Updated Biodiversity, Habitat Baseline Data, and Water Resources Assessment

and

Rapid Cumulative and RegionalEffect Assessment

(By IRIS Consult P.L.C.)

Updating Biodiversity, Habitat Baseline data, and Water Resources Assessment for **Mieso-Dire Dawa Expressway Project**

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Acronyms

CR	Critically Endangered
DD	Data Deficient
EN	Endangered
ESIA	Environmental and Social Impact Assessment
EX	Extinct in the wild
EX	Extinct
IUCN	International Union of Conservation of Nature
KBAs	Key Biodiversity Areas
L/s	Liter per second
LC	Least Concern
m	meter
MCM	Million Cubic Meter
NE	Not Evaluated
NFPA	National Forest Priority Area
NT	Near Threatened
VU	Vulnerable

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Executive Summary

Executive Summary

The Mieso – Dire Dawa Expressway passes on the sides of Mieso, Mulu, Afdem, Bike, Erer, Hurso, Melka Jebdu and Dire Dawa towns. It is part of the Addis – Adama – Awash – Mieso – Dire Dawa – Dewale Highway project to connect Ethiopia to Djibouti. The section of this highway which runs from Mieso – Dire Dawa crosses the *Acacia* shrubland vegetation of Ethiopia. It also crosses two Key Biodiversity Areas (KBAs) of Ethiopia, i.e., the Afdem – Gewane Controlled Hunting Area and the Dengego – Melka Jebdu National Forest Priority Area (NFPA). The Environmental and Social Impact Assessment (ESIA) of this Expressway project was done previously. The main objective of the current study is to update the baseline conditions of the biological (flora, Fauna), physical (natural habitats/protected areas) and water resources (water quality and groundwater) components of the ESIA of the Mieso – Dire Dawa Expressway project.

Plant and animal species were identified in the field and verified in the Laboratory. Interviews with the local communities and experts of Woredas were used to record wildlife diversity of the project area. Bird species determined in the field and verified with published sources.

Information on the IUCN conservation status of all species has been extracted from the global online resource (https://www.iucnredlist.org/species/). The Integrated Biodiversity Assessment Tool was used to extract information on the KBAs of the project area. Plant communities (natural habitats) of the project area were identified based on the dominant species. The current flow of the rivers was calculated by using orange method. The discharge of the rivers ofthe project site was determined based on the type of the riverbed, width and height/depth the revers. Groundwater recharge was analyzed by using WetSpass model.

Plant species diversity and IUCN conservation status

A total of 194 plant species were recorded from the project area. IUCN assessment was not done for all of these species since they are not in an immediate conservation concern. On the other hand, IUCN assessment was done for plant species of conservation concern. As a result,a total of 194 plant species of the project area was assessed and assigned one of the IUCN conservation categories. The table below depicts the proportion of IUCN conservation categories for plant species of the project area and information on these species. The biodiversity baseline check list provides more information on these species (Annex 3).

IUCN Categories	Number
EN	1
NT	1
LC	38
NE	154

Two species of Aloe, *Aloe harlana* and *Aloe pubescens* are endemic to Ethiopia. *A. harlana* is assessed as Endangered (EN) with decreasing population trend. On the other hand, *A. pubescens*

is Near Threatened (NT) with stable population trend. Furthermore, three *Caralluma* species, *Caralluma acurangula, Caralluma priogonium* and *Caralluma speciosa*, were recorded from the project area. These succulent plants are locally rare but were not assessed for IUCN conservation categories. *Klenia dolichocoma*, yellow-flowered species, is locally rare in the project area. This species has been assessed as Least Concern (LC) but it population trend is unknown. It conspecific, *Klenia squarrosa*, pink flowered, is locally common in the project area. Ithas not been assessed for IUCN conservation categories. Another rare species of the project area is *Adenia venenata* and *Kalanchoe lanceolata* which has been recorded only once in the project area. These species were not assessed for the IUCN conservation categories.

Mimulopskummel grows in riverine vegetation and recorded only once but it was assessed as Least Concern (LC) with stable population. Major threats to these species are reduction the extent and degradation of the quality of their natural habitats due to anthropogenic impacts.

Animal species diversity and IUCN conservation status

Mammals

A total of 22 mammal species were recorded from the project area based on interviews with the local communities and natural resources experts of Woredas. In the project area, 5 species of conservation concerns were recorded. These are Cheatah (EN), Leopard & Lion (VU) and Lesser Kudu & Stripped Hyaena (NT). The remaining species are of Least Concern but having different population trend, i.e., decreasing in some and increasing in others.

