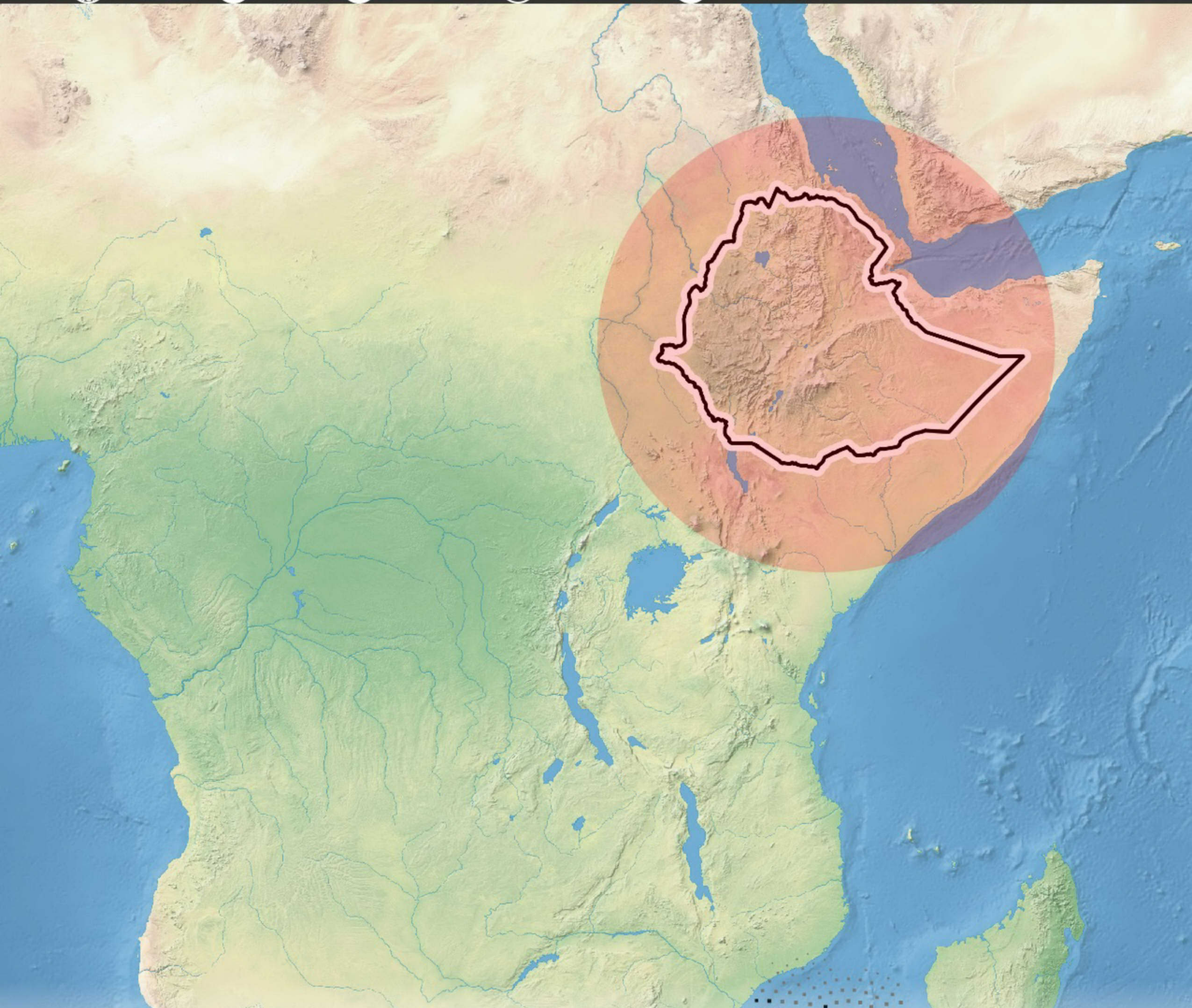
DISASTER RISK PROFILE

Ethiopia

Drought Flood Landslide Earthquake Volcano



Africa Disaster Risk Financing Initiative

Building Disaster Resilience in Sub-Saharan Africa

WORLD BANK GROUP

GFDRR
Global Facility for Disaster Reduction and Recovery

An initiative of the African, Caribbean and Pacific Group of States funded by the European Union

The International Bank for Reconstruction and Development
The World Bank Group
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Washington, D.C. 20433, USA
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INTRODUCTION

Overview

The Africa Disaster Risk Financing (ADRF) Initiative is one of five Result Areas of the European Union (EU) - Africa, Caribbean and Pacific (ACP) cooperation program *Building Disaster Resilience in Sub-Saharan Africa*, which is implemented by several partners, including the African Development Bank (AfDB), African Union Commission (AUC), the United Nations International Strategy for Disaster Reduction (UNISDR) and the World Bank (WB)-managed Global Facility for Disaster Reduction and Recovery (GFDRR). The Program's overall objective is to strengthen the resilience of Sub-Saharan African regions, countries and communities to the impacts of disasters, including the potential impact of climate change, to reduce poverty and promote sustainable development.

The ADRF Initiative, launched in 2015 and implemented by GFDRR and the World Bank, supports the development of risk financing strategies at regional, national and local levels to help African countries make informed decisions to improve post-disaster financial response capacity to mitigate the socio-economic, fiscal and financial impacts of disasters. One of the operational components to achieve this objective is to create an enabling data environment for risk financing. This aims to build the understanding and awareness of disaster and climate risks in Sub-Saharan Africa, providing a fundamental input to developing disaster risk financing strategy, approaches, and tools for financing risks. One of the activities is to develop national-level multiple-peril country risk profiles using globally available and readily accessible local datasets, in combination with scientifically proven methodologies. These are used to catalyze dialogue with government counterparts in the region on the primary disaster risks they face to formulate Disaster Risk Management strategies, such as financial protection and risk reduction investment programs. Furthermore, the risk profiles provide datasets that are a critical input for developing risk financing and insurance strategies.

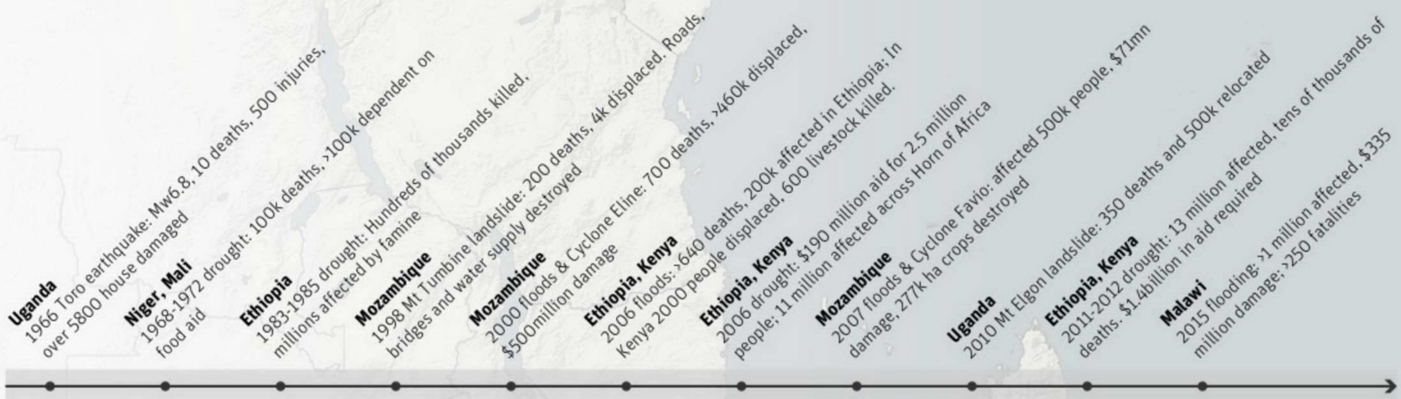
National Risk Profiles

To create an enabling environment for dialogue on risk financing strategies and to further the understanding of disaster risk, national risk profiles have been developed for **eight countries** in the region. The risk profiles provide **visual information and data on the hazards, exposure, and risk for multiple hazards** in each country. The profiles provide an overview of which hazards, sectors and regions are most at risk of disasters, and contribute most to the national level of risk.

Specifically, the national risk profiles provide the estimated impact of disasters on population, building stock, transport networks, critical facilities, and agriculture at the national and sub-national levels. These profiles can guide initial strategic dialogue on financial protection and / or risk reduction investment opportunities to manage disaster risk, as well as help identify priorities for more detailed risk assessments if specific interventions are to be made.

Countries and Hazards

	Drought	Flood	Landslide	Earthquake	Volcano	Cyclone
Cabo Verde	●	●	●	●	●	●
Ethiopia	●	●	●	●	●	
Kenya	●	●	●	●	●	
Malawi	●	●	●	●		
Mali	●	●	●			
Mozambique	●	●	●	●		●
Niger	●	●	●			
Uganda	●	●	●	●	●	



METHODOLOGY AND LIMITATIONS

Use

These risk profiles provide a preliminary view of disaster risk at the national level, and distribution of risk across regions of the country and types of assets. They enable the identification and prioritization of risk drivers, to guide risk management activities and identify the need for further, more detailed risk assessment.

Due to limitations in the content and resolution of the publicly available global and national level exposure and hazard data used in their development, these profiles do not provide sufficient detail for taking final decisions on disaster management investments and policies, or for planning subnational and local scale mitigation projects, such as construction of flood defenses. Such decisions should be informed by a local, and possibly sector-specific disaster risk assessment, which estimates risk at a higher resolution with more locally-specific exposure, hazard, and vulnerability input data.

These risk profiles present a substantial part of the analysis results. However, it has not been possible to present all results in these documents. Full results for all asset types are available from GFDRR Innovation Lab.

