THE MEDICAL GEOGRAPHY OF ETHIOPIA

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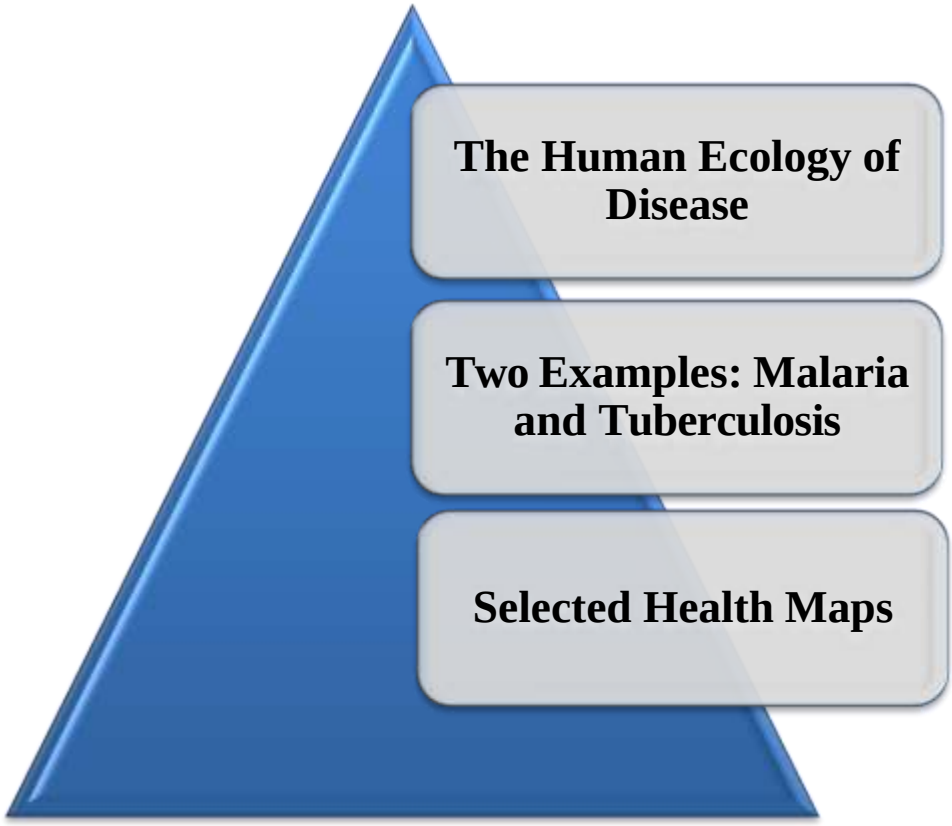
Lesson 11



The Medical Geography of Ethiopia

Spatial analytics focused on the geography of health, diseases, and health care in Ethiopia are presented in this lesson. This section will answer questions such as: What is a geographical approach to disease, health, and health care? How is it different from other approaches? How is Medical Geography defined?

Medical Geography Defined

"Medical geography: An important "new" area of health research that is a hybrid between geography and medicine dealing with the geographic aspects of health and healthcare. Medical geography studies the effects of locale and climate upon health. It aims to improve the understanding of the various factors which affect the health of populations and hence individuals. It is also called health geographics". [1]

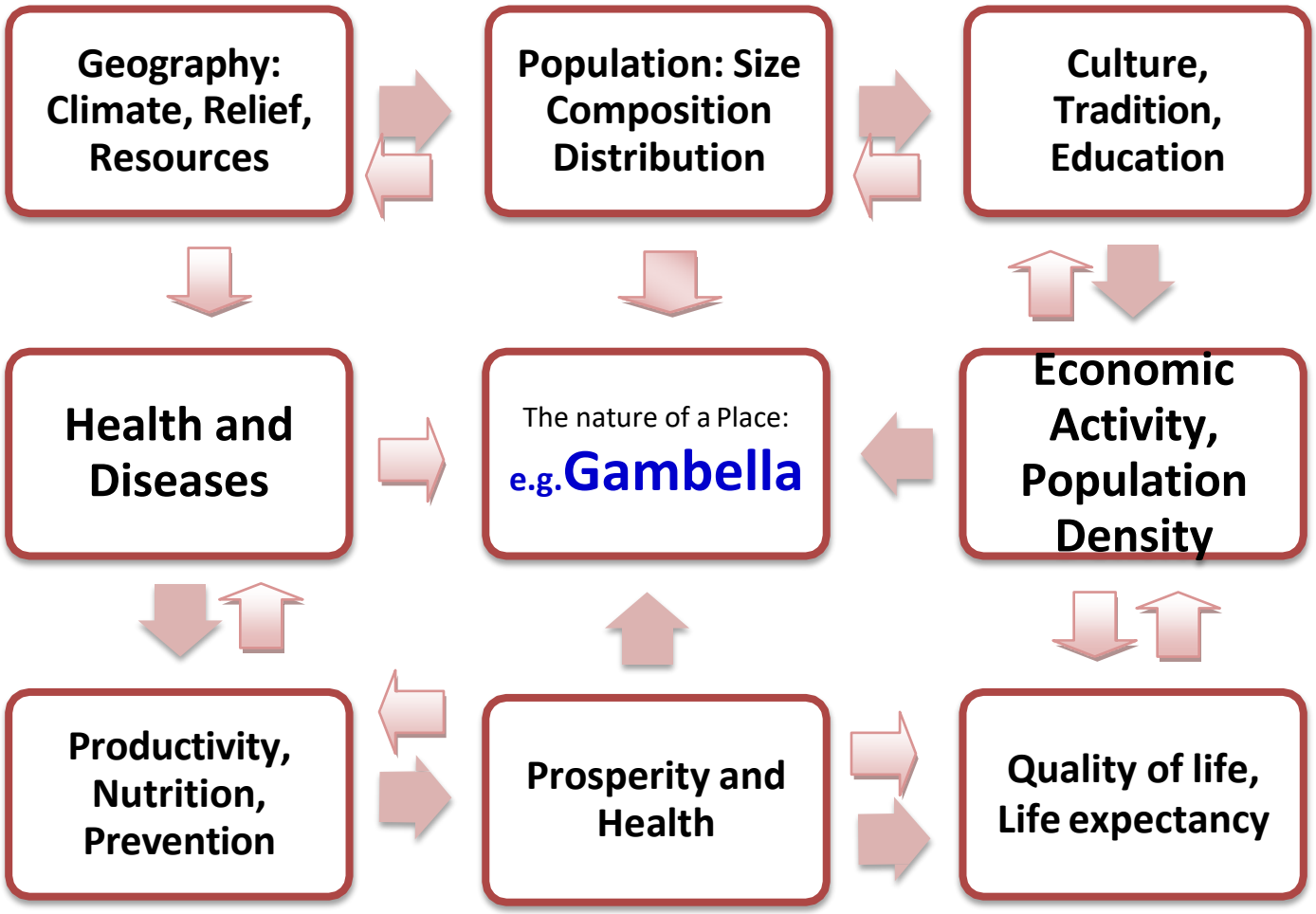
> "Whoever wishes to investigate medicine properly should proceed thus: in the first place to consider the seasons of the year and what effect each of them produces (for they are not at all alike, but differ much from themselves in regard to their changes). Then the winds, the hot and cold, especially such as are common to all countries, and then such are peculiar to each locality. We must also consider the qualities of the waters, for as they differ from one another in taste and weight, so also do they differ much in their qualities. In the same manner when one comes in to a city to which he is a stranger, he ought to consider its situation, how it lies as to the north or the south, to the rising or setting sun. These things one ought to consider most attentively ….." Hippocrtates (c. 400 B.C.) quoted in [2]

The idea that the nature of places may influence the health of living organisms is not new. As far back as the 3rd century BC's it has been known to humans that certain illnesses occur in some places and not in others. For example, it was known that malaria did not exist on high mountain tops.

> A classic piece of research in medical geography was done in 1854 as cholera gripped London. Death tolls rang around the clock from church towers. People feared they were being infected by vapors coming from the ground. A physician by the name of John Snow thought that, if he could locate the source of the disease, it could be contained. He drew maps showing the homes of people who had died of cholera and the locations of water pumps. He found that one pump, the public pump on Broad Street, was central to most of the victims. He figured that infected water from the pump was the culprit. He instructed the authorities to remove the handle to the pump, making it unusable. The number of new cholera cases plummeted. The Broad Street pump was the source of cholera.

Another example comes from early 20th century. Two curious dentists in the state of Colorado USA noticed that in areas with naturally-occurring fluoride in ground water, the children had fewer dental caries; a discovery that showed the link between fluoride and dental health.

The definitions above, will applied to the Ethiopian scene to lay the ground-work for the forthcoming discussions on the link between health and disease on the one hand, and the nature of paces in various parts of the country, on the other hand. The three-word phrase "nature of places" is a loaded one, and has been summarized in the following simple diagram. We have taken Gambella as an Example:



The simplified model above will be applied at the national level in the examination of the complicated relationships between Ethiopian geography, demography, and health.

Health Defined:

The World Health Organization defines health as "… a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." [3]. Audry (cited in [2]) defines it as "…a continuing property that could be measured by the individual's ability to rally from a wide range and considerable amplitude of insults, the insults being chemical, physical, infectious, psychological, and social". One can also use the terms "stimuli" and "hazards" in place of insults.

Examples of Insults or Stimuli: [2]

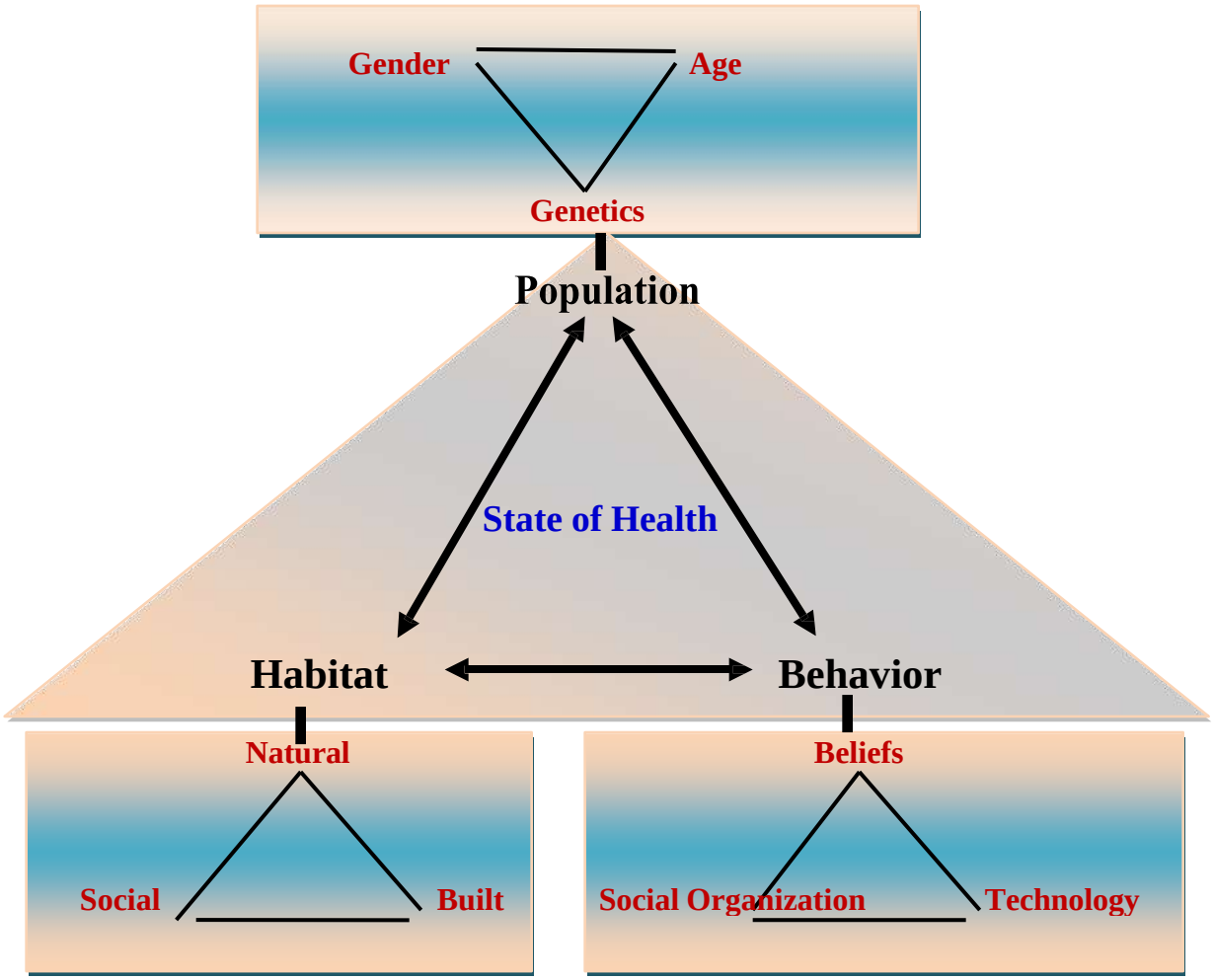
Infectious	**Psychosocial**	**Chemical**	**Physical**
Bacteria	Danger	Drugs	Trauma
Virus	Anxiety	Benzene	Radiation
Rickettsia	Crowds	Micro-nutrient deficiency	Light
Protozoa	Isolation	Paint fumes	Noise
Helminth	Love	Carbon Monoxide	Electricity
Prion	Community	Formaldehyde	Air Pressure

All of these are within the purview of geographical analysis in the Ethiopian context because they can be mapped. "The areas of a town could be mapped based on noise, people's fear of walking down the street at night, air pollution, visual blight or beauty, mosquito density, or alcohol consumption" [2] Likewise, health risks in Ethiopia such as the type and density of disease carrying mosquitoes, risk factors for Tuberculosis including crowding, risk factors for HIV transmission such as the number and location of shady outlets peddling prostitution in Addis, the percentage of population in Somali with access to clean water and sanitation, the volume of garbage collected weekly in Dire Dawa, the population-physician ratios in North Gondar, etc. can all be mapped. The primeval edict " if you can map it, it is geography" is still true.

The Triangle of Human Ecology

The geographical study of health and diseases in Ethiopia is best conducted by adopting the human ecology approach presented below. In this scheme "habitat, population, and behavior form the vertices of a triangle that encloses the state of human health" [2].

> Habitat is that part of the environment within which people live, that which directly affects them. Houses and work places, settlement patterns, naturally occurring biotic and physical phenomena, health care services, transportation systems, schools, and physical phenomena, health care services, transportation systems, schools, and government are parts of the habitat…Population is concerned with humans as biological organisms, as the potential hosts of disease. The ability of a population to cope with insults of all kinds depends on its genetic susceptibility, or resistance, its nutritional status, its immunological status, and its immediate physiological status with regard to time of day or year….Behavior is the observable aspect of culture. It springs from cultural percepts economic constraints, social norms, and individual psychology. It includes mobility, roles cultural practices, and technological interventions." [2]



Source: Based on [2]

1. Natural Habitat

Ethiopia has a very diverse natural environment. Its landforms consist of rugged mountains with pointed peaks and valleys, river basins with flood plains and steep escarpments, an expansive desert with scarce vegetation cover and water sources, a section of the Great East African Rift Valley system, dense forests and patchy desert shrubs, major rivers with tributaries, fertile soils and grass lands, diverse animal life both wild and domestic, a variety of species of birds, invertebrates, amphibians, and insects. All of these can facilitate or place limits on the disease agents and vectors, as well as hosts thereby determining the level of exposure to illness a given person might be facing depending on the nature of his/her micro environmentt.