IUCN categories	Number
EN	1
NT	2
VU	2
LC	17

Reptiles

In an Ethiopian context, there are very limited studies on the herpes, i.e., reptiles and amphibians. Five species of reptiles were recorded from the project areas based on both interviews and field observation. One of these, the African Spurred Tortoise, was recorded only once during the field visit and its was assessed as Endangered (EN) with decreasing population size. Although the occurrences of snakes, Python, lizards and chameleon was reported by the local communities and Woreda experts, no further analysis can be done onthem since they are not well studied.

Birds

A total of 43 bird species were recorded from the project area. Most of these species are of least conservation concern. An exception is one bird species, Abyssinian Ground hornbiil, which was assessed as Vulnerable (VU). One species, Sombre rockchat, was not evaluated and

its population trend is unknown. The remaining bird species, 39, are of leas conservationconcern but with different population trend, i.e., increasing and decreasing.

IUCN categories	Number
VU	1
LC	39
DD	1
NE	2

The project area was found to be a passage for intra-African migratory birds, e.g. Diederik Cuckoo and intra-Ethiopia (e.g. black-bellied sunbird recorded during the field work). It is partof the East Asian – East African flyway of migratory birds. There are, however, no Important Bird Areas in the project area.

Plant communities (natural habitats) of the project area

Terrestrial plant community (natural habitats) along the Expressway and ancillary sites

Nine plant communities (natural habitats) were recorded along the entire stretch of the Mieso – Dire Dawa Expressway. All these plant communities repeat themselves in the entire sections of the Expressway, i.e., they are repetitive natural habitats. One plant community, *Eucleadivinorum*, which occur on flat plain near Mieso town, is restricted to this area. It is a species poor community and grows on a highly disturbed area. Some salient features of these plant communities are given below.

Plant communities (Natural Habitats)	Species of Conservation concern	Characteristics
Acacia mellifera –Croton dichogamous	None but *Caralluma speciosa* is locally rare	This plant community is found close to Mieso town. *Opuntia ficus-indica* occurs abundance and its invasive nature may homogenize this plant community in the future.
Euclea divinorum	None	This is a pioneer community which invaded disturbed habitats
Acacia tortilis - Opuntia ficus-indica - Acalypha fruiticosa	None	The present of *Opuntia ficus-indica* may pose a threat of homogenization of this natural habitat. The herb layer is dominated by *Acalypha fruiticosa*, an opportunistic weed. Its dense grow outcompetes the growth of other species, which accounts for a depauperated species composition of this community
Acacia seyal - Acacia nilotica	None but *Klenia dolichocoma* was found to be locally rare in this community.	This plant community could be homogenized due to the invasion of *Opuntia fiscu-indica*. The mature trees of *Acacia seyal* and scattered *Acacia nilotica* may attract local

		communities and others (during the construction phase) as a source of household firewood.
Opuntia ficus-indica - Acacia nilotica	None	*Opuntia ficus-indica* is invading open sites in this community following disturbances. There is a high potential for this species to homogenize this natural habitat in the future.
Acacia tortilis - Prosopis juliflora	None	*Prosopis juliflora* is known for its aggressive invasiveness and competition for water. Another invasive species of this community is also *Parthenium hysterophorus*. *Acalypha fruiticosa* is forming a dense herb layer, resulting in the reduction of species diversity at this lay. In the future, there is a high probability that this natural system will be converted to densestands of *Prosopis juliflora*.
Acacia tortilis - Opuntia ficus-indica	None	The combined effect of *Prosopis juliflora*, *Parthenium hysterophorus* and *Acalypha fruiticosa* will convert this natural habitat into dense stands of *Prosopis juliflora* in the future.
Acacia senegal - Acacia tortilis	None but *Caralluma* species were found to be locally rare in the community	This natural habitat is characterized by relatively young, scattered trees of *Acacia tortilis* and *Acacia senegal* growing on a rocky hill. Overgrazing and over browsing will further degrade the quality of this natural habitat.
Aloe megalacantha - Acacia mellifera	Two endemic Aloe species, Aloe harlana and Aloe pubescens, are of a high conservation concern. A. harlana is assessed as EN with a decreasing population trend and A. pubescens as NT with stable population trend. Furthermore, *Kleinia dolichocoma*, *Adenia venenata* and *Caralluma speciosa* were found to be locally rare in this community	High anthropogenic disturbance were noted. Acacia mellifera individuals were heavily browsed. *Prosopis juliflora* grows close to this community and it is highly likely that this natural habitat will be converted dense stands of this species in the future.