Risk

Risk calculations require input data describing the hazard, assets ('exposure'), and vulnerability of those assets.

Disaster risk to structural and infrastructure assets is quantified here by estimating the cost to repair and/or replace assets damaged or destroyed in a disaster, i.e. due to ground shaking, flood depth or wind speed, over various time horizons. Assets analyzed are private and government-owned building stock, critical facilities (education and health), and transport networks (road, rail, and bridges).

Risk to population is quantified by assessing the number of people that are expected to be affected by the hazard.

For volcanoes, an indicative measure of volcano risk is given by estimating population and value of assets exposed to the volcanic hazards (no estimation of impact is made).

Losses additional to those incurred due to physical damage are not included in this analysis (e.g., business interruption due to disrupted infrastructure or supply chains).

The cost or number affected is estimated for most hazards at three time periods: a decade (this refers to the 1 in 10 year return period, or 10% chance of a loss being exceeded in any given year); a person's lifetime (1 in 50, or 2% in any year), or for an extreme event (1 in 250, or 0.4% in any year).

Hazard and Vulnerability Data

Drought hazard analysis comprises agricultural (soil moisture deficit) and hydrological (river flow) drought. Drought duration and deficit volume per year are determined by event-based modeling to estimate population affected by water scarcity. Monetary loss reflects the loss in yield and long term average price for each modelled per crop.

River flood risk (urban/surface flooding is excluded) is estimated at 1km resolution using global meteorological data, global hydrological and flood-routing models. Loss estimates are generated by simulating rainfall statistics for 10,000 years based on 40 years of previous rainfall data. Damage functions for four types of buildings, and for roads/railways, are used to estimate loss as a function of flood depth. Population are considered 'affected' if flooding of any depth occurs in the same 1km area. Agriculture loss is estimated by assuming that catastrophic flooding will result in a loss of the annual crop yield.

Earthquake hazard describes the distribution of ground shaking intensity (i.e., peak ground acceleration), based on the locations of known seismic faults and location/size of previous earthquakes. Losses are estimated using fragility and vulnerability models that translate ground shaking into the expected level of (a) damage to different types of structure, and (b) displacement of roads and rails. Based on damage to buildings, a casualty model has been used to estimate the risk of fatalities as well as the population affected by ground shaking. This study includes losses due to damage from earthquake ground shaking only. Secondary hazards (liquefaction and fire following an earthquake) are not accounted for. Landslide hazard is considered under the separate landslide section, where ground shaking is considered as a potential trigger of landslides.

Landslide susceptibility has been defined across each country using an assessment of factors that increase potential for landslides (including slope, vegetation and soil types) combined with landslide trigger events (rainfall and seismic shaking) to create landslide hazard maps. Long-term average annual cost to structures and transport networks has been estimated using vulnerability of different asset types to landslides, based on extensive literature review, empirical data, and expert judgement.

METHODOLOGY AND LIMITATIONS

Average annual population affected, and fatalities, are estimated.

Volcanic eruption scenarios at a small number of key volcanoes are used to estimate the population, and replacement cost of structures and infrastructure exposed to ashfall hazard (i.e. are located in an area that could receive ash in an eruption) and topographic analysis is used to determine the assets and population exposed to flow hazards. Full quantification of risk at all volcanoes is not possible due to limited information on potential frequency and eruption style at many volcanoes in Sub-Saharan Africa.

Cyclone and storm surge hazards are assessed using a record of historical cyclone tracks and wind field modelling, to determine maximum wind speeds on land and accompanying water levels along the coast. Vulnerability of structures to wind and surge is estimated based on previously observed damage sustained at different wind speeds and literature on flood depth impact of different types of structures.

Asset Database

Open and freely available national, regional, and global data sets are used to develop, for the first time, a database of population and multiple built asset types for risk analysis. This is used to inform this risk assessment, in a region where there is significant variability in the availability and content of inventories describing building stock and infrastructure.

Population density is described using WorldPop data. Building stock is described using six development types: rural, residential, high-density residential, informal, urban, and industrial, based on land use data and satellite imagery. In each cell of a 0.5 km resolution grid, the number of buildings and total floor area of each development type is given. The number of buildings is further disaggregated into different construction types to account for the impact different levels of structural vulnerability in the risk analysis.

Critical facilities include education and health facilities. Where possible, the assets have been analyzed using accurate geolocation given in an available building inventory. However, many assets had no geolocation given and were distributed using building density as a proxy for their location; the proportion of geolocated assets varies by country. Education facilities (classified as primary school, secondary school, or universities) and health facilities (hospital or clinics) have been assigned an estimated construction type based on interviews with structural engineers in each country and used to approximate construction cost per square meter.

Transportation data include roads, railways, and bridges, where present. Road surface type (paved, unpaved) is also included where available. Agriculture exposure is described by crop type and subnational distribution, average annual yield, and crop price for risk calculations.

Replacement costs for building stock and critical facilities are calculated using construction cost per square meter for each building or facility type, and cost per kilometer for roads based on road type and for railway lines, based on terrain. Estimates of replacement cost were developed through interviews with local engineering and construction professionals (numbers and sources varied in each country). These were validated and adjusted where necessary using several sources, including site surveys and international literature on construction. Replacement costs used are representative of typical building infrastructure and replacement costs for the entire country. Subnational variations in costs and building distributions (due to cost of materials and labor) will vary and are not accounted for.

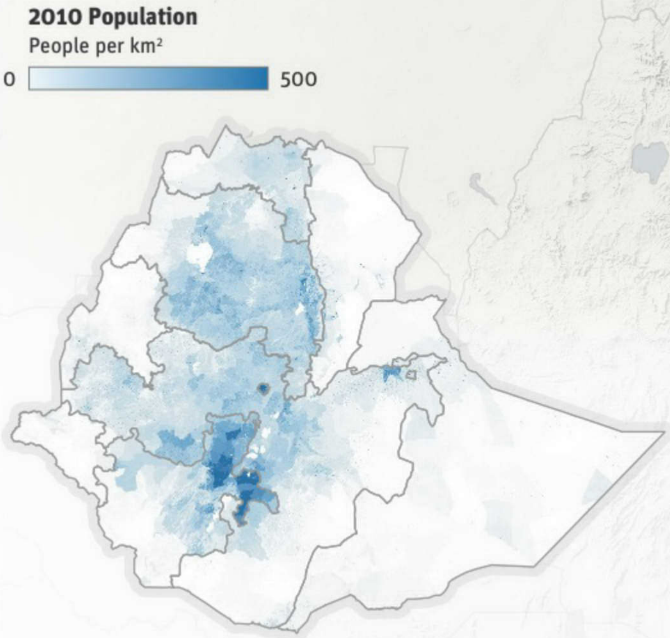
RISK SUMMARY
ETHIOPIA

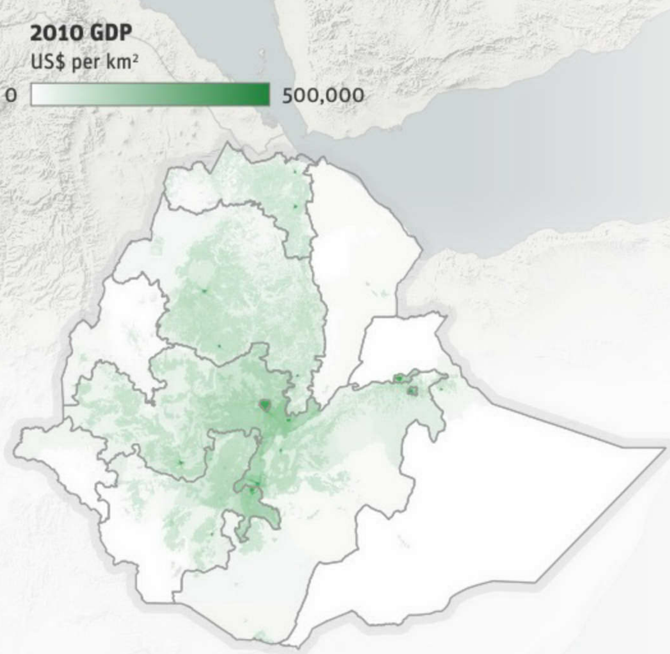
GDP $64.5 billion* **Population 100 million*** ***2015 estimates**

Ethiopia's population stood at 100 million in 2015 but is growing at a rate of 3% each year. By Approximately 80% of the population lives in rural areas[1], with the urban population concentrated in the capital city, Addis Ababa (population 3 million[2]). The country is one of the least developed countries in the world (Ethiopia's Human Development Index is 0.442[3]) and 30% of the population lives below the poverty line[4].

Ethiopia's agricultural sector accounts for 41% of GDP and 85% of overall employment[5]. The industrial sector, largely based on processing agricultural products, accounts for a further 16% of GDP, with the service sector contributing the remaining 43%[6].

Approximately 90% of cereal crops are rain-fed, with harvests vulnerable to rainfall variability. Seven million people are at risk of food insecurity due to drought and floods, and severe drought can shrink farm production by up to 90%[7].





Urban land-use and structures can differ greatly over short distances in Addis Ababa, Ethiopia's capital city.

RISK SUMMARY

ETHIOPIA

All $ amounts are in USD

Drought Flood Landslide Earthquake Volcano

Droughts and floods pose the most significant and recurring risk to Ethiopia, with the highest impacts occurring in the northern and eastern regions.