> ***Ethiopia is a country of great geographical diversity***. Its main topographic features range from the highest peak at Ras Dejene, 4620m above sea level, down to the Afar depression (Kobar Sink) about 110m below sea level. The Great Rift Valley separates the Western and Northern Highlands from the south Eastern and Eastern highlands. These highlands give way to vast semi-arid lowland areas in the east and west and especially in the south of the country. The country is divided into three major ecological zones, Kolla (arid lowlands below 1,000 meters above sea level), Weina Dega (between 1000 meters and 1500 meters

above sea level) and the Dega (between 1500 and 3000 meters above sea level). About 40 percent of the total area of Ethiopia is comprised of highlands, which are found at elevations above 1500m. The highland areas' annual rainfall ranges between 500mm to over 2000 mm. The mean annual temperature in the highlands is below 20oc. The lowland part of Ethiopia covers about 60 percent of the total area of the country. Rainfall in the lowland areas is relatively low, often poorly distributed, and highly erratic. It ranges from 300mm to 700mm annually. The temperature in the lowland areas is greater than 20oc. [4]

Example 1: Malaria

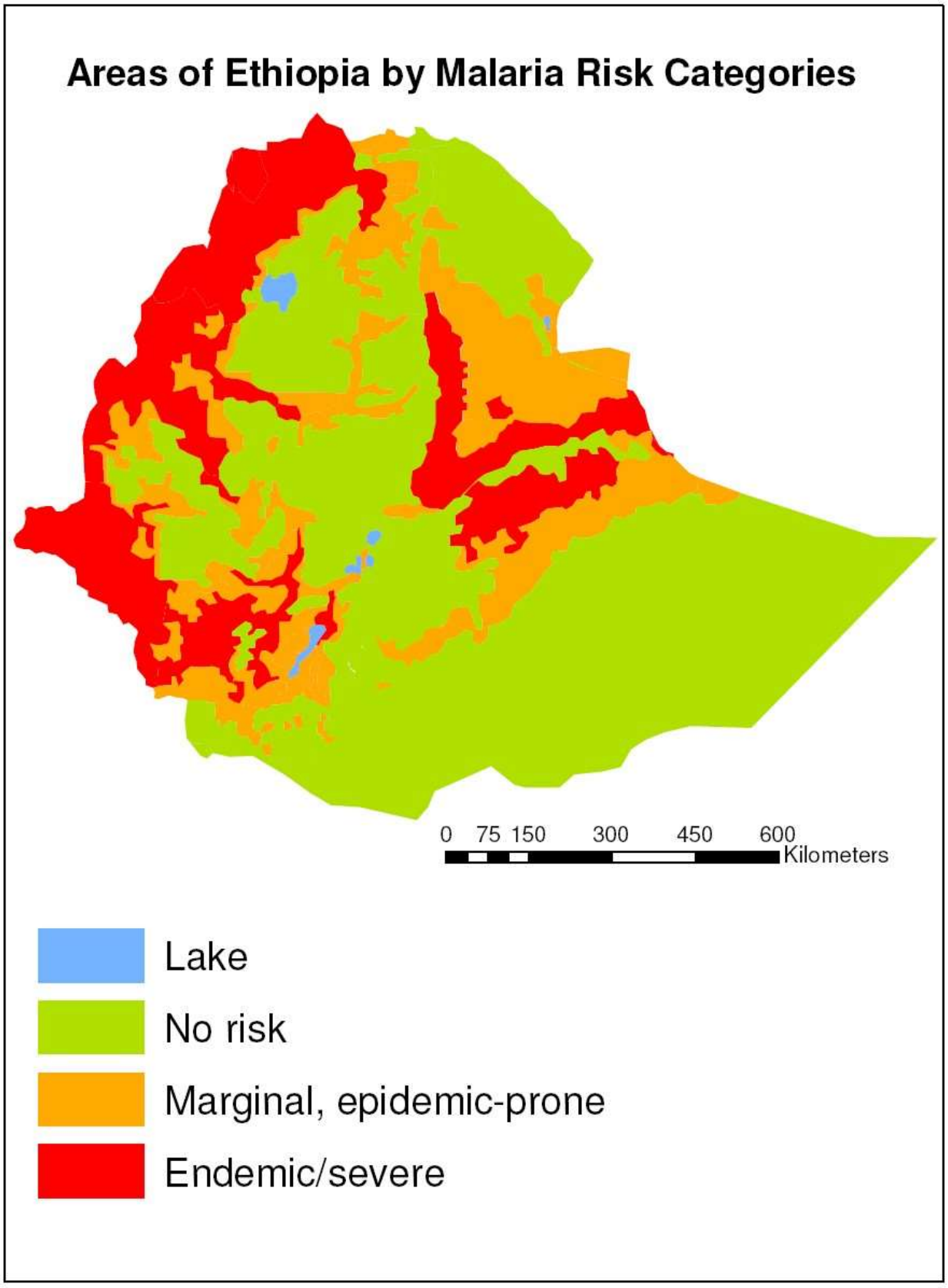
How conducive are the various parts of Ethiopia (described above) as incubators and propagators of infectious disease such as malaria? Do they provide comfort and ideal niches to the agent – ***plasmodium*** – and to the arthropod vector – the anopheles mosquito? "Four types of the plasmodium parasite can infect humans. The most serious forms of the disease are caused by ***Plasmodium falciparum*** and ***Plasmodium vivax,*** but other related species (***Plasmodium ovale***, ***Plasmodium malariae***) can also affect humans [5]. "Other species infect other animals, including birds, reptiles, and rodents" [6]. We will discuss these in greater detail in lesson 15.

Environmental Factors (Habitat)

1a. *Natural Environment*

In Ethiopia, the mosquito that carries the malaria parasite, also known by its scientific name as ***anopheles arabiensis***, provides the critical link in the spread of the disease from one ***host*** to the next. An environment that is not concussive for the survival and reproduction of this species of mosquitoes cuts off that link and renders the land malaria-free. Only a quarter f Ethiopia's land area is malaria-free. Three-quarters of Ethiopia is considered malarious. To know which parts of the country can be described as such one needs to consider the nature, developmental stages, and environmental requirements of the anopheles mosquito.

"Of the approximately 430 *Anopheles* species, only 30-40 transmit malaria (i.e., are "vectors") in nature…Like all mosquitoes, anophelines go through four stages in their life cycle: egg, larva, pupa, and adult. The first three stages are aquatic and last 5-14 days, depending on the species and the ambient temperature. The adult stage is when the female *Anopheles* mosquito acts as malaria vector. The adult females can live up to a month (or more in captivity) but most probably do not live more than 1-2 weeks in nature…. The larvae occur in a wide range of habitats but most species prefer clean, unpolluted water. Larvae of *Anopheles* mosquitoes have been found in fresh- or salt-water marshes, mangrove swamps, rice fields, grassy ditches, the edges of streams and rivers, and small, temporary rain pools. Many species prefer habitats with vegetation. Others prefer habitats that have none. Some breed in open, sun-lit pools while others are found only in shaded breeding sites in forests. A few species breed in tree holes or the leaf axils of some plants…. Like all mosquitoes, adult anophelines have slender bodies with 3 sections: head, thorax and abdomen… Males live for about a week, feeding on nectar and other sources of sugar. Females will also feed on sugar sources for energy but usually require a blood meal for the development of eggs. After obtaining a full blood meal, the female will rest for a few days while the blood is digested and eggs are developed. This process depends on the temperature but usually takes 2-3 days in tropical conditions. Once the eggs are fully developed, the female lays them and resumes host seeking.' [8]


Areas of Ethiopia by Malaria Risk Categories
0 75 150 300 450 600
Kilometers
Lake
No risk
Marginal, epidemic-prone
Endemic/severe

1b. *Malaria: Social Environment*

"The social environment consists of the groups, relations, and societies within which people live". [2] The very diverse social environment in Ethiopia has varying impacts in aiding or curtailing malaria transmissions. The most readily identifiable social factor exposing a given population to malaria infection is mobility. This is a simple case of a population group such as those involved in government resettlement programs moving from malaria-free homelands with no natural immunities to new locations where malaria is endemic. The location of the new settlements site vis-à-vis a standing pool of water and local climate, can determine whether or not new sellers with limited immunity or no immunity at all would be in the cross-hairs of the plasmodium parasite carried by the bite of the anopheles mosquito.

> One of the factors contributing to the reemergence of malaria is human migration. People move for a number of reasons, including environmental deterioration, economic necessity, conflicts, and natural disasters. These factors are most likely to affect the poor, many of whom live in or near malarious areas. Identifying and understanding the influence of these population movements can improve prevention measures and malaria control programs. [9]

The pattern of settlement – clustered or dispersed – knowledge and attitude of inhabitants about malaria and modes of transmission, existence of malaria control programs – local or national – ability and willingness to use insecticide treated nets for prevention and adherence to drug regiments, are among the many social factors acting as intermediary determinants of the scale of malaria problems in a community.

1c. *Built Environment*

The phrase "built environment" often conjures up the image of sky-scrappers in modern metropolitan cities. The reader should instead picture the scenery around individual huts or group of huts in village dwellings of the rural Ethiopian countryside. What type of hut? What is the roof made of? How about the walls? Are there cracks in the walls allowing access to mosquitoes? Do animals spend the night indoors with people? Is the interior heated or cooled? For, example…"it matters to insect ecology (and hence to disease transmission) whether roofs are made out of thatch or corrugated iron, and whether windows are screened". [2]. Globally, the urban built environment has also proved a welcome landscape for malaria-carrying mosquitoes, as the proliferation of pools of accumulating water in pot-holes, tires, urban orchards, abandoned pools, etc., became attractive breeding grounds. "It is estimated that 300 million people currently live in urban areas in Africa and two-thirds of them are at risk of malaria. There is a lack of understanding of the complex interactions between human social structure, the environment and malaria infections." [10]

A recent study of a micro built environment (micro dams) in rural Tigray found a clear connection between human activities and some unintended health consequences. The study sought "to assess the impact of construction of microdams on the incidence of malaria in nearby communities in terms of possibly increasing peak incidence and prolonging transmission". The results were unmistakable: The overall incidence of malaria for the villages close to dams was 141 episodes/1000 child months at risk compared with 1.9 in the control villages—a sevenfold increase. "Incidence was significantly higher in both communities at altitudes below 1900 m." [11]

Behavior

The human animal is a cultural being and as is commonly known "culture creates social organization, structuring relationships of power, status, and control of resources…[it also] creates belief systems, values, [and] perceptions" [2]. Understanding the role each of these plays (singularly or in combination) in malaria transmission in Ethiopia would require extensive studies. Such studies are scarce, however. In a recent urban survey in Assosa, 95% of respondents were aware that mosquitoes bite at night, but "knowledge of the role of mosquitoes in malaria transmission and comprehensive knowledge about malaria prevention strategies among the study population were observed to be lower than 50%." [12]. Due, perhaps to better public education, a rural community in Butajira appeared to be much better informed and knowledgeable about malaria. The study conclusions read as follows:

> Fever, headaches, chills and shivering were the most frequently mentioned symptoms of malaria reported by 89.7%, 87.5% and 81.3% of the study subjects, respectively. About 66% of the study community related the mode of transmission to the bite of infective mosquitoes and 43.7% of them believed that malaria could be transmitted from person to person through the bite of mosquitoes. Mosquitoes are mainly believed to bite human beings at night (73.2%), breed in stagnant water (71%) and rest in dark places inside houses during daytime (44.3%). Malaria was thought to be preventable by 85.7% of the respondents. Of them, 62.4% reported chemoprophylaxis, 39.6% mentioned indoor residual spraying and 25% indicated eliminating breeding sites as preventive methods. The use of modern drugs for malaria was high (92%) including chloroquine (73.5%) and Sulfadoxine-Pyremethamine (60.6%). Chloroquine was believed to be effective for the treatment of malaria by 59% of the respondents, while the remaining replied that it was ineffective. Four hundred two (63.8%) respondents reported Sulfadoxine-Pyremethamine to be the most effective antimalarial drug for the treatment of malaria in contrast to others. [13]

The authors also note that 4 to 5 million Ethiopians fall ill with the disease every year. The results above appear to be a significant improvement over the study results of six randomly selected communities in central Ethiopia in the early 90s where "…only 23% believed that transmission could be prevented" [14]. In a study of the beliefs and traditional treatment of malaria in Kishe settlement area, southwest of Ethiopia, the picture was even worse, in that "eighty three percent of 254 respondents attributed the cause of malaria infection to dirt and rubbish… with 77% prioritizing cleaning dirt and rubbish, while only 36% mentioned drainage of swampy areas" as a method of prevention and control. [15]

Population

In the human triangle of ecology scheme (shown above), "the nature of the population, that is, the characteristics, status, and conditions of individuals as organisms, does much to determine the health consequences of any stimulation". This goes to show that "whether the stimulus is a bacterium, light, drug, sound, or thought, the reaction will differ according to the body's biochemical state". Furthermore, "this physiology is in part inborn through genetic code, but it is also influenced by weather, nutrition, previous experience, age, and so on" [2]

Genetics

How far has malaria been around? A 2003 study suggested that the global spread of malaria was facilitated by early human migrations and a shift away from a hunter-gatherer life style.

> "This coincides with an expansion of both human and mosquito populations brought about by the advent of agriculture. The shift from small groups of hunter-gatherers to larger settled populations was crucial in sustaining P. falciparum transmission and it is noteworthy that a number of malaria-protective polymorphisms also have origins in this timeframe. The antiquity of other Plasmodium species is more uncertain, but preliminary studies of Plasmodium vivax suggest it is considerably older than its more deadly relative" [16]

No studies exist regarding spatial differences, if any, in genetic predisposition to malaria in Ethiopia. The role of genetics is also significant in its protective effects, in that infected populations and individuals are protected from future attacks by a similar strain of malaria parasite through acquired immunity. Unfortunately, however, "***the acquired immune response to malaria is strain-specific*** and is lost if a person moves away from a malaria endemic area". [17]. ***Sickle-cell anemia*** is an example of how the body's attempt at defending against malaria leads, at times, to a totally different type of illness.

> Natural defence mechanisms (or innate factors) against malaria are most apparent in populations continually exposed to malaria parasites. For example, inherited conditions such as sickle cell anaemia and beta-thalassaemia, which cause deformities in red blood cells and are common in people from malarious regions, make it more difficult for malaria parasites to infect red blood cells. Some people have red blood cells that lack proteins called Duffy antigens on their surface. These proteins act as receptors for Plasmodium vivax merozoites, so people without Duffy antigens are resistant to infection from this parasite. [17]

Age

Children are at a greater risk due to lack of acquired immunity because they have not yet built resistance through the biological coding of the immune response to previous attacks by a given strain of malaria. In other words the ability to survive future bouts of the disease is partly dependent on the body's ability to successfully fight off previous infections. This means that the age structure of the population - whether the population is ageing or "younging" - will determine whether the population of the most vulnerable segment (children) is shrinking or rising. A

population pyramid with a wide base that quickly tappers off toward the middle and higher ages characterized the age structure in Ethiopia over many decades, and will continue to do so for some time. This is another way of saying that each coming decade will see greater numbers of children being exposed to malaria risks than the generation before unless the birth→ infancy → childhood cycle is cut off from the fourth component: → exposure to malaria risks. The increase in the number of children would mean that greater numbers become potential victims facing increased mortality risks. This in turn could affect fertility through a process known as "replacements fertility" – a case in which parents seek to replace a deceased child, thereby perpetuating the vicious circle.

Gender

A study in Tigray sought to explore whether there was a difference between mothers and fathers in their malaria prevention efforts, resources expended on the effort, and priorities given as to which family members should get care first [18]. There are no studies focusing exclusively on the relationship between gender and malaria to find out whether, or why, there are differences in infection rates between males and females. However,

> Malaria can impact men and women differently owing to gender norms in society and differing behaviour. Men who work outdoors in forestry, fishing, mining, agriculture or ranching are at a greater occupational risk of contracting malaria if this work occurs during peak biting times. In some pastoral societies, boys and young men leave their homes to watch over livestock as they graze. These boys and young men have very little, if any, protection from malarial mosquitoes and are often far away from treatment facilities should they fall ill. Men from low endemicity regions may also migrate to areas of high endemicity for work, putting them at substantial risk. The division of labour as a result of gender roles may play a significant part in determining exposure to mosquitoes; however few studies have addressed this issue. Women's household responsibilities such as cooking the evening meal outdoors or waking up before sunrise to prepare the household for the day may put them at greater risk of malaria infection than men in their societies. In other cases, men and women are equally at risk for infection given their activities during peak biting hours. Insecticide Treated Net (ITN) use is also subject to gender norms. Acceptability and use of ITNs are strongly linked to culturally accepted sleeping patterns, in which gender plays an important role in who uses the nets. In some instances, young children sleep with their mother and are therefore, protected by her net if she has one. Or, if a household only has one net, priority may be given to the male head of household as he is often considered the primary breadwinner. In other contexts, men have very little access to ITNs if they sleep predominantly outside.
> [19]

Similarly, in Ethiopia women's status in society and their family roles expose them and their daughters to greater risks of infection. Women also shoulder the responsibility for the care of malaria patients. Yet, they have the least access to information, the financial wherewithal, and other resources needed to effectively care for a sick family member sick with Malaria. Therefore, policies focusing on gender issues need to be an integral part of all prevention efforts.