Riverine plant communities (natural habitats) along the Expressway and ancillary sites

The natural habitats (plant communities) of the riverine environment of the project area are highly degraded due to the combined effects of overgrazing and over browsing by a large populations of goats, sheep and camels and the extraction of charcoal and firewood. The reverine natural habitats repeat themselves along the entire section of the Mieso – Dire Dawa Expressway and ancillary sites, e.g., sand sources. There is a clear evidence (based on field

study) that *Prosopis juliflora*, an alien invasive species, is overtaking the riverine vegetation of theproject area. These natural habitats (plant communities) are characterized below.

Plant communities (Natural Habitats)	Species of Conservation concern	Characteristics
Balanites aegyptica - Acalypha fruiticosa	None	This plant community is highly infested with *Opuntia ficus-indica* and *Acalypha fruiticosa*. It is likely that this natural habitat converts into high stands of *Opuntia ficus-indica* in the future.
Acacia nilotica - Balanites Aegyptica	None	It is highly degraded and the banks are devoid of vegetation at places.
Prosopis juliflora dominated	None but there are highly pruned *Sterculia rhynchocarpa, Tamarindus indica, Mimusops kummel* and *Dobera glabra*. *Sterculia rhynchocarpa* was locally rare, so is *Mimusops kummel*.	This natural habitat is highly dominated by dense stands of the alien invasive species, *Prosopis juliflora*. Another aggressive invasive species, *Lantana camara* also grows in this community. Currently, this natural habitat is highly degraded and the invasive features of these two species will affect the remaining native flora and convert this natural habitat

Threats to natural habitats of the project area

The natural habitats of the project area are highly degraded due to extensive and repeated cycles of overgrazing and over browsing, expansion of urban settlement and agriculture. There were also extensive extractions of charcoal from Mieso – Afdem section of the Expressway (interviews with the local communities and experts of Woredas). This has been claimed as a major cause for the absence of mature trees of *Acacia tortilis*, *Acacia seyal*, *A. nilotica* and etc. all along this section of the Expressway. It has been said that the local communities have extensively made charcoal and loaded it on camels' backs for market at Mieso and beyond.

Key Biodiversity Areas (KBAs) of the Project area

The Mieso – Dire Dawa Expressway crosses two KBAs of Ethiopia. These are the Afdem – Gewane Controlled Hunting Area and Dengego – Melka Jebdu National Forest Priority Area. The section of the Expressway from Mieso – Erer (some km beyond Erer as well) crosses the Afdem – Gewane Controlled Hunting Area, which is the IUCN Management Category VI. This is characterized as designated ecosystems and habitats with associated cultural values and traditional natural resources management. This IUCN Management category requires that most portions of this protected area must be in natural conditions. But the section of the Afdem – Gewane Controlled Hunting Area in the project area is highly disturbed and converted into urban settlement and agricultural fields. Overgrazing, over browsing and invasion of this KBA by an an alien invasive species, *Prosopis juliflora*, are also additional major factors resulting in its continues degradation. There is also a tendency of homogenization of this natural habitats of this KBA by the invasion of *Opuntia ficus-indica*.

The Dengego – Melka Jebdu National Forest Priority Area is crossed by the Expressway. The Area of this NFPA was reported as amounting to 536.19 km2 but its parts falling in the project area are replaced by dense stands of *Prosopis juliflora* and agriculture.

There is a clear trend that the vegetation cover of these KBAs of the project area have changed from 1990 – 2020 based on a qualitative analysis of historical and current Google EarthImages.

Aquatic biodiversity

Algal samples the rivers, currently having a pool of water in the case of seasonal rivers and water pool of perennial rivers, has resulted in 9 families of diatoms comprised of 12 genera.The IUCN conservation status of this group of organism was not assessed.

Water quality

The laboratory analysis for trace metals has yielded different results for the trace metals. Cadmium, Chromium and Lead are below detection limit in all water samples. Whereas the detection limit of Cadmium is 0.001 mg/L, that of Chromium and Lead are 0.01 mg/L and 0.06 Mg/L, respectively. The highest concentration of Calcium was recorded in M5 (4.079 ppm) but the lowers value was found for DB-1 (1.097 ppm). Since these values fall below 100 ppm, the water sources of the project area are soft water.