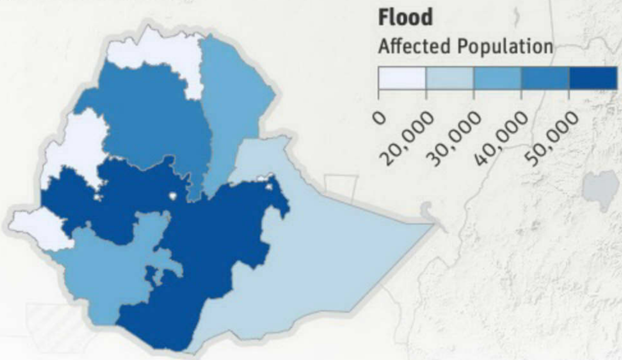
Droughts are prevalent in Ethiopia due to the arid and semi-arid climate in lowland regions and uneven distribution of water resources. On average, 1.5 million people are affected by drought every year, but this number can be substantially higher in dry years.

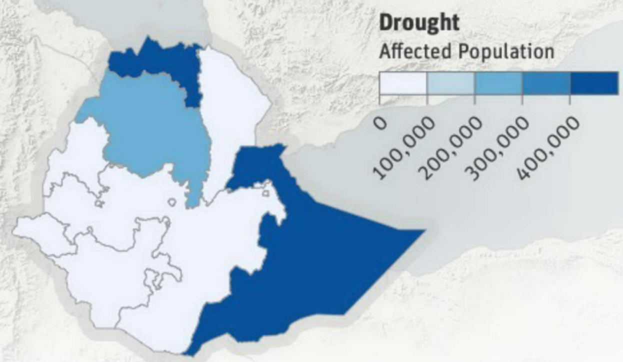
Flooding poses a threat to lowland, highland, and urban areas, with 250,000 people affected by floods each year, on average. A much smaller number of people are at risk from earthquakes, landslides and volcanoes.

Future changes in Ethiopia's population and economy, coupled with changes in climate-related hazards, are expected to increase the impacts of droughts and floods.

Modeled Impact on Population*

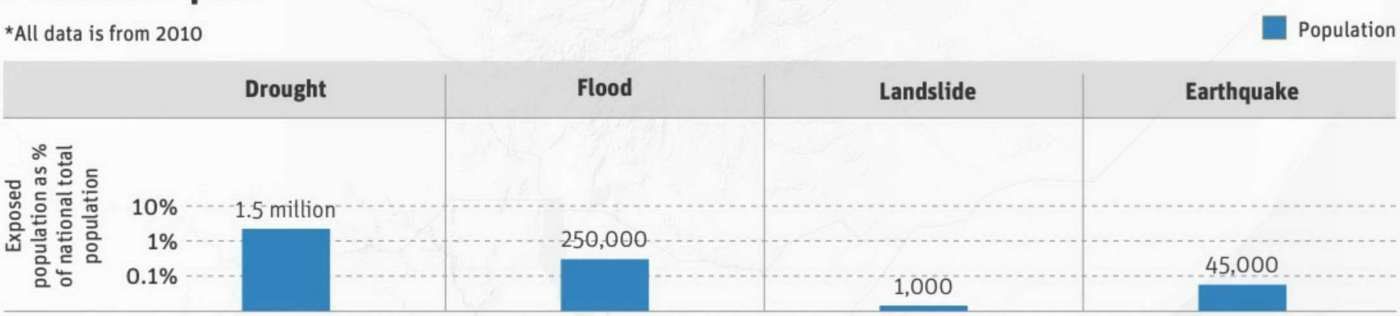
*All data is from 2010





Modeled Impact*

*All data is from 2010



Hazard Summary Table

HAZARD	IMPACT
	On average, around 1.5 million people are affected by water scarcity each year, mainly in northern and eastern regions of Ethiopia.
	On average, 250,000 people and around 200 education and healthcare facilities nationally are affected by river flooding.
	Landslide is a very localized hazard, but could cause up to $3 million of damage to building stock and put over 1,000 people at risk per year, on average.
	Damaging earthquakes are infrequent, but it is estimated that around 300,000 people could experience at least light ground shaking at least once every 50 years.
	Ethiopia has many volcanoes in the heavily populated Rift Valley; around 0.5 million people are potentially exposed to volcanic ashfall around Corbetti volcano alone.

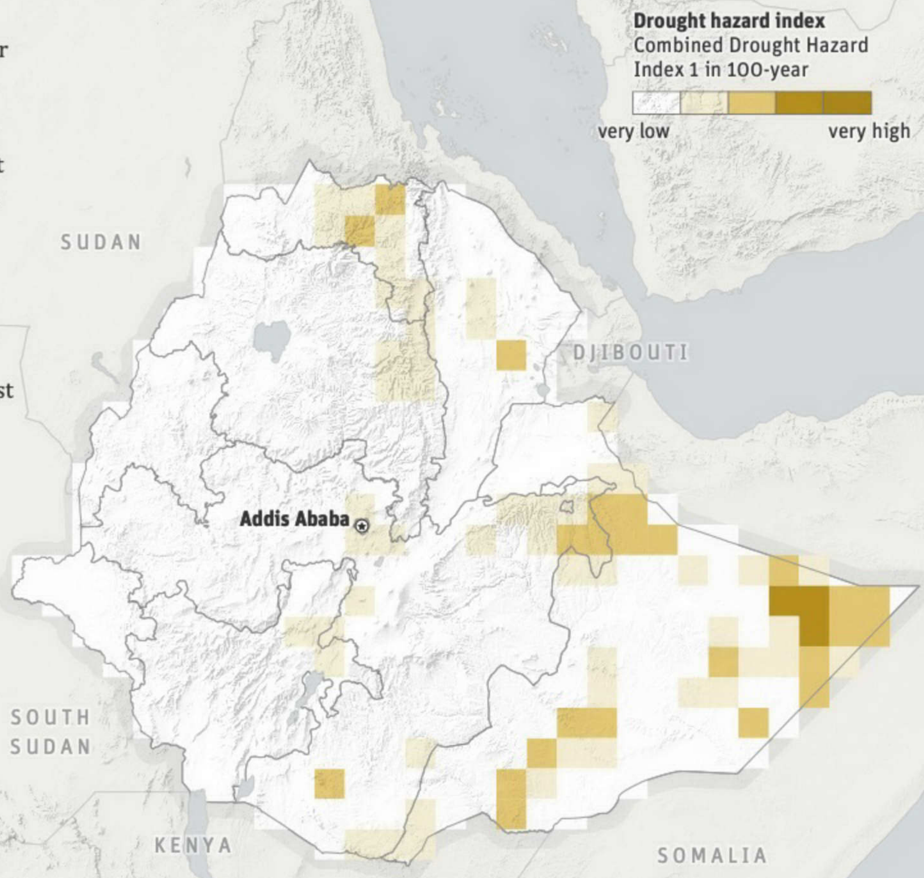
DROUGHT

ETHIOPIA

Droughts are sustained periods of below-normal water availability. Droughts occur due to natural atmospheric variability (e.g. El Niño conditions) and desertification caused by land degradation. Increasing rainfall variability and extremes are increasing drought hazards, already common in the Horn of Africa.

This risk profile assesses **hydrological drought** impacts on population and the effects of agricultural drought on crop income. Hydrological drought is characterized by estimating the potential deficit of water availability in rivers and reservoirs. The greatest deficits occur in the regions of Tigray and Afar in the north, and Somali, which accounts for most of eastern Ethiopia (see main map). Agricultural drought is assessed by estimating the potential for lack of rainfall and its impact on rainfed agriculture.Agricultural income loss refers to the value of crops lost due to agricultural drought.

The barsbelow indicate the number of people located in areas affected by a lack of water availability and the agricultural income loss based on the modeling results.Based on historical records (e.g. Desinventar), the modeling estimates appear to be realistic, but preliminary estimates given the limited validation data. Further detailed modeling and data analysis is necessary to further finetune these numbers.



Key Facts

- Droughts are a recurrent hazard in Ethiopia and the Horn of Africa region. They have contributed to severe food crises including those 1983-1985, 2002-2003, 2011-2012 and in 2015-2018, which was in part due to the 2015/2016 El Niño induced drought.
- The 2011 drought left more than 4.5 million people in need of food assistance, and in 2017 5.6 million people required emergency food assistance.
- Livestock are an important component of the agricultural economy of Ethiopia, and livestock are adversely effected during droughts. However, this analysis does not account for impacts on livestock.