> A gender approach contributes to both understanding and combating malaria. Gender norms and values that influence the division of labour, leisure activities, and sleeping arrangements, may lead to different patterns of exposure to mosquitoes for males and females. There are also gender dimensions to accessing treatment and care for malaria, as well as preventative measures such as mosquito nets. A careful understanding of the gender-related dynamics of

> treatment seeking behaviour as well as of decision making, resource allocation and financial authority within households is key to ensuring effective malaria control programmes. Therefore, gender and malaria issues are increasingly being incorporated into malaria control strategies in order to improve their coverage and effectiveness across contexts. **[19]**

Example 2: Tuberculosis

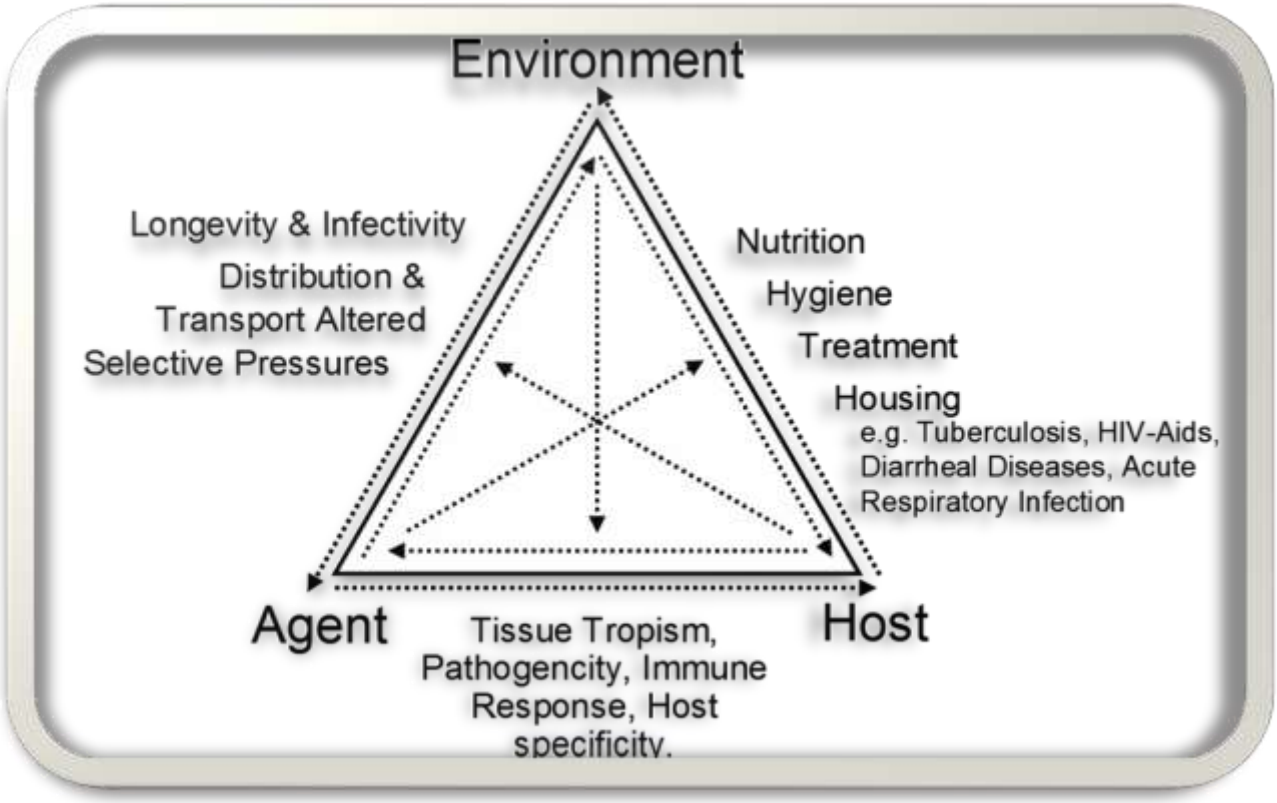
Tuberculosis (TB) is the leading cause of death in the world. About a third of humanity (2 billion people) is infected but a smaller proportion is actually suffering from active TB. The disease is a result of "a bacterial infection caused by a germ called *Mycobacterium tuberculosis*. The bacteria usually attack the lungs, but they can also damage other parts of the body. TB spreads through the air when a person with TB of the lungs or throat coughs, sneezes or talks" [20]

Environmental Factors (Habitat)

A study comparing the role of heredity to that of the physical environment in the transmission of tuberculosis found the environmental impact to be far greater than the genetic effect. Among its many conclusions was that "in a survey of susceptibility to TB among twins, environmental factors (i.e., intensity of exposure to tubercle bacilli) outweighed the importance of hereditary factors. Environmental factors and the context of transmission should be given more emphasis when studying interindividual and population differences in susceptibility to infectious diseases such as TB". [21].

In the context of TB and its mechanisms of spread, the term environment includes availability of and access to health care, housing, nutrition, information, and education (see Fig. below). Ethiopia's status as a low income country has meat that the level of education and knowledge about TB – its causes is low and the risk facts - a high level of crowding, poor nutrition, lack of access to health care, and poor compliance with drug treatment regimes, are not well understood.

> Cultural beliefs about the causes of tuberculosis may influence how people treat their symptoms. In south Ethiopia, people's perception about the cause and management of tuberculosis is unrelated to tubercle bacilli …. Many patients believe that tuberculosis and other diseases are generally caused by imbalances in behaviours or diet, and are best treated by herbal remedies and some special foods. …A recent study from south Ethiopia, has shown that people's perception about tuberculosis, especially in the rural areas, may need many years to change …. Only after symptoms persist for some time and the patient's health deteriorates, are modern tuberculosis control programmes consulted. These social conditions require culturally sensitive health education, taking into account local perceptions of tuberculosis …[22]



Source [23]

The issues in Ethiopia (urban areas in particular) include serious overcrowding, food shortages, malnutrition, lack of TB prevention education, and poor sanitation. All of the risk factors mentioned above have combined to make TB the second major cause of hospital deaths in Ethiopia. [22].

Behavior

Co-infection with Tuberculosis and the Human Immunodeficiency Virus (HIV) has become a death sentence for TB patients in Ethiopia and elsewhere. Since HIV transmission in Ethiopia is primarily through heterosexual contact sexual practice is among the ***behavioral factors*** pushing infected individuals toward rapid progression to active TB and death. Social stigmas, lack of education, low adherence to medication regimes, promiscuity, non-use of preventive measures such condoms, are also behavioral issues that the county needs to address. Among the disciplines looking at the link between behavior and risk of infections is Anthropology.

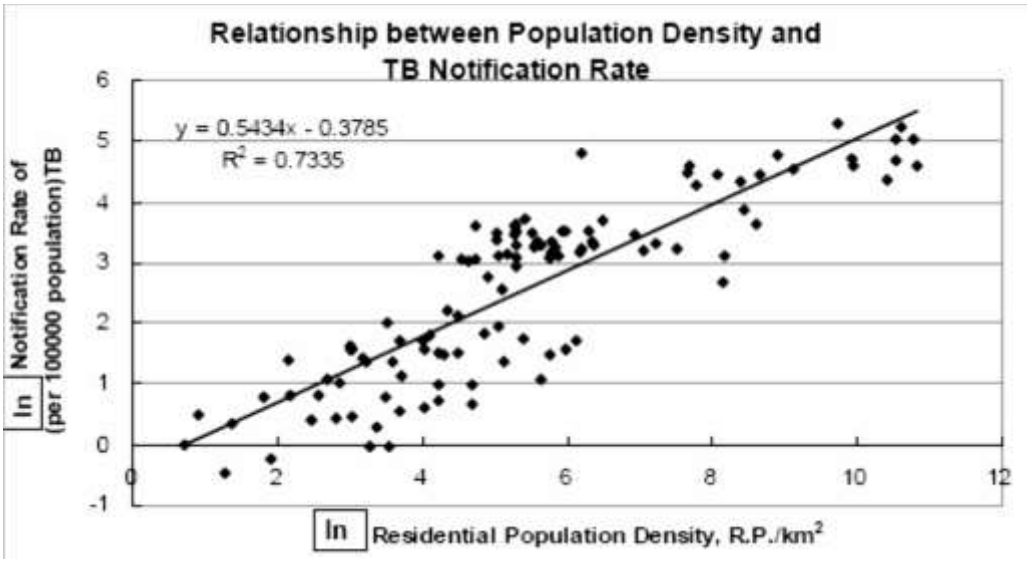
> Anthropological methods and approaches have been … valuable in understanding and addressing the broad range of socio-cultural, behavioral, and structural issues pertinent to TB control…. Studies examining how a local culture interprets TB causes and symptoms help providers understand why people delay seeking treatment. For example, in Thailand, research indicates that some people, associating their TB symptoms with HIV/AIDS, delayed seeking treatment for fear of having AIDS… In Kenya, patients attributed TB to causes such as hereditary predisposition, consumption of alcohol, smoking, or witchcraft, which often resulted in delayed care-seeking at a clinic specifically

for TB patients … Recent work in the Philippines showed that many patients attributed TB symptoms to drinking or smoking, and, thus, delayed seeking treatment for their "harm-less" … Similarly, in a study of the Igbo of Nigeria, TB patients who held rigidly traditional views that TB can be spread by eating beef and other high-protein foods reportedly delayed seeking treatment, often waiting until after they were malnourished.

Etiologic beliefs may influence how people choose to treat or be treated for their symptoms. A study in Malawi showed that patients thought TB resulted from bewitchment or breaking sexual taboos believed they could only be treated by traditional healers, while TB from other causes could be treated with Western medicine … In contrast, other groups express strong preferences for treatment from biomedically trained physicians, with little or no interest in traditional remedies … In Ethiopia, interview respondents believed TB and all diseases were generally caused by imbalances in behaviors or diet, and were best treated by herbal remedies and healthy foods…. A study among the Xhosa-speaking people of South Africa found that people often associated TB with a lack of hygiene and also with witchcraft, specifically the lightning bird, *impundulu*, and sought care first from a diviner….[24]

Habitat/ Population and TB

The following graph (obtained from an Internet source) shows the strong relationship between TB notification rates and urban residential population density on a natural logarithmic scale.



Source: [25]

Direct contact with an infected person is the primary transmission mechanism. As a result, high population density – often referred to as crowding – leads to higher infection rates. This is the main reason jail houses and prisons have achieved notoriety as the deadliest incubators and propagators of the ***Mycobacterium Tuberculosis*** bacteria.

Prisoners around the world have consistently higher rates of tuberculosis (TB) infection and disease than the general population. In the former Soviet Union, TB disease in prisoners is reported to be 200 times more prevalent than in the general population, while the excess ranges from 3-11 times across the United States. The reasons for this elevated

> TB risk are threefold. First, prisoners have a higher risk of being infected with TB than the general population. Prisoners are predominantly young adult males, poorly educated and from socioeconomically disadvantaged groups. They have disproportionate rates of poverty, homelessness and substance abuse, which are risk factors for acquiring TB infection. Second, they have higher rates of risk factors and/or behaviors which predispose to the development of TB disease once infected. For example, prisoners have higher rates of HIV infection and injection drug use than the general population, both of which increase the probability of progression from TB infection to active disease. The internal prisoner hierarchy may create conditions that promote illness in the vulnerable subgroups. For example, food and medicine may be sold, bartered or stolen. Third, environmental conditions within the correctional facilities may facilitate spread of the TB bacteria. Overcrowding in prison facilitates transmission of TB bacteria among inmates. Sharing overcrowded living spaces with prisoners who may have infectious TB disease and then transferring these newly infected inmates within and between prisons has been shown to rapidly spread TB. TB originating in prisoners has been transmitted to staff, visitors, external health care workers and community contacts. [26]

Reproductive Health Care and Maternal Services

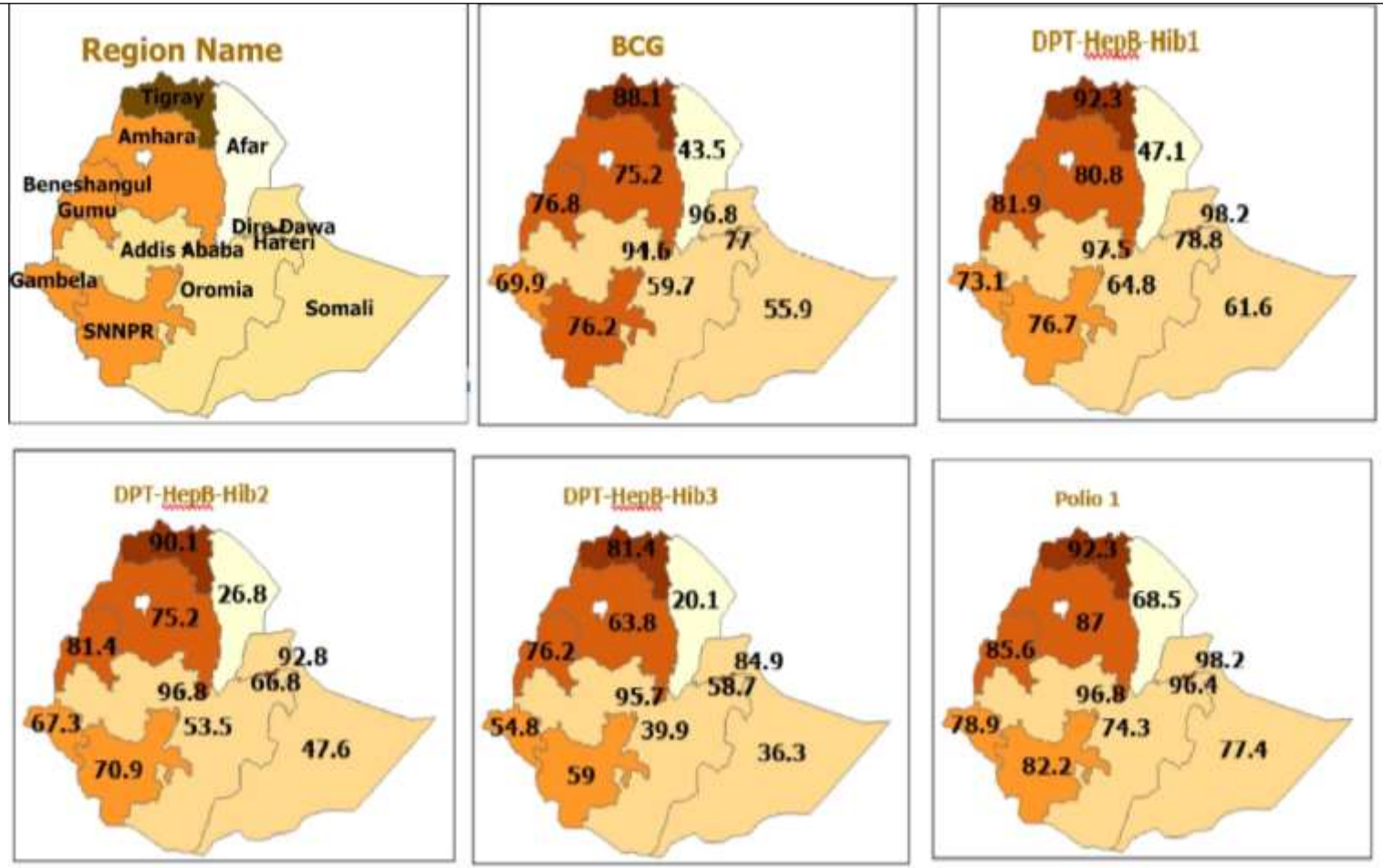
The maps below are based on data collected during Ethiopia's 2016 Demographic and Health Survey (DHS, 2016). They are intended facilitate the geographical analysis of health topics. Sidama *Kilil* is not included as it was it did not have a regional status at the time.