Other trace elements such as Manganese, Magnesium, Copper, Zinc and Nickel are also below threshold. As a result, the ambient water quality of the project area is not polluted by any one of the trace elements considered in this study.

Classification of Rivers/stream

A total of 84 rivers/streams were recorded from the project area. These rivers/stream have altitudinal variations, i.e., four of these have altitudes above 1200 m asl. Only 5 of these rivers and streams are perennial and 79 of them are seasonal. These rivers/streams were mapped to provide spatial information of their distribution in the project area.

The five perennial rivers are:

- *Gota River*
- *Erer River*
- *Gandisa River*
- *Garmam River*
- *Hurso River*

With regard to types of substrates, these rivers/stream have the following substrates.

- Big boulders
- Boulders
- Coarse gravel
- Fine sand
- Mud
- Mud-pebbles
- Mud-sand
- Pebbles-stony

- Pebbles
- Rocky
- Sand
- Sand-gravel
- Silt-sand
- Small boulders
- Small stones
- Stony boulders

Water flow and discharge (m^3/s)

Current water flow was measured for rivers having a running water. Out of the 84 rivers/streams, water flow measurement was done for 6. Details of the flow velocity is given below.

Rivers/streams	Water flow velocity in cm/s
Doba	53.5
Keraba	4.76
Gota	4.37
Hado	18.9
Erer	12.5
Garmam	25.92

The discharge volume of the rivers/streams of the project area was calculated. The discharge volume has ranged from 0.37 m^3/s to 6,000 m^3/s. Twenty-two of the rivers/streams of the project area have a discharge volume greater than 100 m^3/s and were considered as posing potential flood hazards and structural damage following heavy rain in the surrounding highland areas.

Groundwater resources assessment and water balance

The recharge of the groundwater of the project area was analyzed by using WetSpass model. This model uses annual precipitation, mean annual temperature, annual potential evapotranspiration and wind speed as inputs to model the recharge amount (in mm) of the groundwater. Generally, WetSpass calculates the water balance components are actual evapotranspiration, surface runoff and groundwater recharge. It is to be note, however, that theamount of infiltration depends on vegetation cover, slope, soil texture and amount of rainfall.
The current groundwater recharge analysis has revealed that the mean annual groundwater recharge for the project area is 82 mm, which is about 11% of the mean annual rainfall.

The southeaster portion of the project area has a higher groundwater recharge compared to its northeaster part. The annual water balance of the project area, as simulated with WetSpass model is given as follows.

	Annual values (mm/year)				
Water balance component	Min	Max	Mean	Std. Dev.	%ppn (percentage of hydrologic parameter of precipitation)
Precipitation	422	1351	717	274	100

(mm)(P)					
Actual Evapotranspiration (mm) (ETO)	113	1710	536	196	74.7
Surface runoff (S)	0	913	101	203	14
Recharge (mm) (R)	0	668	82	119	11.4
Input minus output	P-(ETO+S+R) = 0				

But a successful wells sitting requires further detailed geomorphological and hydrogeological investigations.

Aquifer characterization

One of the landmark in the Hydrogeology of Ethiopia is the hydrogeological mapping of the country by Aquatest in 2018. The Mieso – Dire Dawa Expressway falls in the Dire Dawa Sheet (NC 37-12). This area is characterized by basalt (35%), sediment (26%), limestone (17%) and sandstone (13%). This geological feature had fissures and is porous and permeable resulting in a moderate productivity and groundwater potential. The remaining 9% is covered by basement and acidic volocanics, which have low or a very low potential that might serve as aquitard or aquiclude.

The project area has four main aquifers. These are:

a) *Moderately productive porous*. This runs from Mieso to Afdem and from Hurso to Melka Jebdu. There are limited number of boreholes, and the depth of the boreholes range from40 – 90 m. The static water level ranges from 28 – 82 m and yield from 5 – 5.5 L/s
b) *Moderate productive basalt aquifers*. This runs from Awash Arba to Mieso. There are limited existing boreholes ranging in depth from 43 – 169 m. The static water level ranges from 25 – 150 m and yield from 0.8 – 4.8 L/s.
c) *Moderate productive, Karastic aquifer*. This is confined to rugged topography. There is one borehole with a depth of 133.6 m with a static water level of 19.6 and yield of 5.5 L/s. However, there are many springs with a yield ranging from 5 – 25 L/s.
d) *Moderate productive fissure and porous aquifer*. This is located in occurs in sandstone covering the southeastern part of the project area, which is characterized by rugged topography. There are limited number of existing boreholes with a depth ranging from 60 – 133 m with a static water level of 20 – 28 m and yield of 3 – 5 L/s. There are few springs with a yield ranging from 0.1 – 1 L/s.