Modeled Impact

Population

Annual average — 1.5 million people affected

1-in-10 year — 5 million people affected

Agricultural Income Loss

AAL — $40 million

1-in-10 year — $25 million

1-in-50 year — $250 million

1-in-200 year — $3.5 billion

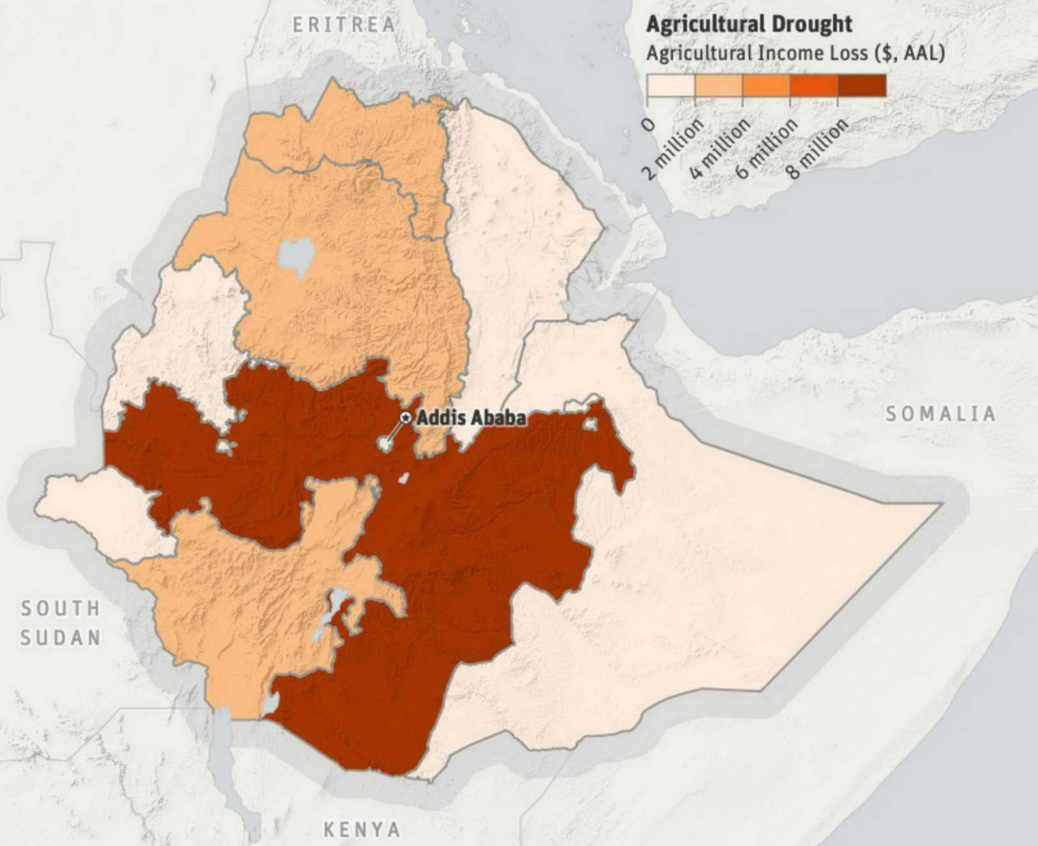
AAL = Average Annual Loss; 1-in-10 year return period equates to a 10% annual probability; 1-in-50 to 2% annual probability; and 1-in-200 to 0.4% annual probability.

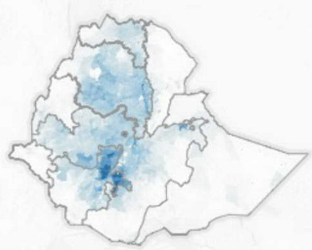
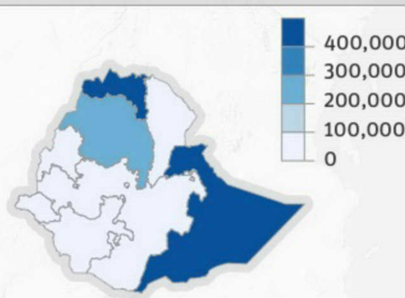
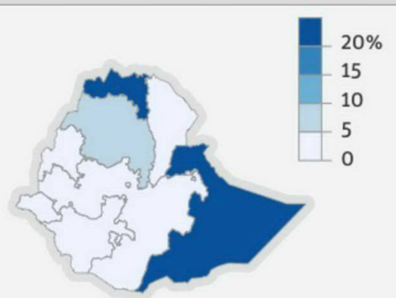
The distribution of drought risk is determined by the occurrence of drought, the location where assets intersect with this hazard, and the vulnerability of those assets. For more detail, see the Methodology section.

ETHIOPIA

Hydrological drought risk is greatest in the regions of Somali, Tigray and Amhara. In Somali 1.6 million people live in areas expected to suffer water scarcity each year, with a further 1.3 million people in Amhara and Tigray.

On average, once every 10 years a loss of at least $25 million in agricultural income will occur in Ethiopia. Oromia, Amhara and SNNPR are the regions that provide the greatest contribution to national crop losses.



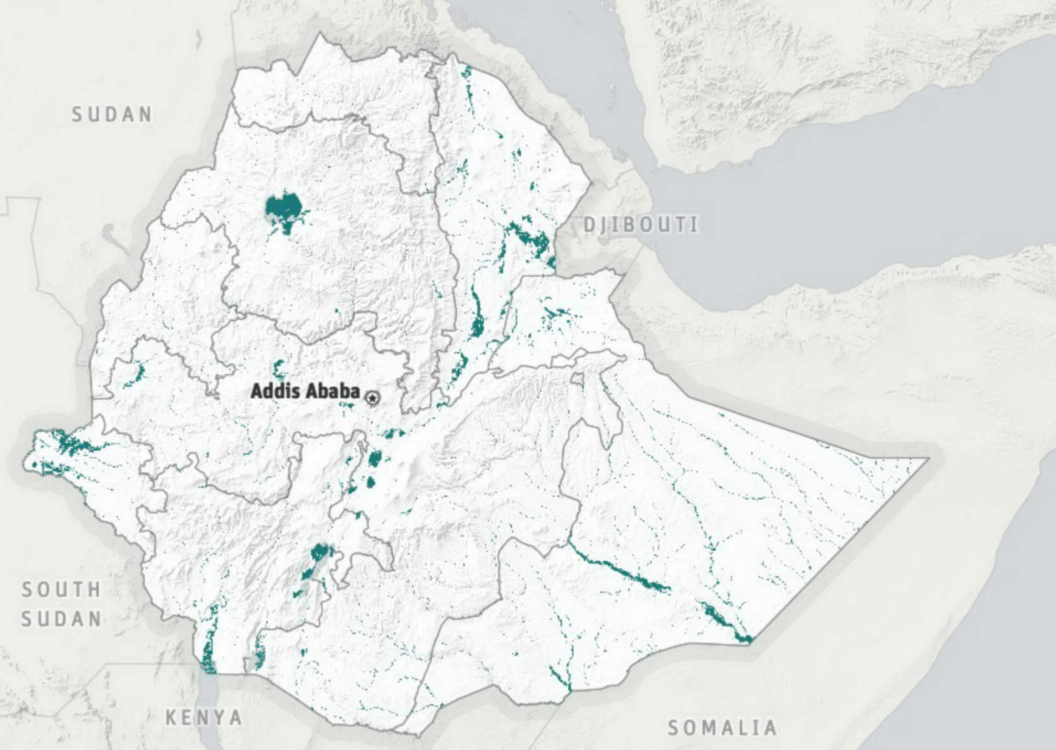
	Asset Distribution	Average annual affected (water scarcity) Per region	Average Annual Loss Contribution to national average loss
Population Pop. exposed to water scarcity			

FLOOD
ETHIOPIA

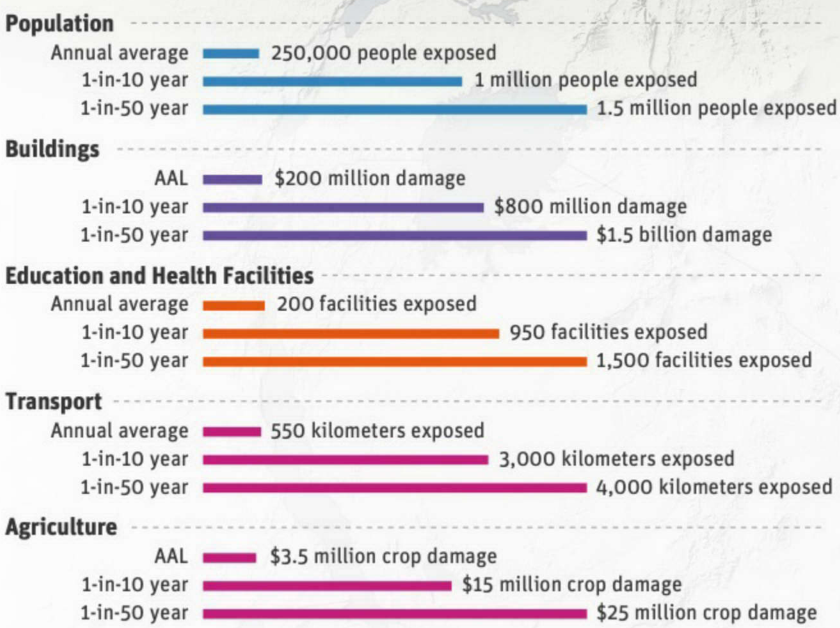
Large-scale river floods occur most commonly in the lowland areas of Ethiopia, with flash floods occurring in the highlands and particularly in the Awash River basin in the Rift Valley. Urban areas, particularly Addis Ababa experience annual flooding along streams descending from nearby hills. The national scale of these profiles means the focus is on river flooding, and surface flooding (including urban flood) is not included in the risk estimates.

Ethiopia has 12 river basins of which the Blue Nile, draining Lake Tana and the western highlands, flowing through Oromia and Amhara, is the largest and accounts for over 40% of the annual total runoff in Ethiopia. Two other basins of similar size cover the eastern parts of Oromia and southern Somali but they account for much less runoff (7% between them). Here, the flood potential of the Shebelle, Gestro and Ganale Rivers can be seen in the main map. Four river basins drain the Rift Valley, and the system includes a series of lakes. The Awash River drain the areas around Addis Ababa, flowing north to Djibouti.

In Ethiopia, the greatest flood potential occurs during and following the most intense and sustained rainfalls in the June, July and August rainy season.



Modeled Impact



AAL = Average Annual Loss; 1-in-10 year return period equates to a 10% annual probability; and 1-in-50 to 2% annual probability.

Key Facts

- Flooding in 2006 killed nearly 1000 people, including over 360 people in South Omo (SNNPR). In West Shewa (Oromia) more than 16,000 people were displaced. In Dire Dawa, 10,000 people (of a population of less than 300,000) were displaced. Nationally, half a million people were affected.
- According to the Desinventar database of disaster impacts, there have been over 3,000 deaths, 1.3 million displaced and 10 million affected by flooding in Ethiopia since 1991. In that time, over half a million Hectares of crops have been damaged and 280,000 cattle lost.