The first set of maps show immunization coverage by region. Expectedly, the two autonomous urban regions – Addis Ababa and Dire Dawa – have the highest coverage. It is not clear if the word expectedly applies equally to the highest coverage in a primarily rural region. It is very clear however, that Tigray *Kilil* has the highest coverage of the primarily rural regions. Could this be due to the dominant position the Tigrian Liberation Front had in governing Ethiopia for over a quarter century. The 2016 Demographic and health Survey shows Tigray's vaccination coverage to be on par with Addis Ababa's and Dire Dawa's.

The two regions with the worst vaccination coverage are Afar at the very bottom and Somali in second place from bottom. Interestingly, the largest region in both area and population size and, arguably the richest, – Oromia – is barely above the bottom two in coverage. This is something the region's administrators should find worthy of note in today's highly charged environment of Oromo politics takes where ethnicity center stage and crowds out all issues including health.

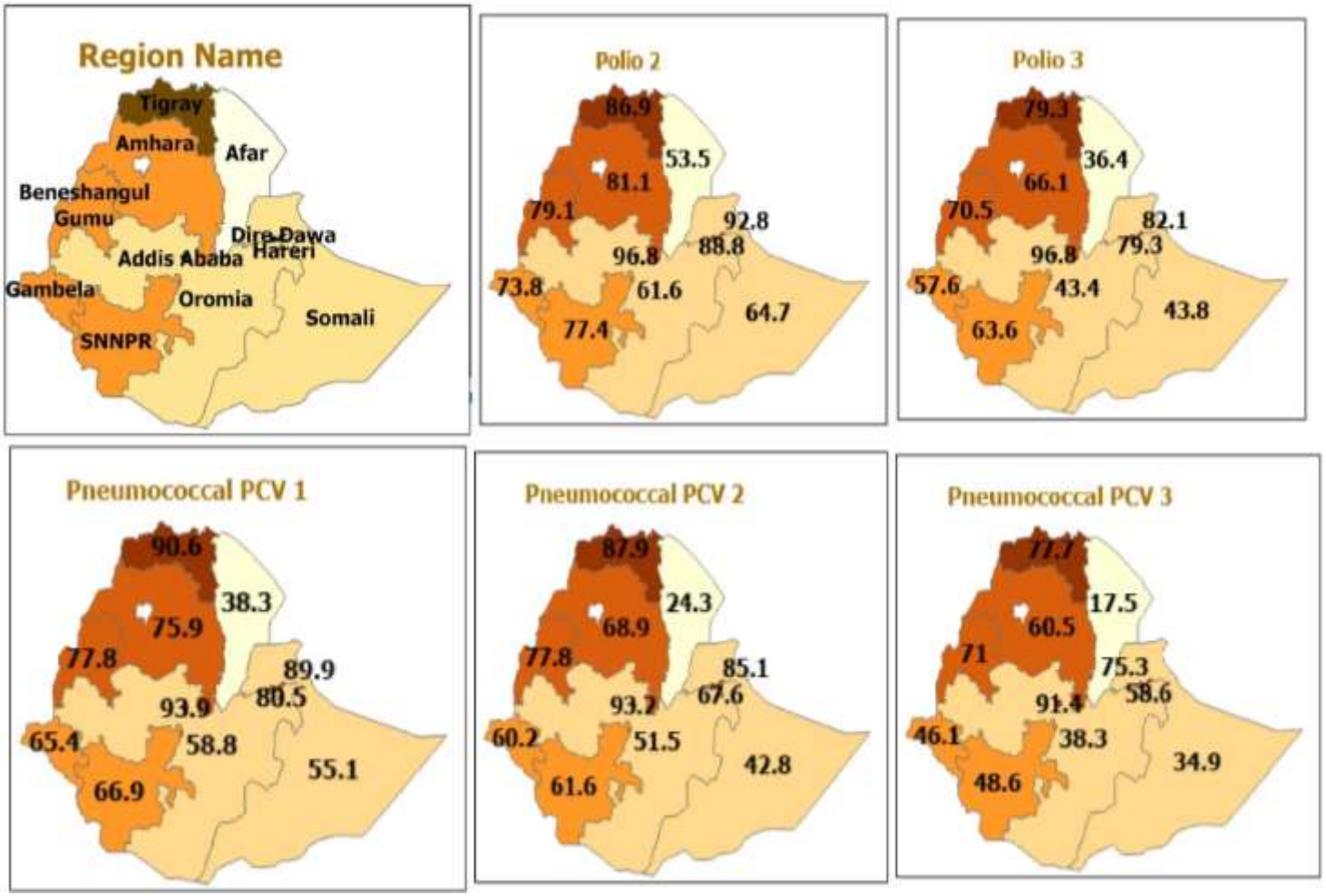
Percentage of children age 12-23 months and children age 24-35 months who received specific vaccines at any time before the survey (according to a vaccination card, health facility, or the mother's report), percentage with all basic vaccinations, and percentage with all age-appropriate vaccinations, according to background characteristics

(Ethiopia DHS 2016)



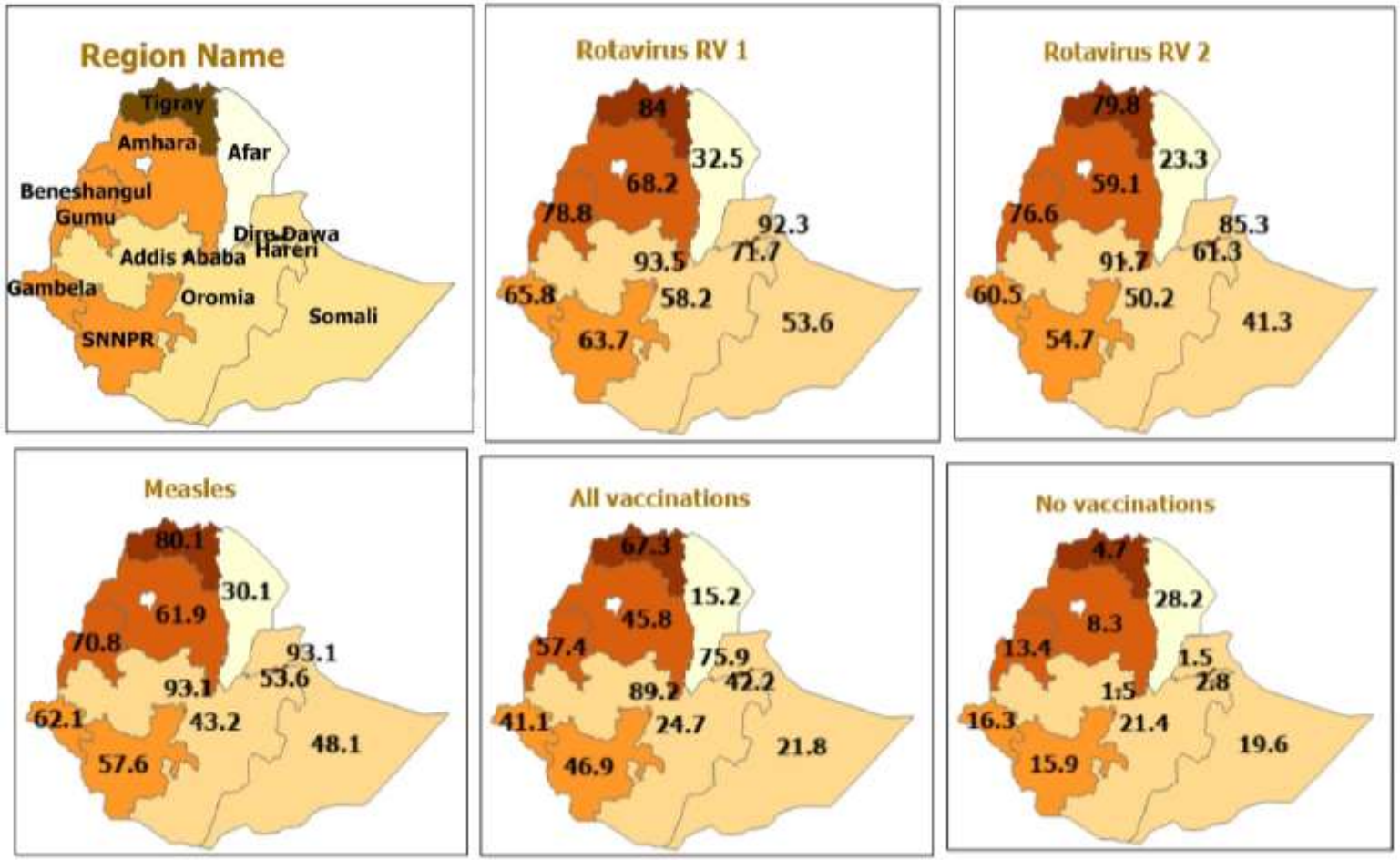
Percentage of children age 12-23 months and children age 24-35 months who received specific vaccines at any time before the survey (according to a vaccination card, health facility, or the mother's report), percentage with all basic vaccinations, and percentage with all age-appropriate vaccinations, according to background characteristics

(Ethiopia DHS 2016…. contd.)



Percentage of children age 12-23 months and children age 24-35 months who received specific vaccines at any time before the survey (according to a vaccination card, health facility, or the mother's report), percentage with all basic vaccinations, and percentage with all age-appropriate vaccinations, according to background characteristics

(Ethiopia DHS 2016…. contd.)



The 2015-16 Health Sector Transformation Plan (HSTP) has ranked maternal and newborn health as top priorities for the Government of Ethiopia. The HSTP's key priorities are child birth at health facilities with skilled medical attention and hygienic conditions; reduction in infections and complications during pregnancy, labor, and delivery; follow-up postnatal care to treat complications from delivery; and education of mothers regarding self-care and infant care [30]. According to the 2016 DHS report [30], the proportion of women between the ages of 15 and 49 who received any antenatal care (ANC) from a skilled provider "has increased from 27% in 2000, to 28% in 2005, 34% in 2011, and 62% in 2016". This source highlights the following additional facts:

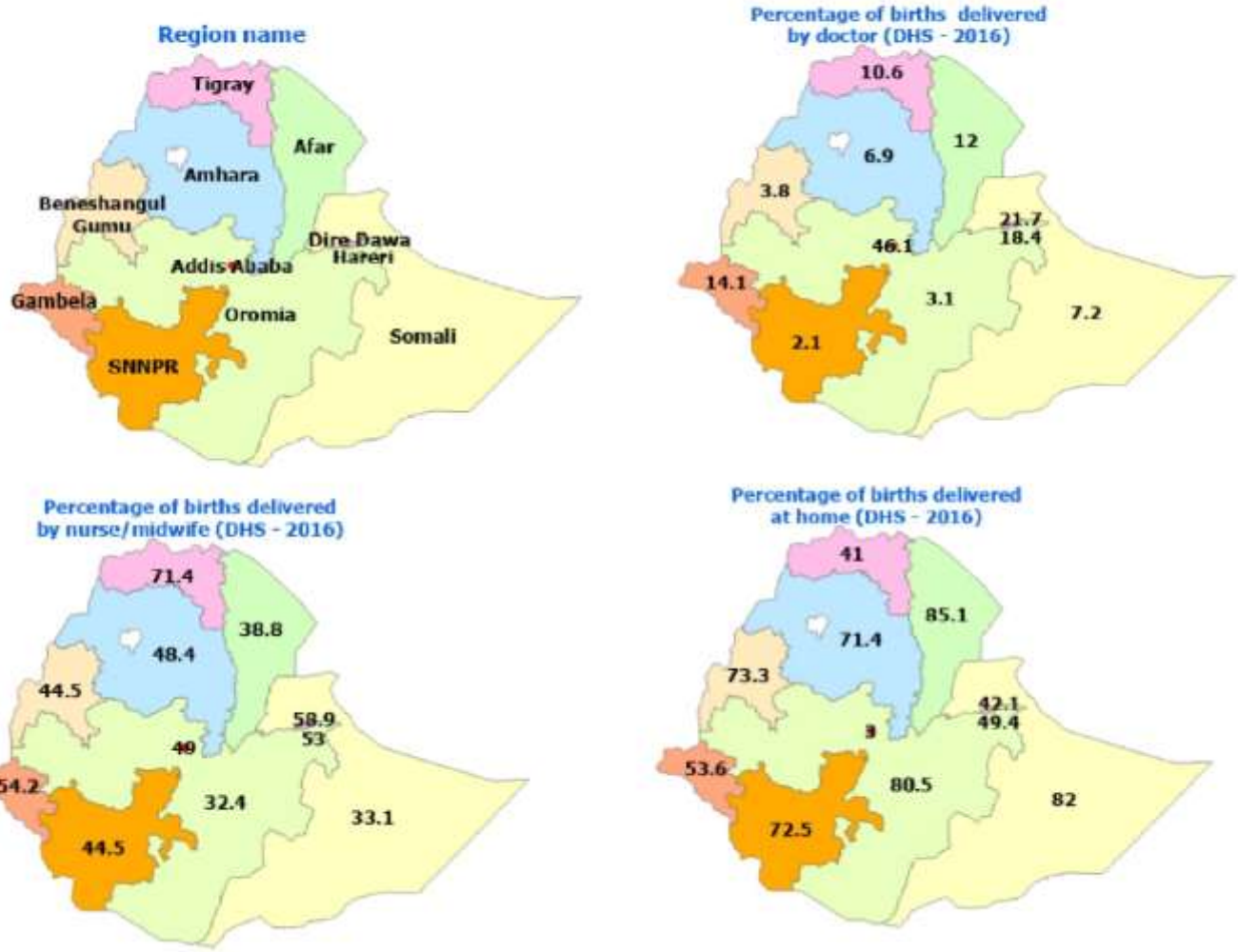
- Higher order births are less likely to receive ANC than lower order births
- Urban women are more likely than rural women to receive any ANC from a skilled provider (90% and 58%, respectively).
- Mothers' education plays a significant role – 53% women with no education obtained ANC services from a skilled provider compared to 98% of women that had more than secondary education
- Expectedly, wealth also plays a big role as women in the highest wealth quintile had a much higher level of access to ANC (85%) than those in the lowest quintile (48%)
- 32% of women had at least four ANC visits during their last pregnancy, while 37% had no such visits
- The proportion of women receiving the WHO recommended four or more ANC visits increased from 10% in the year 2000 to 32% in 2016.

The second group of maps features percentage distributions of women age 15-49 who had a live birth in the 5 years before the 2016 national Demographic and Health Survey (DHS) by persons providing assistance during delivery and by women's region of residence. Also shown are antenatal care (ANC) provision during pregnancy for the most recent birth and percentage receiving antenatal care from a skilled provider for the most recent birth, according to the women's region of residence. In addition, the percentage distribution among women age 15-49 giving birth in the 2 years before the survey, percent distribution by the mother's first postnatal check for the most recent live birth is mapped by mothers' region of birth.

The results show significant differences in the percentage of deliveries attended by a doctor between two urban administrations - Addis Ababa (46.1%) and Dire Dawa (21.7%) on the one hand, and the gap between the two and the nine primarily rural regions where the percentages below five percent including in the largest region by population and size – Oromiya (3.1%), SNNPR (2.1%) and Benishangul Gumuz (3.8%). Overall, however, institutional deliveries have increased from Around 5% in 2000 to 10% in 2011, and 26% in the 2016. In the same time period, there have been sharp declines in home deliveries which declined from 95% in 2000 to 73% in 2016. Meanwhile, institutional deliveries for women living in rural increased substantially - from 2% in 2000 to 20% in the 2016 EDHS and health institution delivery among urban women increased from 32% in 2000 to 79% in 2016 [30].