Sustainable yield is usually, as a rule of thumb, considered to be 50% of the groundwater recharge amount in mm. Based on the current analysis, the sustainable yield of the project areais 45 MCM (Million Cubic Meter). But further detailed studies (hydeogeology and Hydrogeophysics) are required for a successful and productive well sitting.

Water risk assessment based on Aquaduct data

Data on water risk of the project area were extracted from the Aquaduct online global resource. Based on this, information on the following overall water risks of the project areawere given. These are:

- Water stress
- Water depletion
- Interannual variability
- Ground tabke decline
- Riverine flood risk
- Drought risk

Future overall water risks of the project area for the time period 2040 was given. Aqueduct database provides three futurescenarios (optimistic, business as usual and pessimistic) but the business as usual scenario was considered for the Mieso – Dire Dawa Expressway was considered. Information on the following future overall water risks of the project area were given.

- Water stress
- Seasonal variability
- Water supply
- Water demand

Impact on Biodiversity and Management Plan

Impact on the biodiversity of the project area during project implementation and operation include (i) habitat loss and degradation, (ii) habitat fragmentation and edge effect, (iii) loss of rare and threatened species, (iv) invasive species proliferation/expansion, (v) impact on water resources, (vi) loss of ecosystem services, (vii) air quality impact, (viii) noise and vibration impact, (ix) impact due to light, and (x) collision of project vehicles with fauna. Measures are proposed to avoid, reduce/minimize, and mitigate these impacts. Further, impacts management and monitoring plan has been proposed.

1. Introduction

The Mieso – Dire Dawa Expressway is part of the Addis Ababa – Djibouti highway, which linked Ethiopia directly to Djibouti. The project lies in the dryland area of Ethiopia. The vegetation is the project area is part of the Acacia shrubland and bushland. The plants of this ecoregion are adapted to moisture limited soil environment. They have developed water stress adaptation mechanisms such as small leaves (e.g. *Acacia* species) and succulent body (e.g. different *Aloe* species).

The Right-of-Way (RoW)of the Expressway is 90 m. The total length of the Expressway is estimated to be 114.8 km. Its salient features are double carriageway, and each has two lanes of 3.6m width, 9 m median, 1.5 m inner hard shoulder and 3 m outer hard shoulder. The project area of influence is classified into two: the direct impact Zone and secondary impact zone. The direct impact zone is the areas of the 90 m RoW and access roads to transport construction materials such as sand and gravel. The area of influence will be directly impacts by the activities of the project, e.g. clearing of vegetation and excavation. The secondary impact zone includes areas which are not directly impacted but receive impacts indirectly due to the project activities. The secondary impact zone includes (i) areas contiguous with the direct impact zone and (ii) wider, broader, regional areas where the impacts could materialize or could be felt. For example, the surrounding vegetations along the RoW and access roads could be covered by dust, which could potentially impact their photosynthetic processes. Furthermore, the movement of wildlife could be limited around the RoW and access roads. On the other hand, both terrestrial and aquatic animals that are affected by the project could move considerably away from the direct impact zone. Also, the project could affect the watershed systems and aquatic organisms, particularly downstream of the direct impact zone including through altering river morphology and hydrology on which aquatic organisms depend as a result of surface and groundwater flow modifications, clearing of riverine vegetation, dredging, blocking, channel modifications, etc.; creating barrier or restricting movement of aquatic organisms; reduction of available water in the watershed system due to resource competition and utilization for various construction activities; and contaminating of water bodies by heavy metals, hydrocarbons, and other pollutants.

The current study has considered both the direct and secondary impact zones.

2. Objectives

The Environmental and Social Impact Assessment of this Expressway was done. But there were some gaps in the baseline conditions of the biodiversity and Key Biodiversity Areas of the project area. The current assignment is, therefore, to fill these gaps and assess species according to the IUCN Red list conservation categories.

3. Methods

3.1. Biodiversity Assessment

3.1.1. Desk Study

Review of Existing Data/Information

Existing information/data was collected and reviewed including information on plant and animal species in the project area of influence, on the key biodiversity areas, and other relevant studies and maps.