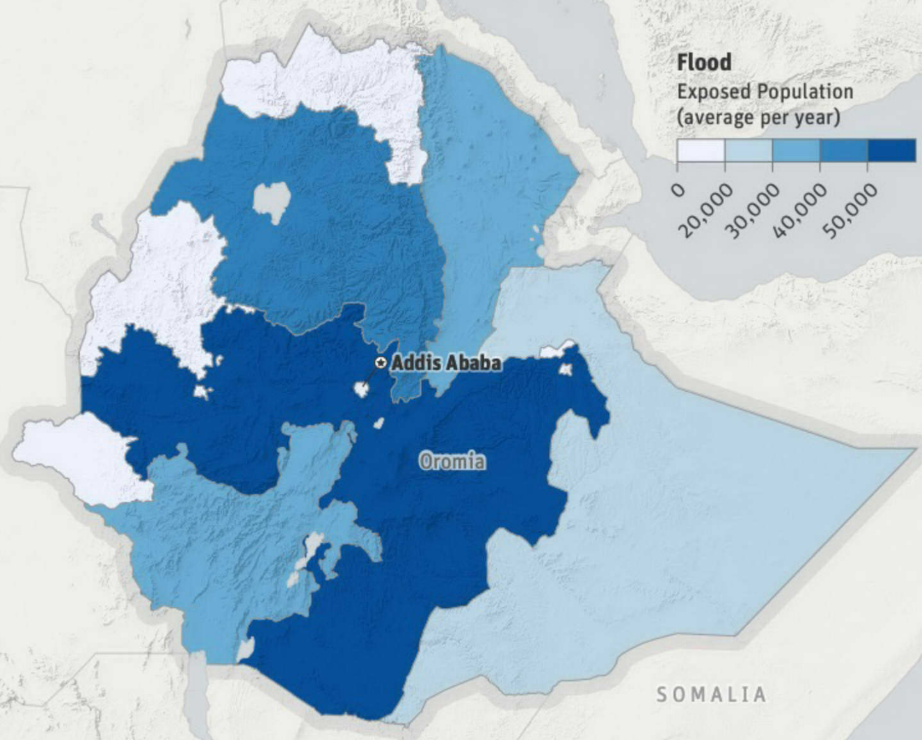
i The distribution of flood risk is determined by the occurrence of flood events, the location where assets intersect with these hazards, and the vulnerability of those assets. For more detail, see the Methodology section.

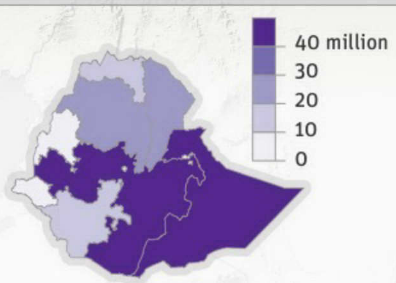
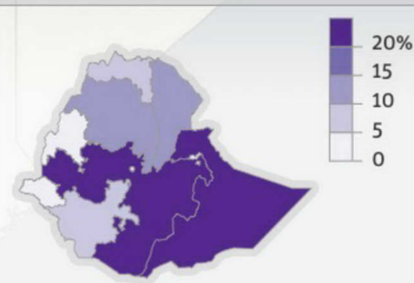
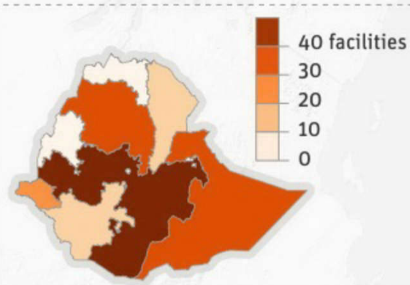
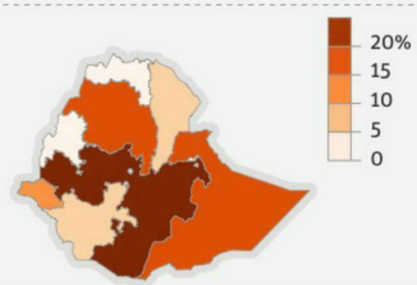
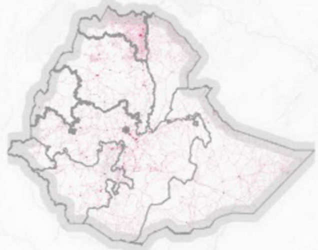
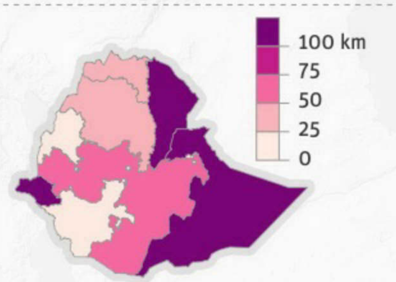
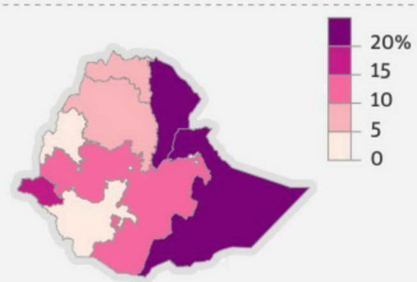
FLOOD

ETHIOPIA

There is high flood hazard in many parts of Ethiopia. Damage of over $25 million to crops and $1.5 billion of damage to the building stock may occur in at least one flood in a person's lifetime based on the modeling results. It is expected that on average each year, over 250,000 people will be affected by flooding and 200 education and health facilities are exposed to floods.

The estimated number of affected people in Ethiopia on a yearly basis appears to be realistic compared to historical records (e.g. Desinventar). The estimated building damage seems relatively high compared to (very limited) historical records. Uncertainties in the modeling of loss estimates, but also under-recording of the impact of historical events may explain this. Further analysis of flood risk damage to assets in Ethiopia is required.



	Asset Distribution	Average Annual Loss Per Province	Average Annual Loss per Province Relative to national total
Buildings $ Damage			
Education and Health Facilities Facilities exposed			
Transport Km exposed			

LANDSLIDE

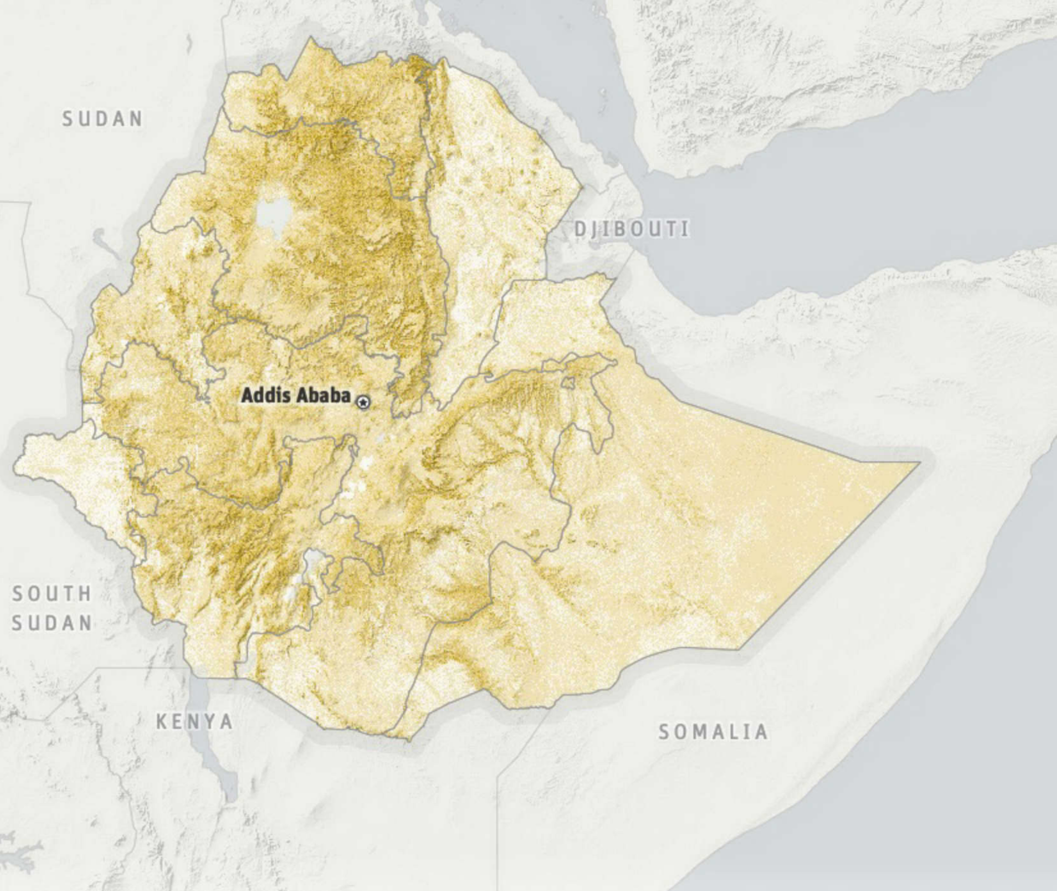
ETHIOPIA

The highest landslide hazard in Ethiopia exists in the central areas, stretching along the eastern boundary of the Tigray region into the Amhara region and down the western flank of the Rift Valley. Approximately 1% of of the total land area of Ethiopia is classified as very high landslide hazard, and 18-30% of the land is classified as medium hazard or higher. The lowlands of Gambela, Afar, and Somali regions have the lowest landslide hazard.

The highlands are susceptible to various types and sizes of landslide due to their variable topography and geology. The highlands cover about 44% of the country, and are home to over 60% of the population[8].

Landslides in Ethiopia are primarily triggered by heavy rainfall in the later parts of the rainy season (around late August) saturating soils, but they can also be caused by earthquake ground shaking. Human-induced landslides are becoming more common as agriculture, road cutting, urbanization, and deforestation destabilizes slopes.

Damage due to landslide has been estimated across the whole country using a novel method that enables estimation of annual average risk using landslide susceptibility factors combined with earthquake and rainfall triggers, and the potential impact of different size landslides on the population, buildings, and transport networks.