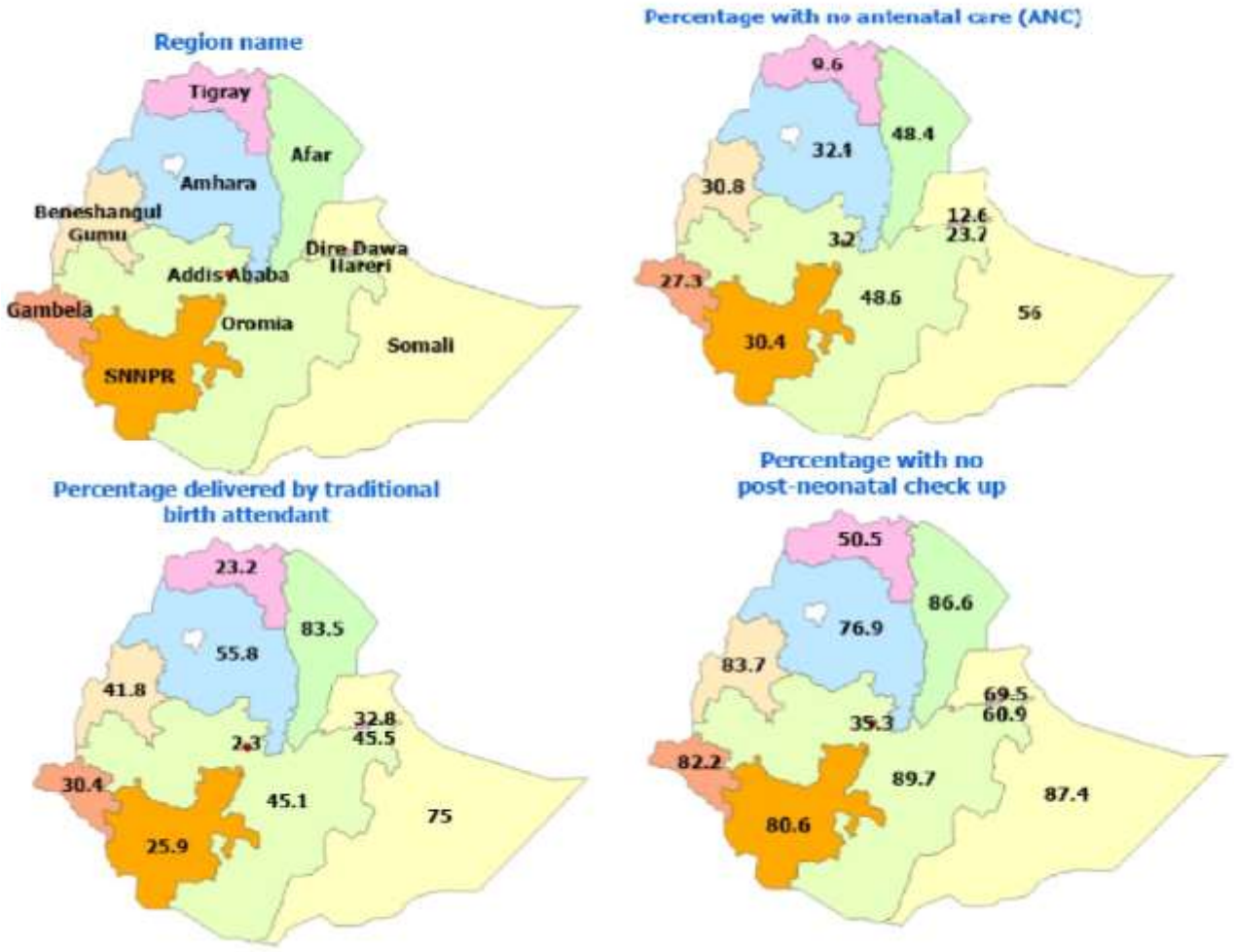
Percentage distribution of women aged 15-49 who had a live birth in the 5 years before the 2016 national Demographic and Health Survey (DHS) by persons providing assistance during delivery and by women's region of residence

(Ethiopia DHS 2016)



Percentage distribution of women aged 15-49 who had a live birth in the 5 years before the 2016 national Demographic and Health Survey (DHS) by reception of antenatal care, attendance of traditional midwives, absence of post neonatal check and by women's region of residence

(Ethiopia DHS 2016…. contd.)



Health Care Facilities

The next group of maps show point locations of hospitals health centers and clinics by region. A 2018 Shapefile layer downloaded from https://data.humdata.org/dataset/ethiopia-health lists a total of 903 health care facilities in the country. Of these, 163 are located in Addis Ababa. The table below shows population sizes by region based on an internet site [31] and the number of people served by a single hospital, health center, and clinic. The top two population giants – Oromia and Amhara - have the worst statistics for the number of persons per hospital which is over 1.5 million each. Somali Region has by far the worst ratio of population to a health center – over a million.

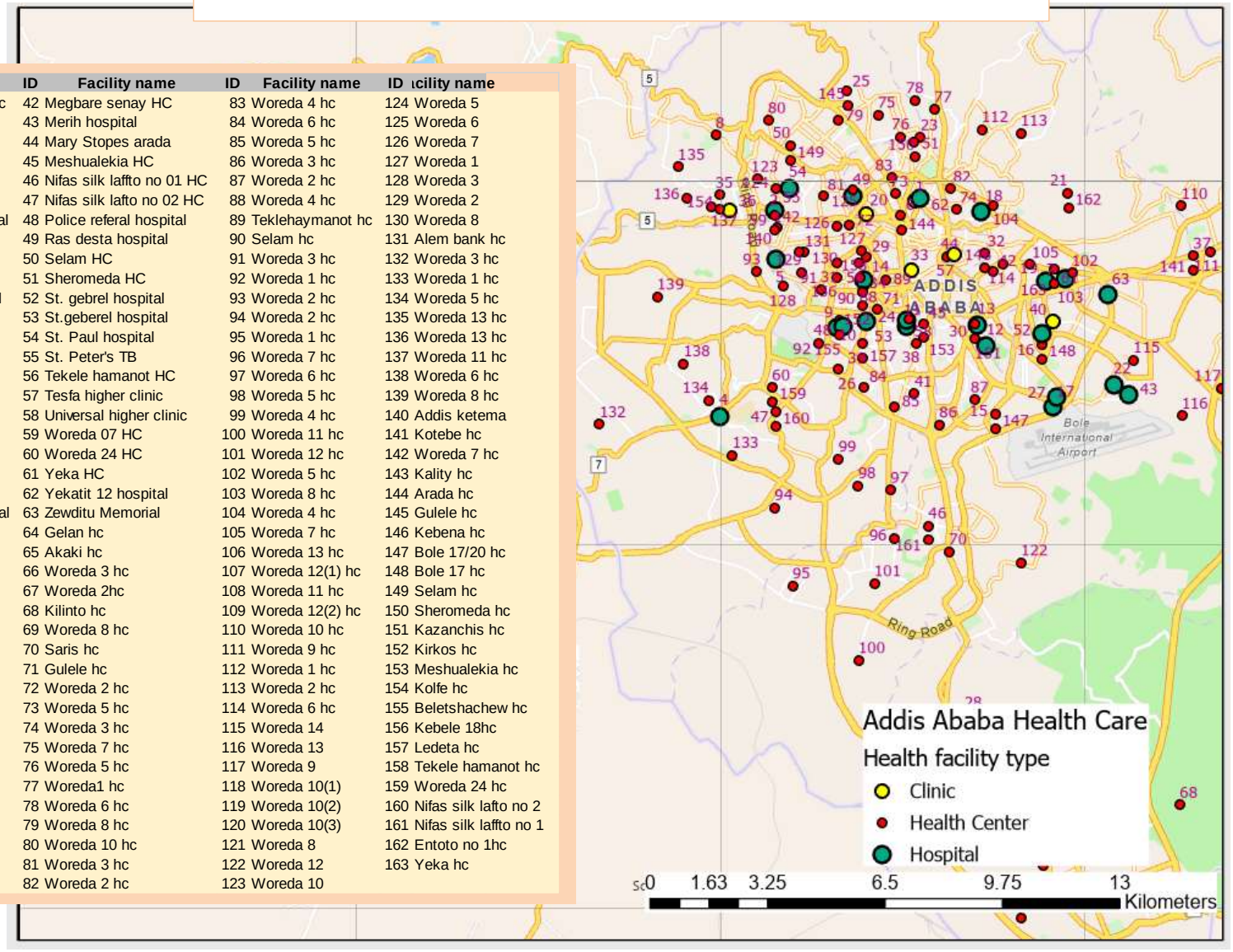
Number of Clinics, Health Centers, Hospitals and Population per Facility by Region

Region	Clinic	Health Center	Hospital	Grand Total	Population Jan 1 2021	Population per Health Center	Population per Hospital
Addis Ababa	6	134	23	163	4,646,759	34,677	202,033
Afar		14	2	16	2,323,380	165,956	1,161,690
Amahara		171	18	189	30,087,766	175,952	1,671,543
Benishangul G.		14	2	16	1,045,520	74,680	522,760
Dire Dawa		6	3	9	580,845	96,808	193,615
Gambella		9	1	10	464,675	51,631	464,675
Harari		4	5	9	232,338	58,085	46,468
Oromiya		201	27	228	40,542,973	201,706	1,501,592
SNNP		173	19	192	22,652,952	130,942	1,192,261
Somali		6	5	11	6,970,138	1,161,690	1,394,028
Tigray	1	46	13	60	6,853,970	148,999	527,228
Grand Total	**7**	**778**	**118**	**903**	**116,401,316**	**149,616**	**986,452**

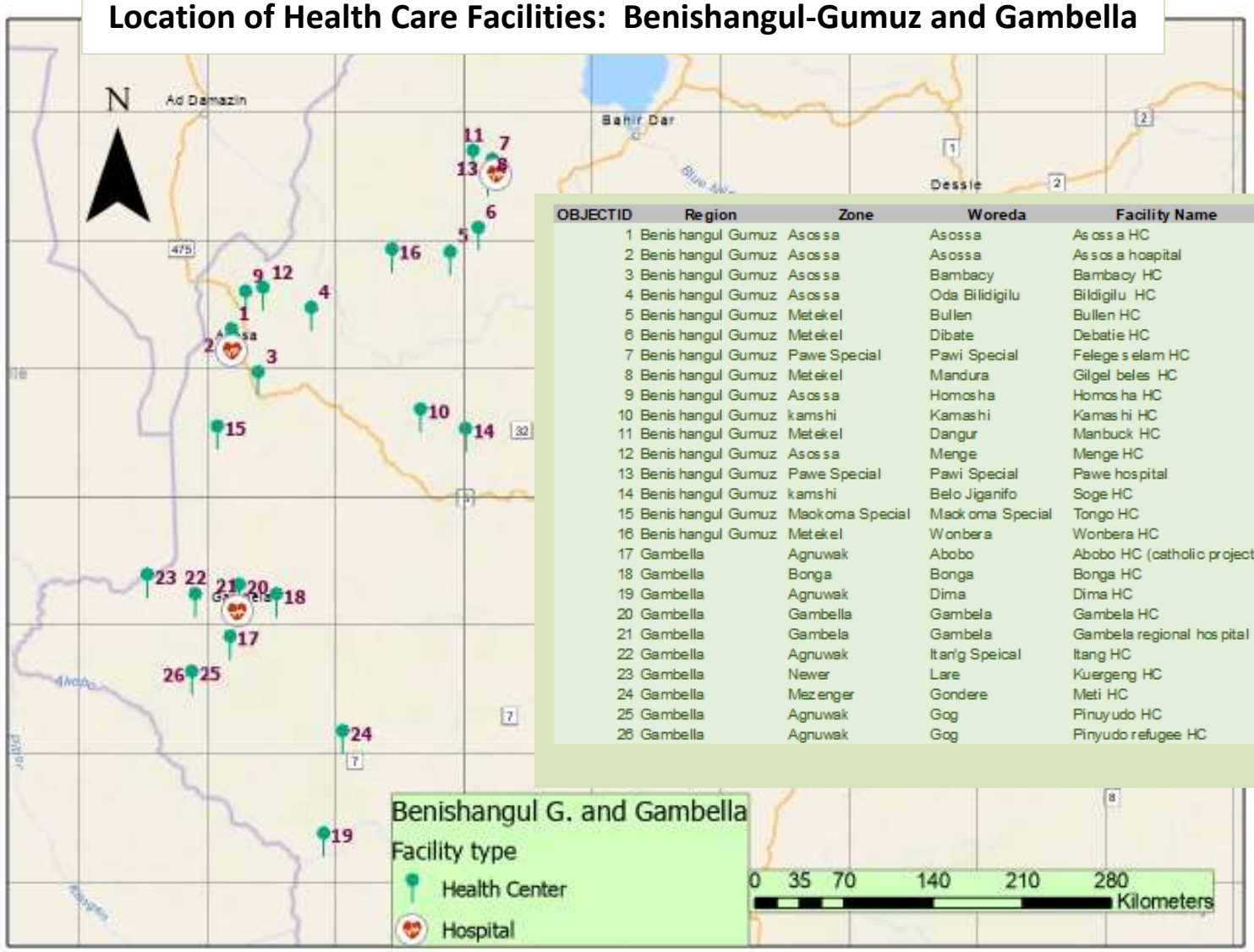
Location of Health Care Facilities: Addis Ababa

Location of Health Care Facilities: Addis Ababa

ID	Facility name	ID	Facility name	ID	Facility name	ID	Facility name
1	Adawa higher clinic	42	Megbare senay HC	83	Woreda 4 hc	124	Woreda 5
2	Addis ketema	43	Merih hospital	84	Woreda 6 hc	125	Woreda 6
3	Akaki HC	44	Mary Stopes arada	85	Woreda 5 hc	126	Woreda 7
4	Alert hospital	45	Meshualekia HC	86	Woreda 3 hc	127	Woreda 1
5	Amanuel hospital	46	Nifas silk laffto no 01 HC	87	Woreda 2 hc	128	Woreda 3
6	Arada HC	47	Nifas silk lafto no 02 HC	88	Woreda 4 hc	129	Woreda 2
7	Asegedech hospital	48	Police referal hospital	89	Teklehaymanot hc	130	Woreda 8
8	Awolia HC	49	Ras desta hospital	90	Selam hc	131	Alem bank hc
9	Balcha hospital	50	Selam HC	91	Woreda 3 hc	132	Woreda 3 hc
10	Beletshachew HC	51	Sheromeda HC	92	Woreda 1 hc	133	Woreda 1 hc
11	Bethzatha hospital	52	St. gebrel hospital	93	Woreda 2 hc	134	Woreda 5 hc
12	Betsegaw hospital	53	St.geberel hospital	94	Woreda 2 hc	135	Woreda 13 hc
13	Bgm mch hospital	54	St. Paul hospital	95	Woreda 1 hc	136	Woreda 13 hc
14	Black Lion	55	St. Peter's TB	96	Woreda 7 hc	137	Woreda 11 hc
15	Bole 17/20 HC	56	Tekele hamanot HC	97	Woreda 6 hc	138	Woreda 6 hc
16	Bole HC	57	Tesfa higher clinic	98	Woreda 5 hc	139	Woreda 8 hc
17	Brass Maternity	58	Universal higher clinic	99	Woreda 4 hc	140	Addis ketema
18	Dagmawi Menelik	59	Woreda 07 HC	100	Woreda 11 hc	141	Kotebe hc
19	Din berwa mch	60	Woreda 24 HC	101	Woreda 12 hc	142	Woreda 7 hc
20	Dr Negatu	61	Yeka HC	102	Woreda 5 hc	143	Kality hc
21	Entoto no 1 HC	62	Yekatit 12 hospital	103	Woreda 8 hc	144	Arada hc
22	Ethio-korea hospital	63	Zewditu Memorial	104	Woreda 4 hc	145	Gulele hc
23	Firimetodist HC	64	Gelan hc	105	Woreda 7 hc	146	Kebena hc
24	Gandhi Memorial	65	Akaki hc	106	Woreda 13 hc	147	Bole 17/20 hc
25	Gulele HC	66	Woreda 3 hc	107	Woreda 12(1) hc	148	Bole 17 hc
26	Harer higer clinic	67	Woreda 2hc	108	Woreda 11 hc	149	Selam hc
27	Hayat hospital	68	Kilinto hc	109	Woreda 12(2) hc	150	Sheromeda hc
28	Kality HC	69	Woreda 8 hc	110	Woreda 10 hc	151	Kazanchis hc
29	Katederal HC	70	Saris hc	111	Woreda 9 hc	152	Kirkos hc
30	Kazanchis HC	71	Gulele hc	112	Woreda 1 hc	153	Meshualekia hc
31	Kebele 18 HC	72	Woreda 2 hc	113	Woreda 2 hc	154	Kolfe hc
32	Kebena HC	73	Woreda 5 hc	114	Woreda 6 hc	155	Beletshachew hc
33	Kibre higher clinic	74	Woreda 3 hc	115	Woreda 14	156	Kebele 18hc
34	Kirkos HC	75	Woreda 7 hc	116	Woreda 13	157	Ledeta hc
35	Kolfe HC	76	Woreda 5 hc	117	Woreda 9	158	Tekele hamanot hc
36	Kolfe higher clinic	77	Woreda1 hc	118	Woreda 10(1)	159	Woreda 24 hc
37	Kotebe HC	78	Woreda 6 hc	119	Woreda 10(2)	160	Nifas silk lafto no 2
38	Kt gebrel HC	79	Woreda 8 hc	120	Woreda 10(3)	161	Nifas silk laffto no 1
39	Ledeta HC	80	Woreda 10 hc	121	Woreda 8	162	Entoto no 1hc
40	Magenagna clinic	81	Woreda 3 hc	122	Woreda 12	163	Yeka hc
41	Mary Stopes	82	Woreda 2 hc	123	Woreda 10		

