems to encourage dispersion of business; strictly adhering to environmental impact assessment; and assigning professionals in the appropriate positions.

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Adam Jones	Wukro, Wolkait Hills
Africa on the Rise	Seasame seeds not used
Agame Ethiopia Blogger	White Honey Agame, Agame mess
Aljazeera	Ashegoda young kid
BBC	Sattelite map Tekeze, Mekele, Negash mosque scarred, Mosque destroyed
Borkena	Mekelle Urban sprawl not used
Chipa by the Dozen	Teff enjerra
Dreamstime.com	Marble, Axum pond, Hidmo Village of hadamu,
En.wikipedia.org	Tekeze
Ephrem Twitter	Beles
Eritrea	Mereb River Flood
Eritrea focus.org	Flocking 1984 famine trip
Ethiocepic Ethiopia wordpress	Siwa drinkers
Ethiopian economy Blog	Tekeze dam high flood
Ethiopias April-May 2015	Adwa Water supply Midmar
Europa European Commission	Beehives
Face book Agulae	Hibishti
Food Network	Maize enjerra
Frankensaurus.com	Larger Arato
Geo Supplies.Ltd	Dolerite
G.S.E (V. Kazmin)	Geology map of Ethiopia 1972
Geological Survey of Ireland	Geologic timetable
Geology rocks and Minerals	Greywake Braided, Breccia
Geology Science	Silt stone
Geology.com	Pictures of Rocks, Basalt, Diorit, Schist
Hadgi	Hugumbirda forest
Hodmedod's	Oats

I love Tigray Facebook	Tihlo, Hilbet
Jan Nyssen	Alaje basts, Mereb Miti, Degua Tembien, Siwa Wancha
Journey by Design	Korkor Lodge beautiful Gerealta
Kindeya Twitter	Adwa three Plugs, Gerealta Block
Kranky Kids	Barka Breed (not Done)
Mamo Hagos Twitter 2019	Gunda Gundo
Mehari Hiben facebook	SEsa Dam around Adwa
Minube	Yohannes IV palace limestone
Origin of Geez Ethiopia Tours	Raya mountains
Pinterest	Phonolite, Oxen Plowing
Rad Waddington	Ganta Afeshum High bright mountain, Endamehoni
Research Gate	Wereda map of Tigray, Humera Plains, Wereda Map of Ethiopia, Soil Conservation Mesobo, Adi Zeboy, Animal feed cactus, Negash Slate
Sandatlas	Trachyte, Diamictite
Satellites.pro	Images
Semantic Scolar	Bagait Breed used white black cow
Skyscrapercity	Giba Dam
Spice Chronicles	Sorghum enjerra
Springerlink	Adwa Green, Raya Cattle Raya Breed Used long horn
Stanford.edu	Atsbi
Sweet Crusader Reports	Tekeze Dam,
Tegaru Tube	Tsegede Mountains
Tesfa Trek	Gerealta Red Sisial
TesfaMichael et al 2010	Abi Adi Sandstone
The Daring Gourmet	Finger millet enjerra
The Guardian	Famine women lining, Camel Caravan

The Martha’s Vineyard times	Woman Carrying wood
The Water Channel	Lake Hashenge grey foreground blue water
Think Africa	Abune Nemata GuhTall
Tigraionline.com	Mesobo Factory
Tigray Mass Media Agency	Nebelet
Times for Change Kichen	Barley enjerra
Travel Notes	Abrha Weatsebeha
Travel the whole world	Adwa Plugs
Tropic Air Kenya	Tekeze from Air dramatic view
Twitter Bisrat	Weri Brown left boulder outcrops bush right foreground
Viaggio in Ethiopia	Ashenda Used
Victorstacle.com	Tigray outline
VY Maps.com	Mehoni Tigray
Wikipedia	Adua Plugs many
Wikimedia commons	Oxen treshing, Interior of Hidmo ceiling,
Wikipedia	Granite Stele, Amba Aradam Formation, Enticho Sandstone, Himbasha, Pool in Giba River Green Both sides ridge far, Giba over Antalo Limestone Rocky bed, Lower Giba bridge one leg on stream, Giba River 3 photos, Tsaliet River silt and flooding deep gorge, Tekeze low flow half sand, Mereb River dry, Gereb Segen May Gabat White sand blue water, Kafta Humera, Tekeze River, Tekeze Dam, Arato, Chichat, Tekeze Dam Reservoir dark Blue,Tekeze wide in the foreground, Himbasha, Ashenda

	May be not used, Abergelle Breed used, Abergelle Cattle, Sub-Saharan Africa, Adigrat sandstone, Tekeze, Edaga arbi tillites,
Wikiwand	Enticho Sandstone, Tsaliet, Ilala River Romanat falls
Workamba Ethiopia Tour and Travel	Kafta Sheraro woodland Brown grass lined trees, Sheraro, Tekeze Kafta Sheraro wide blue river with distant hills
World Trade	Sesame used
WWW. press.et	Desa Forest
YouTube	Kaza River White ripple
Youtube.com	Tihlo

"The first condition of understanding a foreign country is to smell it."

Rudyard Kipling

Tigray: The Geography of an Ancient Land

Millions of tourists flock to northeastern Africa; one of their major destination is Tigray. Other uninformed millions stay away and miss the excitement derived from the historical, religious, cultural, geological, climatic, geomorphologic, and demographic wonders. Many mistakenly link Tigray with perpetual war and famine. However, these are not inherent ills; they have been externally imposed on it. This book is organized in four chapters with details of the geology, geomorphology, drainage, climate, and rural and urban geography. The approach used in the book is both descriptive and analytical. It is well illustrated with maps, charts, and pictures. It is the first of its kind for Tigray and can serve as an excellent guide for tourism and investment.

Mapio.net

Tigray is where in sub-Sahara Africa Christianity and Islam first set foot.

Tigrayans are brave, peace-loving, kind, and hardworking. Read this book to know better.

Yohannes Aberra Ayele- PhD, Associate Professor (Geography, Environment, and Development); Educated in Addis Ababa University and Delhi University (Delhi School of Economics); Served in teaching and research in Bahir Dar and Addis Ababa Universities for 30 years, in BA, MA, and PhD programmes; Published several articles and book chapters, co-edited a book on pastoralist development with IPSS; Participated in international projects as researcher; Served in academic administrative posts; Visiting research fellow at IDP-Tokyo-Japan; Been to six African countries for workshops. Author is passionate about solving social problems.