Modeled Impact

Population

Annual average — 1,000 people affected

Buildings

AAL — US$3 million damage

Education

AAL — $1.5 million damage

Health

AAL — $350,000 damage

Transport

AAL — $300,000 damage

Key Facts

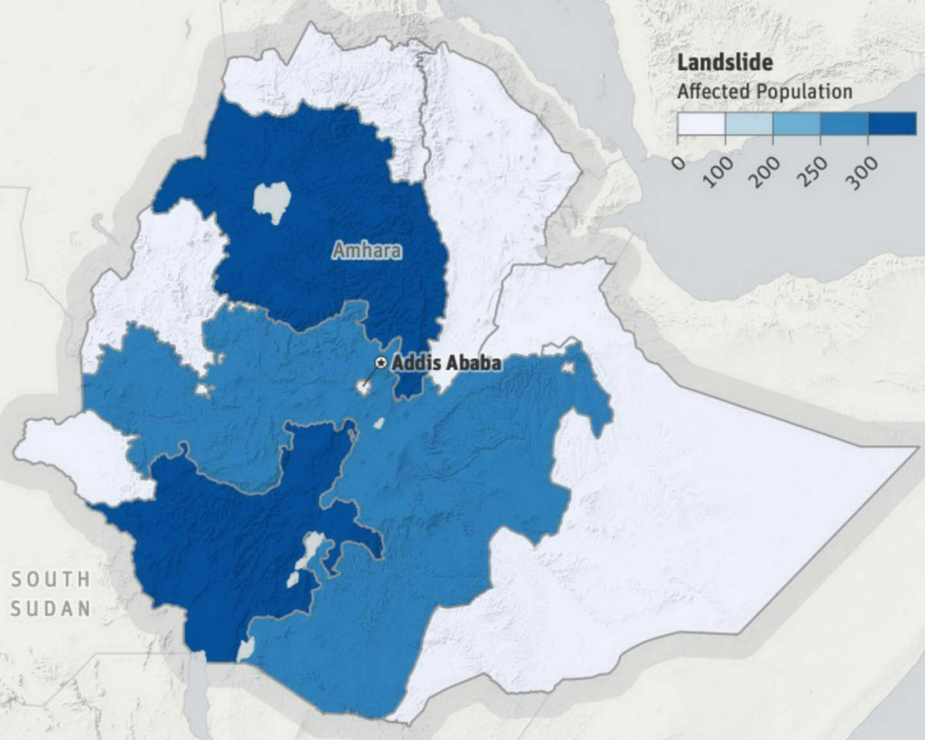
- According to the Desinventar database of historical disaster impacts, there have been 260 deaths and 1500 houses destroyed by landslides in Ethiopia, since 1992. Over 130,000 people have been relocated. The majority of deaths have occurred in Amhara and SNNPR

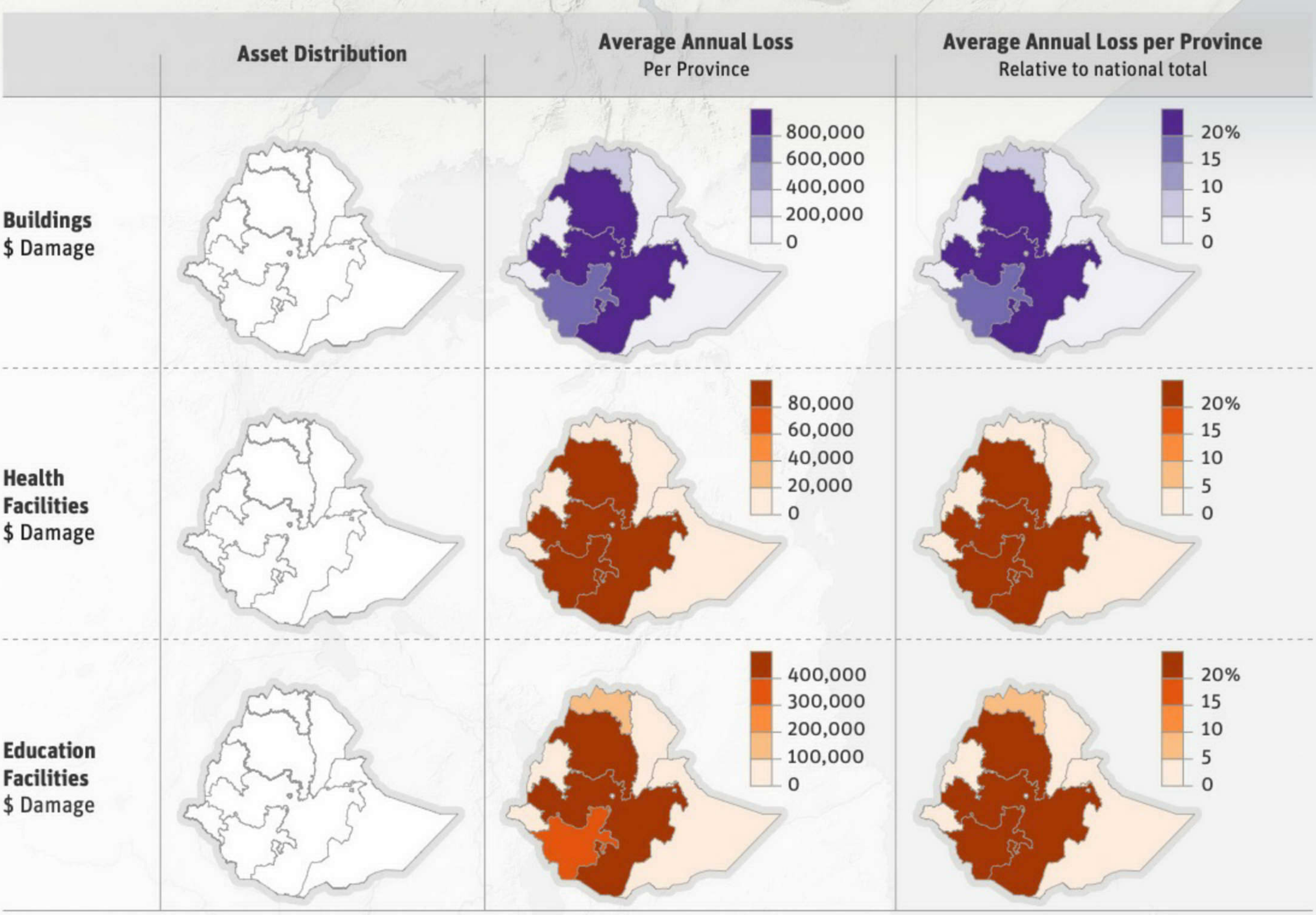
i Landslide risk is a function of population and assets being located in areas susceptible to landslides (based on slope angle, vegetation cover and soil type), and the potential for earthquakes and rainfall to trigger landslides there. For more detail, see the Methodology section.

ETHIOPIA

On average, each year 1000 people are at risk of being affected by landslides, with the modelling suggesting a long term average of 100 fatalities per year nationally.

The annual average damage to building stock is expected to be $3 million, and education facilities could sustain $1.6 million of damage annually. In terms of impact on each sector, the most at-risk regions of Ethiopia are Tigray, Amhara, and SNNPR (see main map). These regions, in addition to Oromia, contribute the majority of losses to the national landslide risk profile.