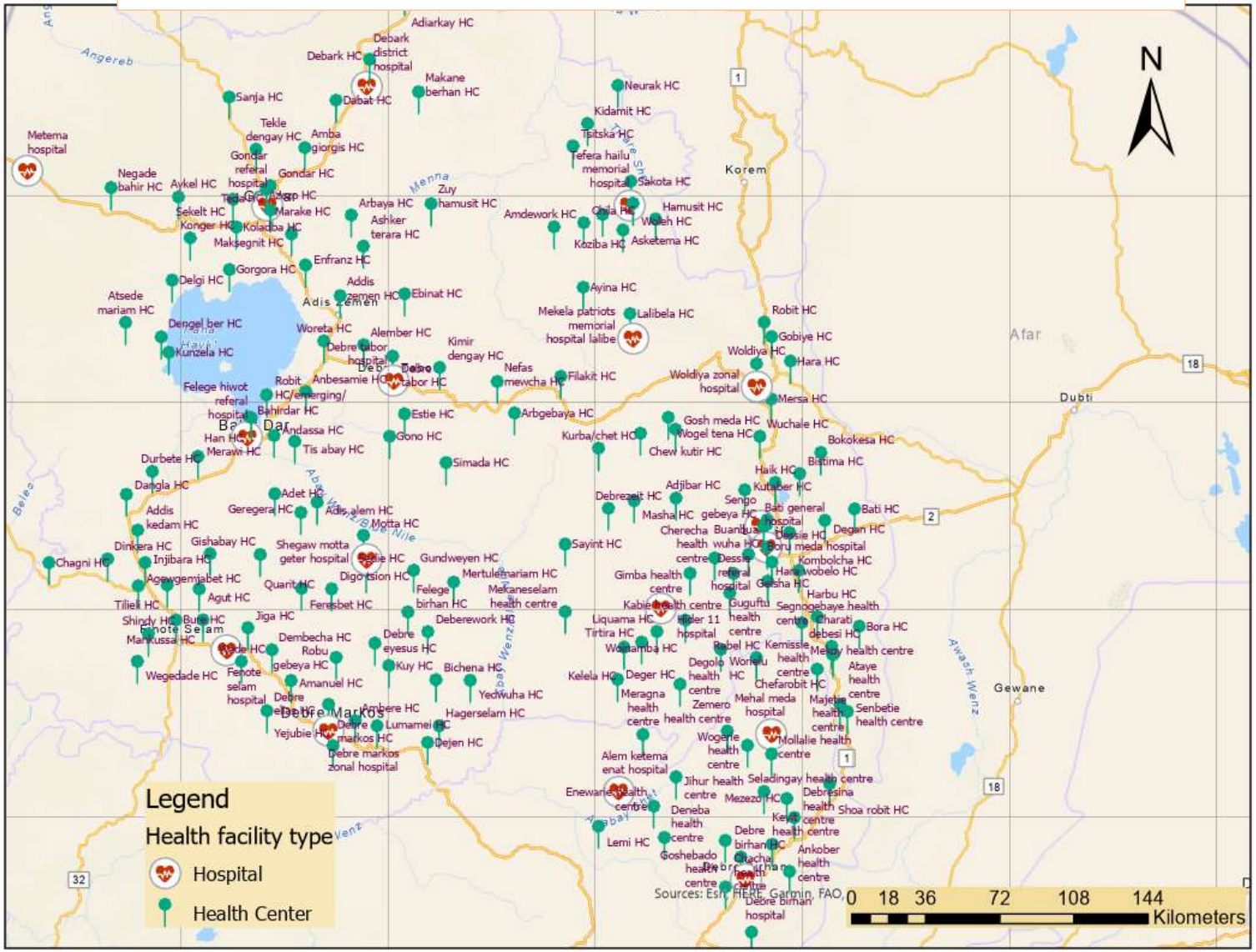


Location of Health Care Facilities: Benishangul-Gumuz and Gambella

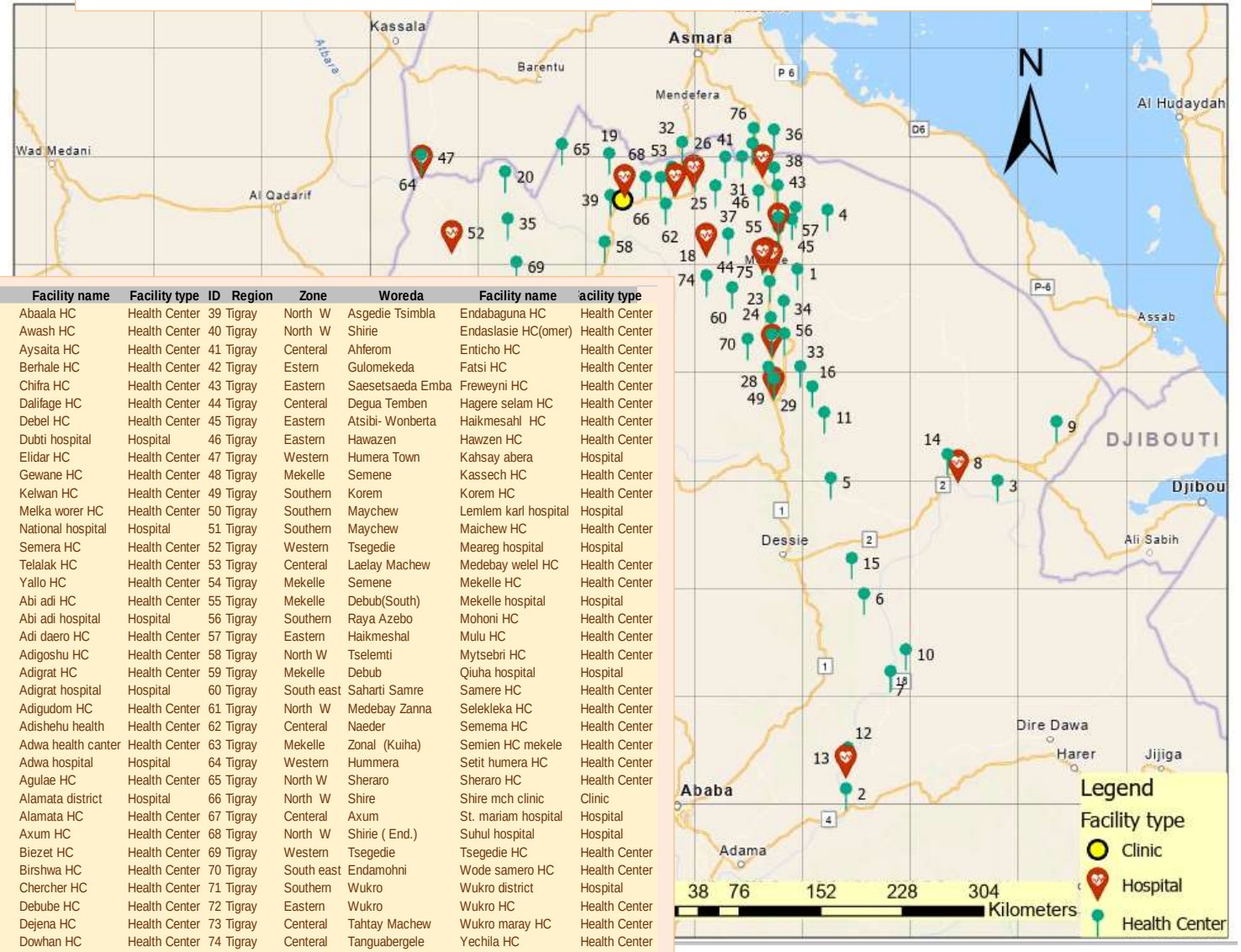


OBJECTID	Region	Zone	Woreda	Facility Name	Facility Type
1	Benishangul Gumuz	Asossa	Asossa	Assossa HC	Health Center
2	Benishangul Gumuz	Asossa	Asossa	Assosa hoapital	Hospital
3	Benishangul Gumuz	Asossa	Bambacy	Bambacy HC	Health Center
4	Benishangul Gumuz	Asossa	Oda Bilidigilu	Bildigilu HC	Health Center
5	Benishangul Gumuz	Metekel	Bullen	Bullen HC	Health Center
6	Benishangul Gumuz	Metekel	Dibate	Debatie HC	Health Center
7	Benishangul Gumuz	Pawe Special	Pawi Special	Felege selam HC	Health Center
8	Benishangul Gumuz	Metekel	Mandura	Gilgel beles HC	Health Center
9	Benishangul Gumuz	Asossa	Homosha	Homosha HC	Health Center
10	Benishangul Gumuz	kamshi	Kamashi	Kamashi HC	Health Center
11	Benishangul Gumuz	Metekel	Dangur	Manbuck HC	Health Center
12	Benishangul Gumuz	Asossa	Menge	Menge HC	Health Center
13	Benishangul Gumuz	Pawe Special	Pawi Special	Pawe hospital	Hospital
14	Benishangul Gumuz	kamshi	Belo Jiganifo	Soge HC	Health Center
15	Benishangul Gumuz	Mao komo Special	Mao komo Special	Tongo HC	Health Center
16	Benishangul Gumuz	Metekel	Wonbera	Wonbera HC	Health Center
17	Gambella	Agnuwak	Abobo	Abobo HC (catholic project)	Health Center
18	Gambella	Bonga	Bonga	Bonga HC	Health Center
19	Gambella	Agnuwak	Dima	Dima HC	Health Center
20	Gambella	Gambella	Gambela	Gambela HC	Health Center
21	Gambella	Gambela	Gambela	Gambela regional hospital	Hospital
22	Gambella	Agnuwak	Itang Speical	Itang HC	Health Center
23	Gambella	Newer	Lare	Kuergeng HC	Health Center
24	Gambella	Mezenger	Gondere	Meti HC	Health Center
25	Gambella	Agnuwak	Gog	Pinuyudo HC	Health Center
26	Gambella	Agnuwak	Gog	Pinyudo refugee HC	Health Center

Location of Health Care Facilities: Amhara Region

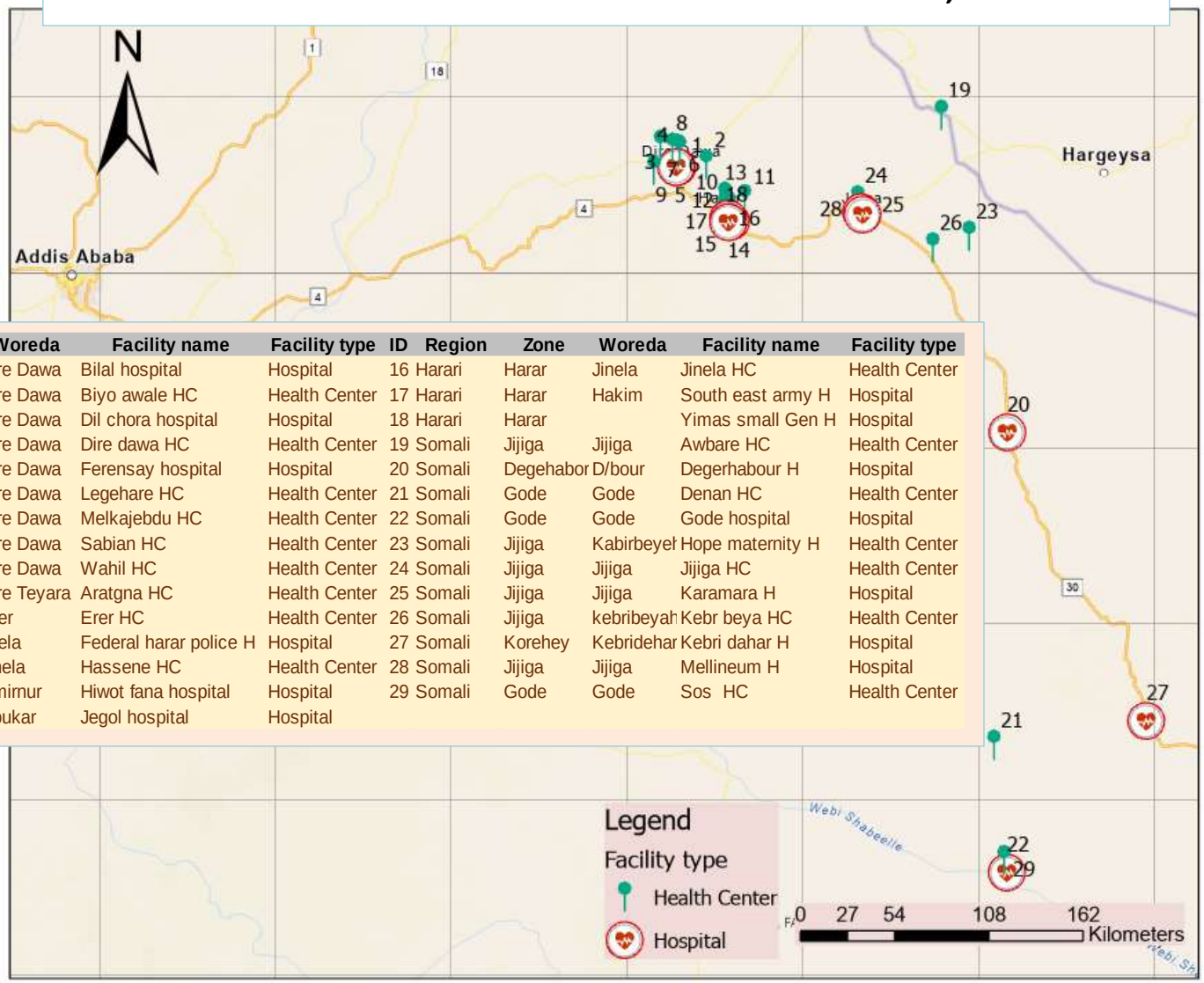


Location of Health Care Facilities: Tigray and Afar



ID	Region	Zone	Woreda	Facility name	Facility type	ID	Region	Zone	Woreda	Facility name	Facility type
1	Afar	Zone 2	Abl'ala	Abaala HC	Health Center	39	Tigray	North W	Asgedie Tsimbla	Endabaguna HC	Health Center
2	Afar	Zone 3	Awash Fentale	Awash HC	Health Center	40	Tigray	North W	Shirie	Endaslasie HC(omer)	Health Center
3	Afar	Zone 1	Aysaita	Aysaita HC	Health Center	41	Tigray	Centeral	Ahferom	Enticho HC	Health Center
4	Afar	Zone 2	Berhale	Berhale HC	Health Center	42	Tigray	Estern	Gulomekeda	Fatsi HC	Health Center
5	Afar	Zone 1	Chifra	Chifra HC	Health Center	43	Tigray	Eastern	Saesetsaeda Emba	Freweyni HC	Health Center
6	Afar	Zone 5	Dalifage	Dalifage HC	Health Center	44	Tigray	Centeral	Degua Temben	Hagere selam HC	Health Center
7	Afar	Zone 3	Buromedgto	Debel HC	Health Center	45	Tigray	Eastern	Atsibi- Wonberta	Haikmesahl HC	Health Center
8	Afar	Zone 1	Dubti	Dubti hospital	Hospital	46	Tigray	Eastern	Hawazen	Hawzen HC	Health Center
9	Afar	Zone 1	Elidar	Elidar HC	Health Center	47	Tigray	Western	Humera Town	Kahsay abera	Hospital
10	Afar	Zone 3	Gewane 03	Gewane HC	Health Center	48	Tigray	Mekelle	Semene	Kassech HC	Health Center
11	Afar	Zone 4	Gulina	Kelwan HC	Health Center	49	Tigray	Southern	Korem	Korem HC	Health Center
12	Afar	Zone 3	Amibara 01	Melka worer HC	Health Center	50	Tigray	Southern	Maychew	Lemlem karl hospital	Hospital
13	Afar	Zone 3	Amibara 01	National hospital	Hospital	51	Tigray	Southern	Maychew	Maichew HC	Health Center
14	Afar	Zone 1	Dubti	Semera HC	Health Center	52	Tigray	Western	Tsegedie	Meareg hospital	Hospital
15	Afar	Zone 5	Telalak	Telalak HC	Health Center	53	Tigray	Centeral	Laelay Machew	Medebay welel HC	Health Center
16	Afar	Zone 4	Yallo	Yallo HC	Health Center	54	Tigray	Mekelle	Semene	Mekelle HC	Health Center
17	Tigray	Centeral	Abiadi	Abi adi HC	Health Center	55	Tigray	Mekelle	Debub(South)	Mekelle hospital	Hospital
18	Tigray	Centeral	Abiadi	Abi adi hospital	Hospital	56	Tigray	Southern	Raya Azebo	Mohoni HC	Health Center
19	Tigray	North W	Laelay Adiyabo	Adi daero HC	Health Center	57	Tigray	Eastern	Haikmeshal	Mulu HC	Health Center
20	Tigray	Western	kafta Humora	Adigoshu HC	Health Center	58	Tigray	North W	Tselemti	Mytsebri HC	Health Center
21	Tigray	South east	Adigrat	Adigrat HC	Health Center	59	Tigray	Mekelle	Debub	Qiuha hospital	Hospital
22	Tigray	Estern	Adigrat	Adigrat hospital	Hospital	60	Tigray	South east	Saharti Samre	Samere HC	Health Center
23	Tigray	Southern	Hiintalo wejerat	Adigudom HC	Health Center	61	Tigray	North W	Medebay Zanna	Selekleka HC	Health Center
24	Tigray	Southern	Alage	Adishehu health	Health Center	62	Tigray	Centeral	Naeder	Semema HC	Health Center
25	Tigray	Centeral	Adwa	Adwa health canter	Health Center	63	Tigray	Mekelle	Zonal (Kuiha)	Semien HC mekele	Health Center
26	Tigray	Centeral	Adwa	Adwa hospital	Hospital	64	Tigray	Western	Hummera	Setit humera HC	Health Center
27	Tigray	Eastern	Agulae(Kilte A.)	Agulae HC	Health Center	65	Tigray	North W	Sheraro	Sheraro HC	Health Center
28	Tigray	Southern	Alamata	Alamata district	Hospital	66	Tigray	North W	Shire	Shire mch clinic	Clinic
29	Tigray	Southern	Alamata	Alamata HC	Health Center	67	Tigray	Centeral	Axum	St. mariam hospital	Hospital
30	Tigray	Centeral	Axum	Axum HC	Health Center	68	Tigray	North W	Shirie (End.)	Suhul hospital	Hospital
31	Tigray	Estern	Ganta Afeshum	Biezet HC	Health Center	69	Tigray	Western	Tsegedie	Tsegedie HC	Health Center
32	Tigray	Centeral	Mereb Leke	Birshwa HC	Health Center	70	Tigray	South east	Endamohni	Wode samero HC	Health Center
33	Tigray	Southern	Raya Azebo	Chercher HC	Health Center	71	Tigray	Southern	Wukro	Wukro district	Hospital
34	Tigray	South east	Hentalo Wajerat	Debube HC	Health Center	72	Tigray	Eastern	Wukro	Wukro HC	Health Center
35	Tigray	Western	Wolkait	Dejena HC	Health Center	73	Tigray	Centeral	Tahtay Machew	Wukro maray HC	Health Center
36	Tigray	Eastern	Erob	Dowhan HC	Health Center	74	Tigray	Centeral	Tanguabergele	Yechila HC	Health Center
37	Tigray	Centeral	Werie Lake	Edaga arabi HC	Health Center	75	Tigray	Mekelle	Debub(South)	Yeha midam hospital	Hospital
38	Tigray	Eastern	Saese tsadaemba	Edaga hamus HC	Health Center	76	Tigray	Eastern	FATSI Gulomekeda	Zalambesa HC	Health Center

Location of Health Care Facilities: Dire Dawa Harari, Somali

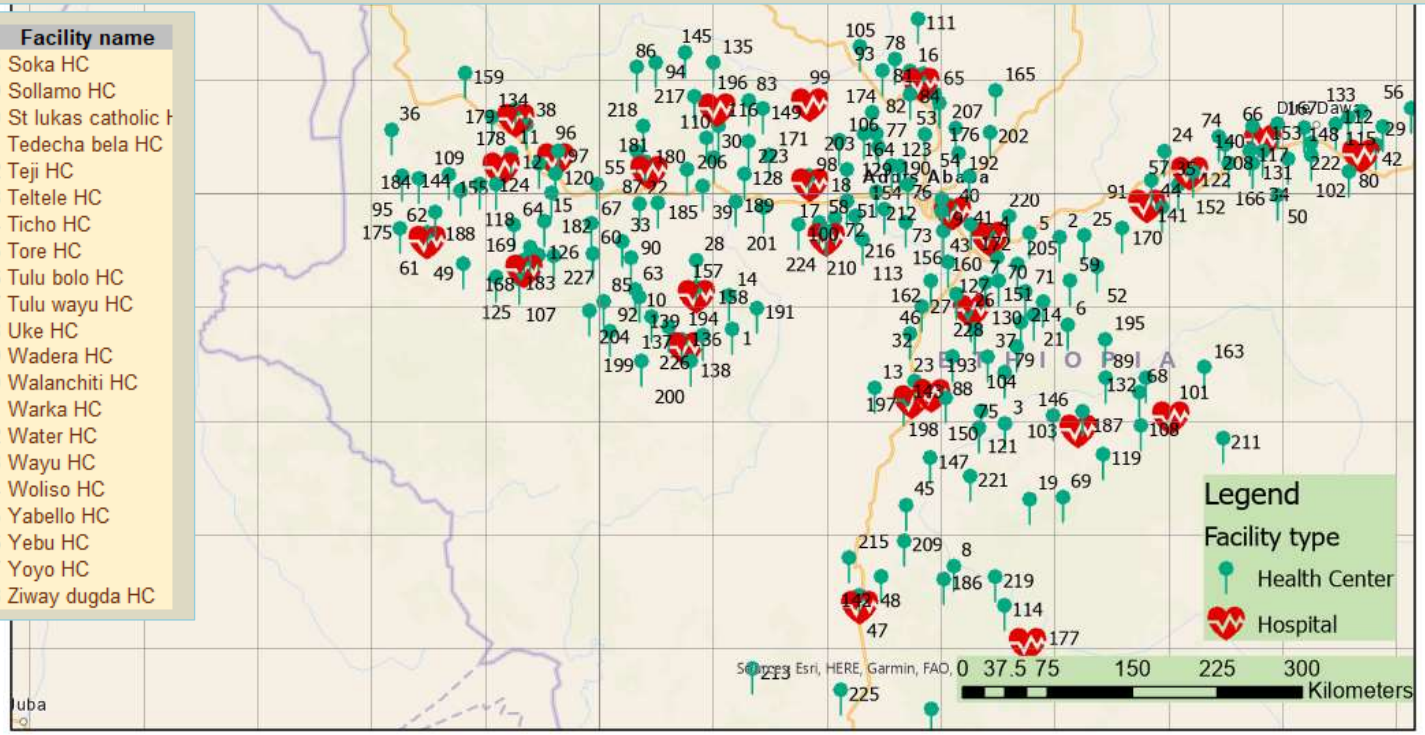


ID	Region	Zone	Woreda	Facility name	Facility type	ID	Region	Zone	Woreda	Facility name	Facility type
1	Dire Dawa	Dire Dawa	Dire Dawa	Bilal hospital	Hospital	16	Harari	Harar	Jinela	Jinela HC	Health Center
2	Dire Dawa	Dire Dawa	Dire Dawa	Biyo awale HC	Health Center	17	Harari	Harar	Hakim	South east army H	Hospital
3	Dire Dawa	Dire Dawa	Dire Dawa	Dil chora hospital	Hospital	18	Harari	Harar		Yimas small Gen H	Hospital
4	Dire Dawa	Dire Dawa	Dire Dawa	Dire dawa HC	Health Center	19	Somali	Jijiga	Jijiga	Awbare HC	Health Center
5	Dire Dawa	Dire Dawa	Dire Dawa	Ferensay hospital	Hospital	20	Somali	Degehabor	D/bour	Degerhabour H	Hospital
6	Dire Dawa	Dire Dawa	Dire Dawa	Legehare HC	Health Center	21	Somali	Gode	Gode	Denan HC	Health Center
7	Dire Dawa	Dire Dawa	Dire Dawa	Melkajebdu HC	Health Center	22	Somali	Gode	Gode	Gode hospital	Hospital
8	Dire Dawa	Dire Dawa	Dire Dawa	Sabian HC	Health Center	23	Somali	Jijiga	Kabirbeyel	Hope maternity H	Health Center
9	Dire Dawa	Dire Dawa	Dire Dawa	Wahil HC	Health Center	24	Somali	Jijiga	Jijiga	Jijiga HC	Health Center
10	Harari	Harar	Dire Teyara	Aratgna HC	Health Center	25	Somali	Jijiga	Jijiga	Karamara H	Hospital
11	Harari	Harar	Erer	Erer HC	Health Center	26	Somali	Jijiga	kebribeyah	Kebr beya HC	Health Center
12	Harari	Harar	jinela	Federal harar police H	Hospital	27	Somali	Korehey	Kebridehar	Kebri dahar H	Hospital
13	Harari	Harar	Jinela	Hassene HC	Health Center	28	Somali	Jijiga	Jijiga	Mellineum H	Hospital
14	Harari	Harar	Amirnur	Hiwot fana hospital	Hospital	29	Somali	Gode	Gode	Sos HC	Health Center
15	Harari	Harar	Abukar	Jegol hospital	Hospital						

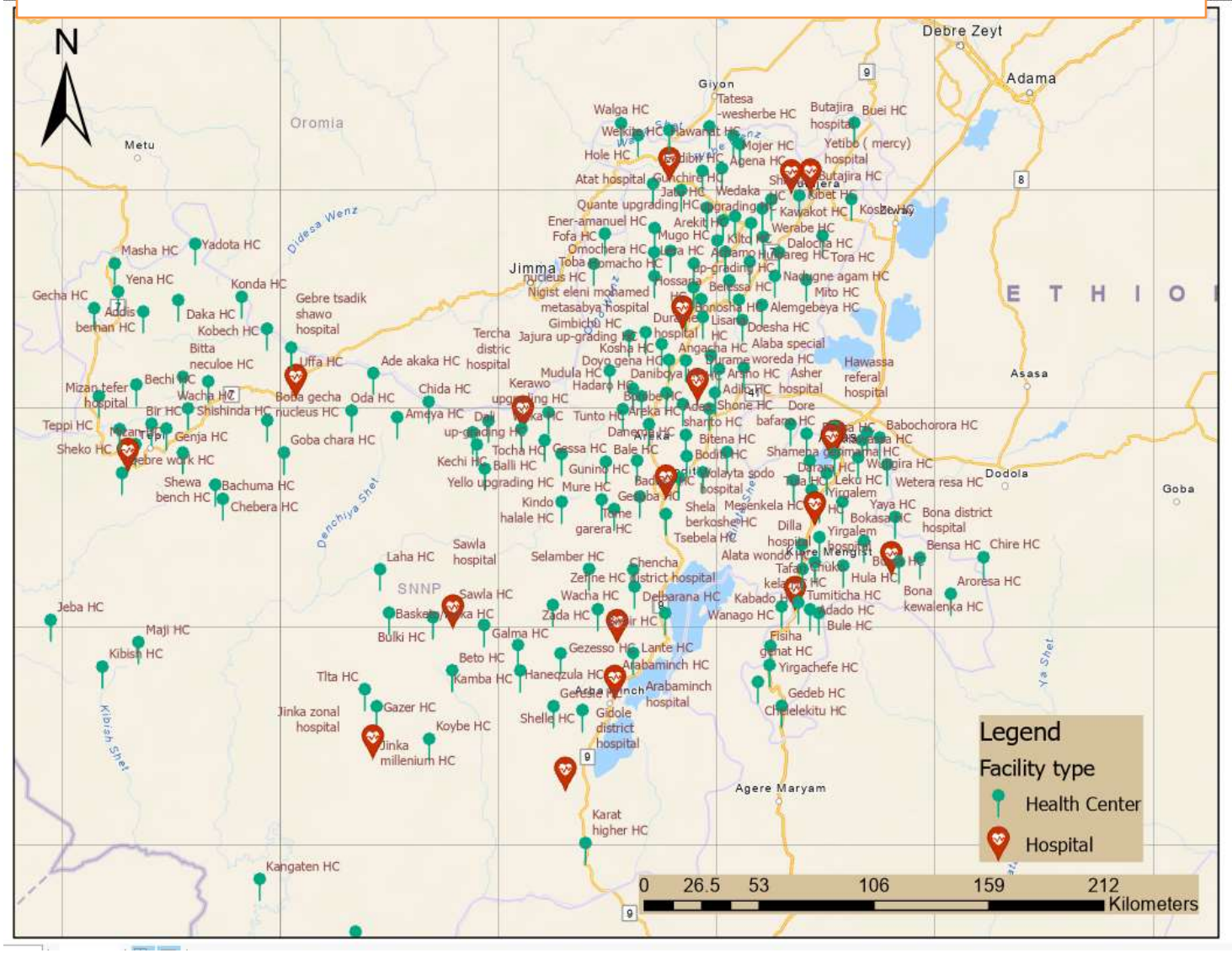
Location of Health Care Facilities: Oromia Region

ID	Facility name	ID	Facility name	ID	Facility name	ID	Facility name	ID	Facility name	ID	Facility name	ID	Facility name	ID	Facility name	ID	Facility name	ID	Facility name	ID	Facility name
1	Abendabo HC	16	Ambesso HC	31	Bared HC	46	Bulbula HC	61	Dambi dolo HC	76	Dukem HC	91	Gelemso H	106	Gojo HC	121	Hasasa HC	136	Jimma HC	151	Kulla HC
2	Abomsa HC	17	Ambo HC	32	Batu HC	47	Bule hora HC	62	Dambi dolo hospital	77	Ejere HC	92	Gera HC	107	Gore HC	122	Hirna HC	137	Jimma H 2 HC	152	Kuni HC
3	Adaba HC	18	Ambo hospital	33	Bedele HC	48	Bule hora hosptal	63	Dambi HC	78	Ejere HC	93	Geraguracha HC	108	Goro HC	123	Holeta HC	138	Jimma Univ H	153	Kurfachele HC
4	Adama HC	19	Angetu HC	34	Bedeno HC	49	Bure HC	64	Darimu HC	79	Enkelo wabe HC	94	Gida ayena HC	109	Gudetu kebe HC	124	Homa HC	139	Joba HC	154	Kussaye HC
5	Addis hiwot HC	20	Arero HC	35	Bedessa HC	50	Burka HC	65	Debretsige HC	80	Fechatu HC	95	Gidami HC	110	Gudeya bila HC	125	Huka HC	140	Karamelee HC	155	Lalo HC
6	Adele HC	21	Ari robe HC	36	Begi HC	51	Bussa HC	66	Deder hospital	81	Fiche HC	96	Gimbi adventist H	111	Gundomeskel HC	126	Hurumu HC	141	Kemona HC	156	Lemen HC
7	Adma hospital	22	Arjo HC	37	Bekoji HC	52	Chancho HC	67	Dega HC	82	Fiche hospital	97	Gimbi HC	112	Gursum HC	127	Huruta HC	142	Kercha HC	157	Limu genet HC
8	Adola woyu HC	23	Arsi negelle HC	38	Bila HC	53	Chancho HC	68	Dello sabro HC	83	Fincha HC	98	Ginchi HC	113	Habru chullule HC	128	Ijajji HC	143	Kersa HC	158	Limu genet H
9	Adulala HC	24	Asebot HC	39	Bilo HC	54	Chefe donsa HC	69	Delomana HC	84	Fital HC	99	Gindeberet H	114	Harakalo HC	129	Inchini HC	144	Keto HC	159	Manasibu HC
10	Agaro HC	25	Aseko HC	40	Bishoftu HC	55	Chewaka HC	70	Dera HC	85	Gaitera HC	100	Gindo HC	115	Haramaya HC	130	Itaya HC	145	Kirmu HC	160	Medhanielm H
11	Aira guliso HC	26	Assela HC	41	Bishoftu hospital	56	Chinaksen HC	71	Diksis HC	86	Galila HC	101	Ginir hospital	116	Harato HC	131	Jaja HC	146	Kofele HC	161	Mega HC
12	Aira hospital	27	Assela hospital	42	Bisidimo hospital	57	Chiro hospital	72	Dilala HC	87	Galo HC	102	Girawa HC	117	Harawacha HC	132	Jara HC	147	Kokosa HC	162	Meki HC
13	Aje HC	28	Atnago HC	43	Bofe HC	58	Chitu HC	73	Dire HC	88	Gambo rural H	103	Goba hospital	118	Haro sabu HC	133	Jarso HC	148	Kombolcha HC	163	Melka mecha HC
14	Ako HC	29	Babile HC	44	Boke HC	59	Cholea HC	74	Doba HC	89	Gasara HC	104	Gobesa HC	119	Harodumal HC	134	Jarso HC	149	Kombolcha HC	164	Menagesha HC
15	Algie HC	30	Bako HC	45	Bore HC	60	Chora HC	75	Dodola HC	90	Gechi HC	105	Gohatsion HC	120	Haru HC	135	Jarte HC	150	Kore HC	165	Mendida HC