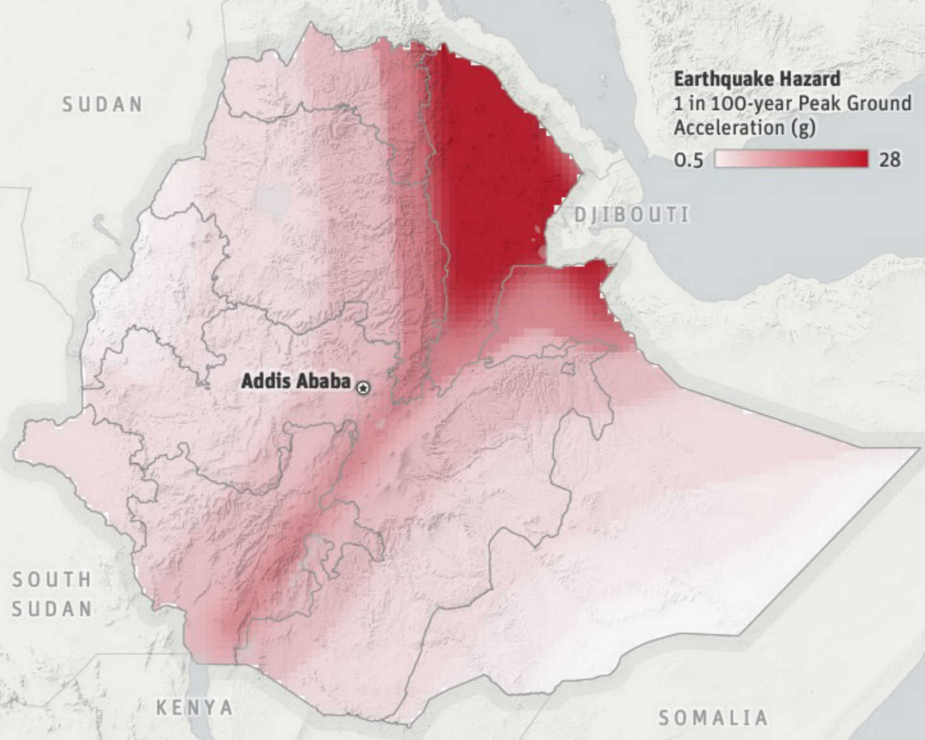




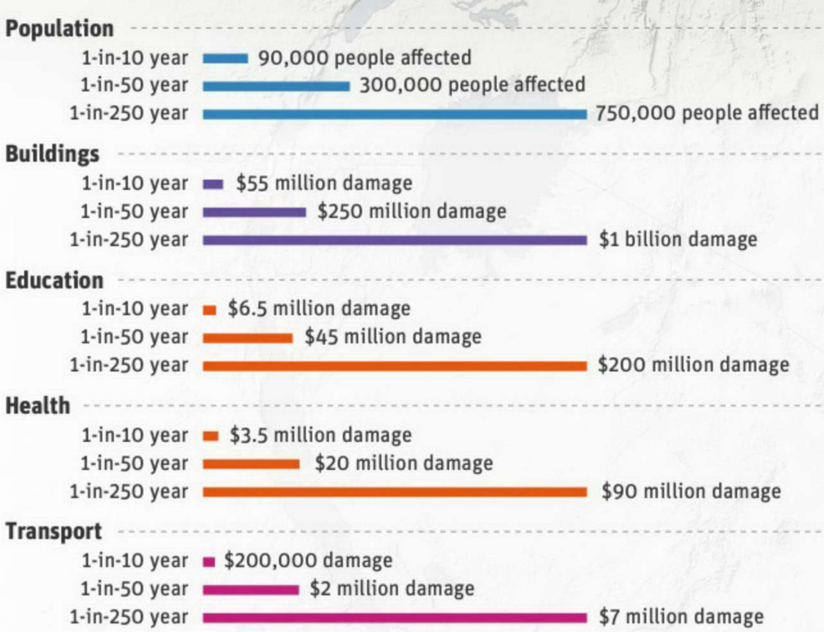
EARTHQUAKE
ETHIOPIA

Earthquakes pose the threat of building damage and collapse, particularly where seismic-resistant design of buildings is not generally applied, as in Ethiopia. They can also cause damage and disruption to transport networks and essential services due to ground motion displacing roads, rails, bridges and other essential services. Earthquakes can cause sufficient ground shaking to trigger rockfalls and landslides in areas susceptible to such hazards (i.e. steep terrain).

Ethiopia lies within a tectonically active region. The Ethiopian Rift Valley runs northeast to southwest across the country from the Afar Triangle, where three tectonic plates meet; the highest earthquake hazard in Ethiopia occurs in Afar (see main map). Several major cities and towns, including the capital city Addis Ababa, are situated along the Rift Valley in areas with moderate earthquake hazard. Earthquakes could cause moderate ground shaking in Addis Ababa and along the Rift Valley, and strong shaking in Afar, at least once in a person's lifetime. Buildings of poor and moderate quality construction could sustain damage, but extent of damage would be strongly dependent on local seismic and construction factors. Away from the Rift Valley, the hazard is much lower.



Modeled Impact



AAL = Average Annual Loss; 1-in-10 year return period equates to a 10% annual probability; 1-in-50 to 2% annual probability; and 1-in-250 to 0.4% annual probability.

Key Facts

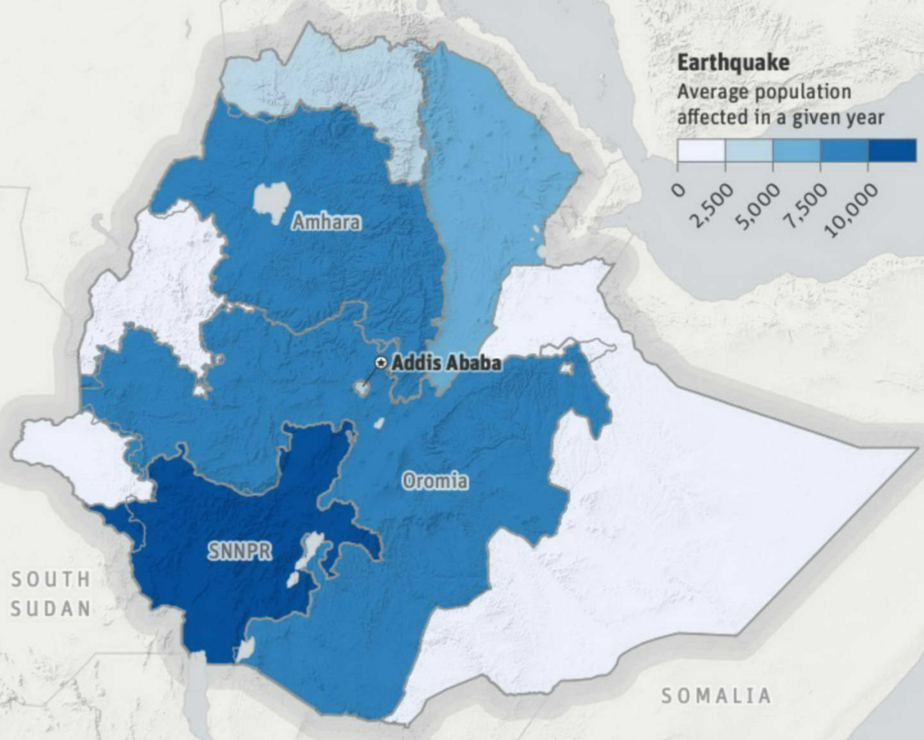
- Most known earthquakes in Ethiopia have been shallow (<25km deep). These can cause significant damage even with moderate magnitudes of 5-6, especially if they occur beneath or close to major urban areas.
- Damaging earthquakes of Magnitude 5-6 (MMI 8-9) have occurred in Ethiopia. In 1969, strong earthquakes destroyed the town of Serdo in central Afar, killing 40 people and injuring 160. In 1961, 30 people were killed in Karakore, Amhara.
- In 1906, a large earthquake estimated to be Magnitude 6.8 occurred <100 km from Addis Ababa. The ground shaking from such an event could cause significant damage in the capital city and nearby areas today.

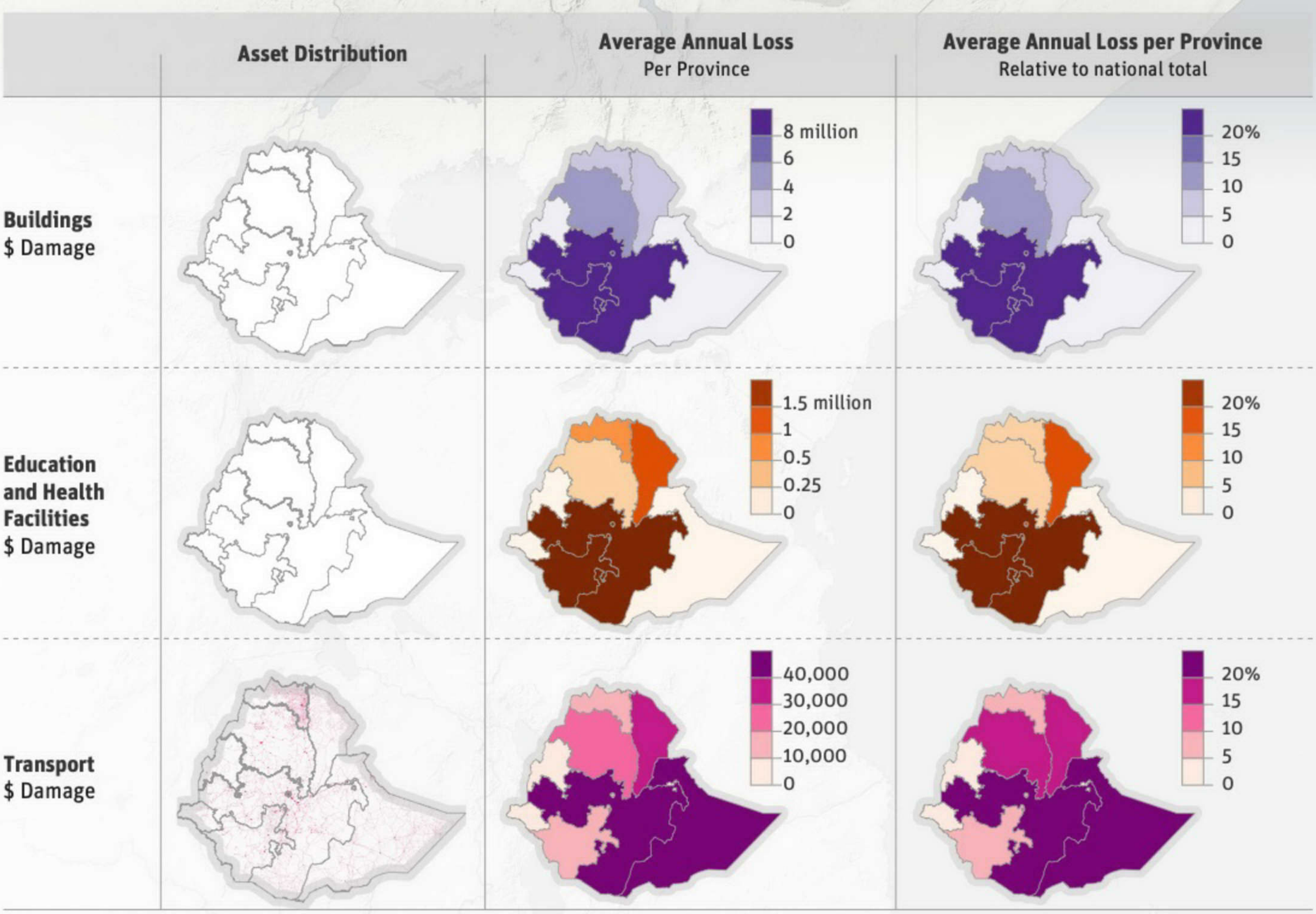
i The distribution of earthquake risk is determined by modeled earthquake hazard events, the location where assets intersect with these hazards, and the vulnerability of those assets. For more detail, see the Methodology section.

EARTHQUAKE
ETHIOPIA

It is possible that, at least once in a person's lifetime, an earthquake could occur that affects 300,000 people with at least light ground shaking (see bars, opposite). In such an earthquake, there is likely to be at least light to moderate building damage in some areas. The cost of this would be approximately $250 million, with potential for $70 million of damage to education and health facilities.

Oromia, Addis Ababa, SNNPR and Amhara regions contribute most to national damage total. Afar has the highest seismic hazard occurring but the sparse population and asset distribution there means it ranks lower than Amhara in contribution to national damage estimates. However, Afar has the highest risk relative to the assets within the region.





VOLCANO
ETHIOPIA

Volcanoes in Ethiopia are situated in two distinct areas: along the Ethiopian Rift Valley, and in the Afar Depression, in Afar region. There are 59 volcanoes in the Rift Valley, of which 25 are active or have erupted in the last 500 years. Many have significant local populations: 25 volcanoes have more than 100,000 people living within a 30 km radius, where they could be affected by multiple volcanic hazards. These include the heaviest ashfalls highly destructive pyroclastic flows during an eruption and lahars (volcanic mud flows) during eruptions, or when heavy rain falls on loose deposits upto years after an eruption.

Pyroclastic flow, lahars, and ashfall are analyzed here. Additional volcanic hazards not included are: lava flow, impact of ballistics (e.g. large boulders thrown by explosive eruptions) close to a vent, ground fissuring, or volcanic gases (which affect people, livestock and crops). The potential eruption style and frequency is not well know for many volcanoes in Ethiopia, so selected volcanoes were analyzed for this risk profile, prioritized by local experts' perception of risk to population: Fentale, Alutu, Corbetti Caldera, plus the volcanic fields of Bishoftu and Butajiri-Silti (see main map).

Key Facts

- In 2011, Nabro volcano near Ethiopia's northern border in Eritrea erupted, depositing ash over several towns in the Afar region.
- Aluto volcano has shown signs of recent activity and along with Fentale and Corbetti have had ashfall and flow hazards modelled. The two volcanic fields have been analyzed for flow hazards only.
- Erte Ale, located in Afar, is considered to be the most active volcano in Ethiopia, having been in an ongoing eruptive state since 1967. However, this volcano produces lava that feeds a permanent lava lake, and is not considered likely to produce other hazards of concern at large distances from the volcano.

Modeled Exposure

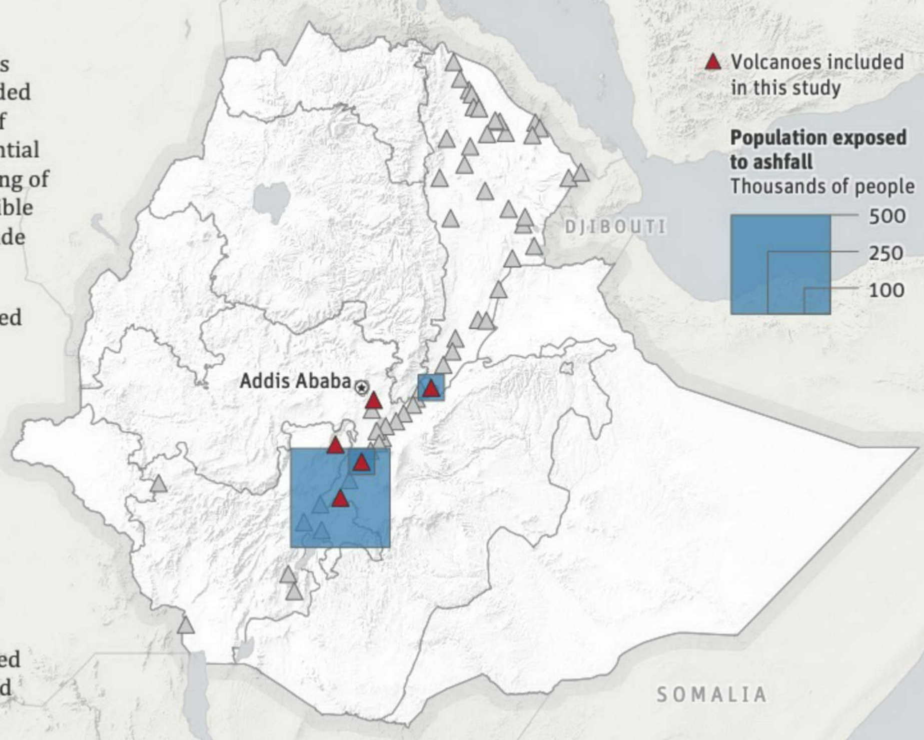
The distribution of volcano exposure is determined by analyzing the intersection of volcanic hazard with location of assets. For more detail, see the Methodology section.

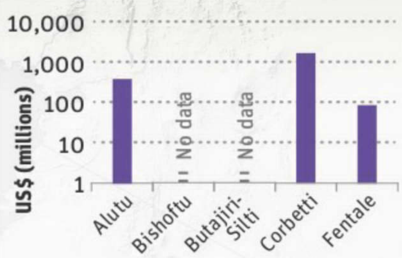
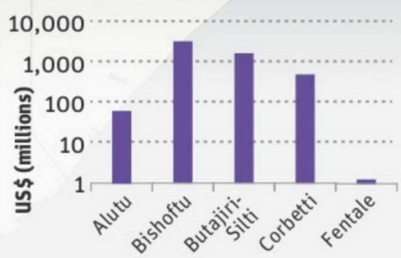
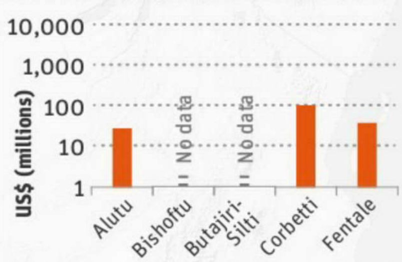
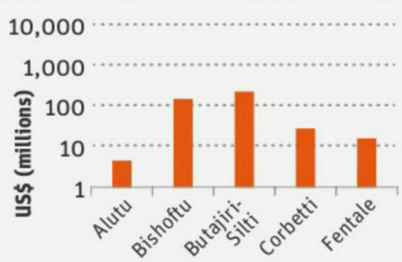
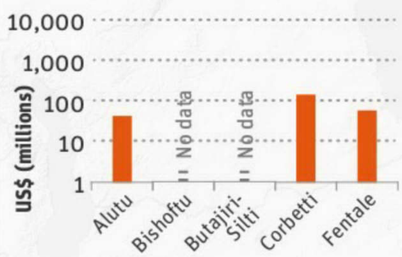
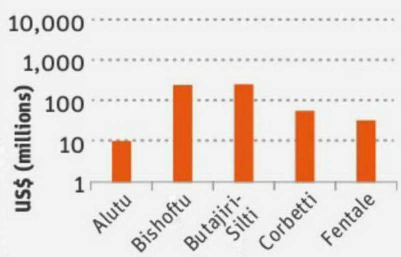
VOLCANO
ETHIOPIA

Exposure to volcanic flows and ashfall hazard is presented for selected volcanoes. This is intended to be indicative of volcanic risk. Due to a lack of information on frequency and severity of potential eruptions in Ethiopia, and limited understanding of vulnerability to volcanic hazards, it is not possible to reliably estimate the likelihood and magnitude of losses.

A significant amount of building stock is exposed to ashfall from the three volcanoes analyzed: $86 million exposed to Fentale, $375 million to Aluto, and $1.6 billion to Corbetti. The population potentially exposed to ashfall is 190,000 (Fentale), 150,000 (Aluto), and 530,000 (Corbetti). Additionally, several hundred education and health facilities, are exposed at each of these volcanoes.

The Butajira and Bishoftu volcanic fields cover large areas so exposure to flow hazards are significant, although in an eruption it is expected that only a small part of the whole volcanic field would be affected by flows.



	Asset Distribution	Ashfall Exposure (Millions US$)	Flow Hazard Exposure (Millions US$)
Buildings $ Exposed Value			
Health Facilities $ Exposed Value			
Education Facilities $ Exposed Value			

GLOSSARY AND NOTES

Glossary

Average annual loss

Average annual loss (AAL) is the estimated impact (in monetary terms or number of people) that a specific hazard is likely to cause, on average, in any given year. It is calculated based on losses (including zero losses) produced by all hazard occurrences over many years.

Exposure

Exposure refers to the location, characteristics, and value of assets such as people, buildings, critical facilities, and transport networks located in an area that may be subject to a hazard event.

Hazard

Hazard refers to the damaging forces produced by a peril, such as ground shaking induced by an earthquake or water inundation associated with flooding.

Risk

Disaster risk is a function of hazard, exposure, and vulnerability. It is quantified in probabilistic terms (e.g., Average Damage Per Year, and return period losses) using the impacts of all events produced by a model.

Vulnerability

Vulnerability is the susceptibility of assets to the forces of a hazard event. For example, the seismic vulnerability of a building depends on a variety of factors, including its structural material, quality of construction, and height.

Notes

[1] Central Intelligence Agency, The World Factbook, 2015, https://www.cia.gov/library/publications/the-worldfactbook/.

[2] Ibid.

[3] United Nations Development Programme, *Human Development Report 2015: Work for Human Development* (New York: United Nations Development Programme, 2015), http://hdr.undp.org/en/data.

[4] Central Intelligence Agency, The World Factbook, 2015, https://www.cia.gov/library/publications/the-worldfactbook/.

[5] Ibid.

[6] Ibid.

[7] Ibid.

[8] K. Woldearegay, "Review of the Occurrences and Influencing Factors of Landslides in the Highlands of Ethiopia: With Implications for Infrastructural Development," *Momona Ethiopian Journal of Science* 5, no. 1 (2013): 3–31, http://www.mu.edu.et/mejs/pdfs/v5n1/4%20MEJS%2000131-%203-31.pdf.

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