ID	Facility name	ID	Facility name	ID	Facility name
166	Mesela HC	187	Robe HC	208	Soka HC
167	Meta HC	188	Robi gebiya HC	209	Sollamo HC
168	Metu HC	189	Sayo HC	210	St lukas catholic H
169	Metu karl H	190	Sebeta HC	211	Tedecha bela HC
170	Micheta HC	191	Sekuro HC	212	Teji HC
171	Midakegn HC	192	Sendafa HC	213	Teltele HC
172	Mojo HC	193	Sequre HC	214	Ticho HC
173	Moyale HC	194	Serbo HC	215	Tore HC
174	Mugher Ent HC	195	Seru HC	216	Tulu bolo HC
175	Mugi HC	196	Shambu hospita	217	Tulu wayu HC
176	Muketuri HC	197	Shashemen HC	218	Uke HC
177	Negele borena H	198	Shashemene Ge	219	Wadera HC
178	Nejo HC	199	Shebe HC	220	Walanchiti HC
179	Nejo hospital	200	Sheki HC	221	Warka HC
180	Nekemte HC	201	Shenen HC	222	Water HC
181	Nekemte hospital	202	Sheno HC	223	Wayu HC
182	Nole kaba HC	203	Shino HC	224	Woliso HC
183	Nopha HC	204	Sigmo HC	225	Yabello HC
184	Nunu HC	205	Sire HC	226	Yebu HC
185	Nunu kumba HC	206	Sire HC	227	Yoyo HC
186	Odoshakiso HC	207	Sirxi HC	228	Ziway dugda HC



Location of Health Care Facilities: Southern Nations Nationalities and People



The Geographic Relationship Between Health and Wealth

The next group of maps include a geographic raster of wealth index generated by Ethiopia's 2016 Demographic and Health Survey. Here is what the publication [31, page 45] says about the construction of the index:

> **Wealth index**
>
> Households are given scores based on the number and kinds of consumer goods they own, ranging from a television to a bicycle or car, in addition to housing characteristics such as source of drinking water, toilet facilities, and flooring materials. These scores are derived using principal component analysis. National wealth quintiles are compiled by assigning the household score to each usual (de jure) household member, ranking each person in the household population by her or his score, and then dividing the distribution into five equal categories, each comprising 20% of the population.

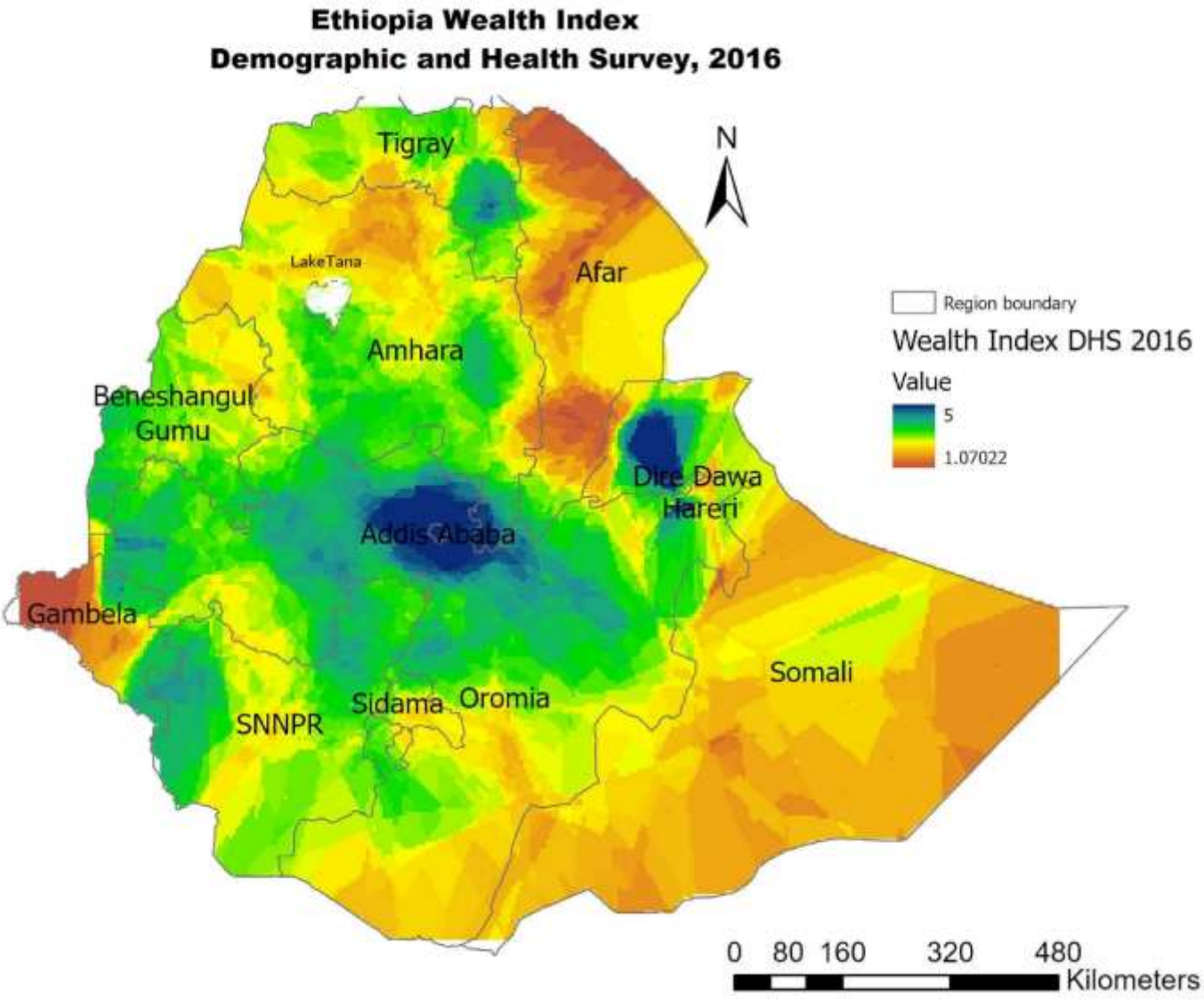
A geographical interpolation method in ArcGIS Pro was used to turn the wealth indices recorded at 645 sampling clusters (202 urban and 443 rural) into continues geographic surfaces (raster) with values ranging from 1 (bottom 20%) to 5 (top 20%). This methodology in the geospatial analytics or is known as spatial interpolation, which is the prediction of cell values in a raster from a limited number of sample data points [32]. "The assumption that makes interpolation a viable option is that spatially distributed objects are spatially correlated; in other words, things that are close together tend to have similar characteristics "[32]. One of the many methodologies used in spatial interpolation is kriging. There are two kriging methods: ordinary and universal. We used the ordinary method

The kriging formula [33]:

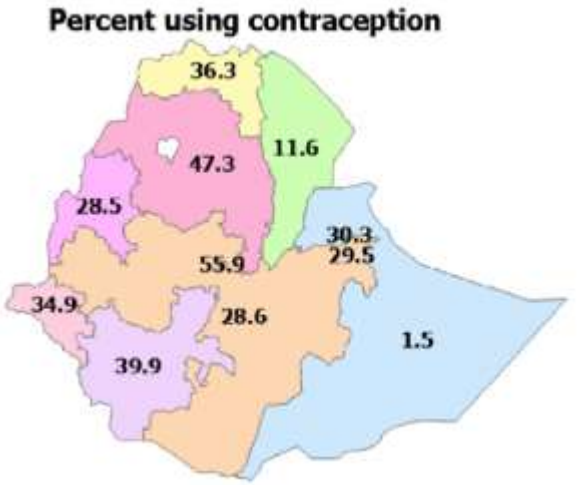
$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i)$$

Weighted sum formula
where:
Z(si) = the measured value at the ith location
λi = an unknown weight for the measured value at the ith location
s0 = the prediction location
N = the number of measured values

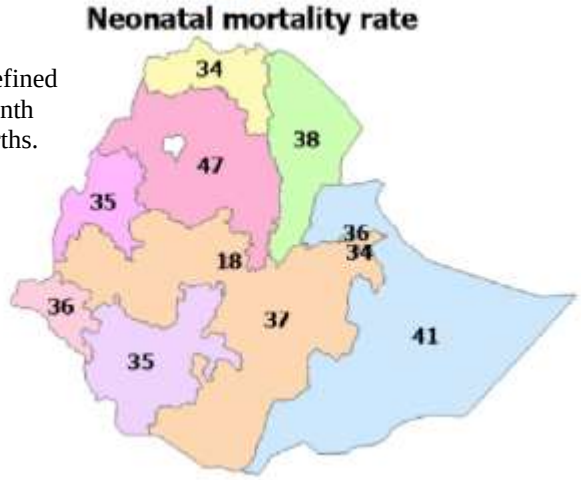
The (raster) map below shows over three-quarters of Afar and Somali Region's and two thirds of Gambella Region as being in the lowest two wealth quintiles and Addis Ababa, Dire Dawa, Harer, and, to a lesser extent, Mekele as being in the highest wealth quintiles. Is there a geographic association between this pattern and the pattern of demographic indicators – contraceptive use, birth rates, infant and child mortality, etc.? The answer provided by subsequent maps appears to be a yes. Afar, and Somali regions have high birthrates, high infant and child mortality rates and low prevalence of contraceptive use. The observation is dramatically opposite for Addis Ababa and Dire Dawa where birth rates are low, contraceptive use rates have been high and rising and infant and child mortality rates are low. This is not unexpected given the study findings in Ethiopia which showed that 44 and 71 percent of "better off" women (those in the upper quintiles of DHS wealth index) had four or more antenatal visits and utilized skilled birth attendants respectively against the respective low utilization rate of just 20 and 29 percent among women from poorest households (those in the lowest quintiles of DHS wealth index) [34].

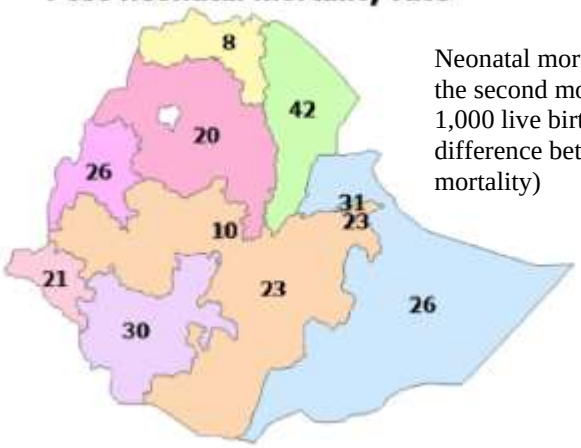

Ethiopia Wealth Index
Demographic and Health Survey, 2016
Tigray
N
LakeTana
Afar
Amhara
Beneshangul
Gumu
Region boundary
Wealth Index DHS 2016
Value
5
1.07022
Dire Dawa
Hareri
Addis Ababa
Gambela
Somali
Sidama
Oromia
SNNPR
0 80 160 320 480
Kilometers

Percent distribution of currently married women age 15-49 by contraceptive method currently used, according to background characteristics, Ethiopia DHS 2016 and Neonatal, postneonatal, infant, child, and under-5 mortality rates for the 10-year period preceding the survey, according to background characteristics, **Ethiopia DHS 2016**



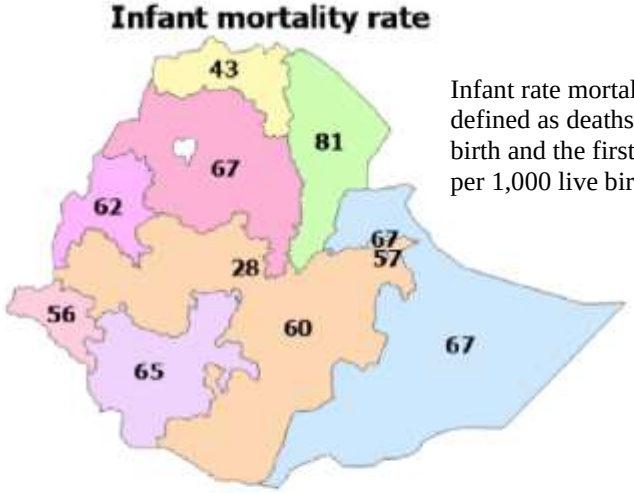
Neonatal mortality is defined as deaths in the first month of life per 1,000 live births.





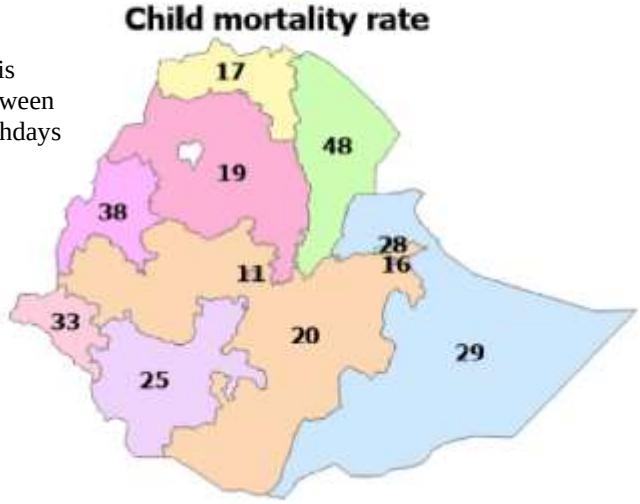
Neonatal mortality is defined as deaths in the second month to the first birthday per 1,000 live births (also computed as the difference between infant and neonatal mortality)

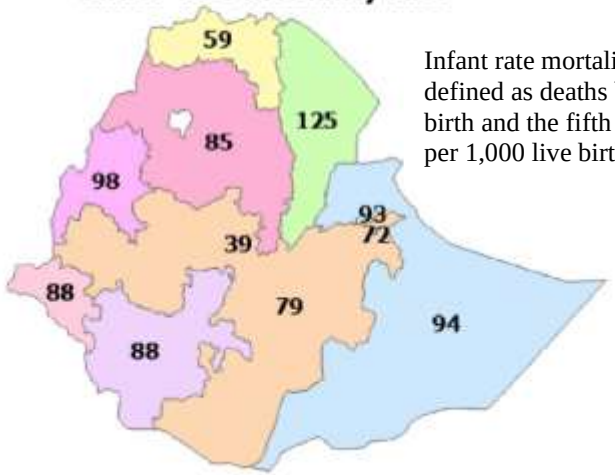
Percent distribution of currently married women age 15-49 by contraceptive method currently used, according to background characteristics, Ethiopia DHS 2016 and Neonatal, postneonatal, infant, child, and under-5 mortality rates for the 10-year period preceding the survey, according to background characteristics, **Ethiopia DHS 2016**



Infant rate mortality is defined as deaths between birth and the first birthday per 1,000 live births.

Infant rate mortality is defined as deaths between the first and fifth birthdays per 1,000 live births.





Infant rate mortality is defined as deaths between birth and the fifth birthday per 1,000 live births.

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