Google Earth-based Historical and Current Vegetation Data

To understand qualitative changes in the vegetation of the project area, historical Google Earth images were compared with the current images. For historical qualitative vegetation assessment, year 1985 was selected because its relatively higher resolution. Year 2020 was used to assess qualitative changes of the vegetation from year 1985 – 2020. This comparison will give visual comparison of the extent of vegetation of the study area in 1985 and its currentstatus.

Biodiversity Index Assessment

Previous assessment conducted in the project area of influence has been reviewed to assess the biodiversity index. Shannon's index (H'), evenness (H'/Hmax), and Species richness are used to assess the plant species diversity. Tessema et al (2022) conducted plan species diversity assessment in the Dengego – Melka Jebdu KBA. Mekonnen et al (2012) conducted plant species diversity in Asebot dry Afromontane Forest which is in the Afdem – Gewane KBA. Also, Shiferaw et al (2019) assessed the *Prosopis juliflora* invasion in Afar region, in an area contiguous with the Afdem – Gewane KBA with similar ecological characteristics. Ahmed et al (2015) assessed representative area outside of the two KBAs. The results of these studies were used to provide an overall picture on plan species diversity of the project area.

3.1.2. Field Study

Plant Collection

Plant species of the project area were identified in the field. Taxonomic verifications were done in the Laboratory (the National Herbarium of Ethiopia, Addis Ababa University) and by using published Flora of Ethiopia and Eritrea. Plants were collected in the field by using standard herbarium techniques and dried for further taxonomic evaluation.

Plant Community Identification

Plant communities of the project area were identified based on the dominance of species. The communities are named after two most dominant species. Species composition of each community was identified in the field and verified in the Laboratory (the National Herbarium of Ethiopia, Addis Ababa University). Photographs and GPS points of these plant communities were taken.

Fauna Species Identification

The species composition of wildlife was acquired from two sources: interview with the local communities and experts at Woredas and field observation. To record bird diversity of the project area, field observation by using a binocular was used. Species were identified in the field by using two illustrated books of African birds.

3.1.3. Stakeholder Consultations

Consultations with stakeholders were used to identify biodiversity composition in the project area of influence. Consultations were conducted with the local communities and woreda experts. The local communities and woreda experts are project affected parties that are directly influenced by the project, as described in the project SEP. The stakeholders consultations conducted for the purpose of the biodiversity and water resources assessment used the general approach described in the SEP (stakeholders mapping and analysis). The objectives of the stakeholders consultations were:

i. to identify biodiversity (plant, wildlife) composition of the project area of influence
ii. to identify the main ecosystem services of the biodiversity of the area
iii. to identify the main sources of water the local communities use for domestic and animal water demand
iv. to understand the value the community put to the biodiversity of the project area
v. to understand other project area of influence valued ecological components.

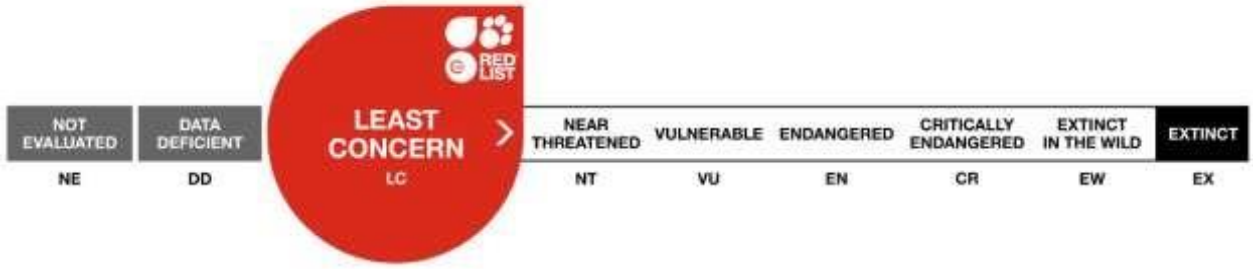
The main results of the consultations are:

i. the project affected parties indicated that the woodlands of the project area serve as livestock grazing and browsing areas on which their livelihood depends on
ii. also, the woodlands are source of firewood for domestic energy need
iii. the local communities harvest incense and earn income from its sale
iv. the local communities indicate that the perennial rivers in the project area are the main source of water for domestic and animal water demand
v. because of the benefits mentioned above, the community put high value to the biodiversity of the project area of influence
vi. further, the community indicated other ecological components which they put high value such as water resources, cultural heritage, labor influx, their livelihoods, and movement of their livestock for grazing and browsing.

3.1.4. Data Analysis and Interpretation

Plant Species Classification

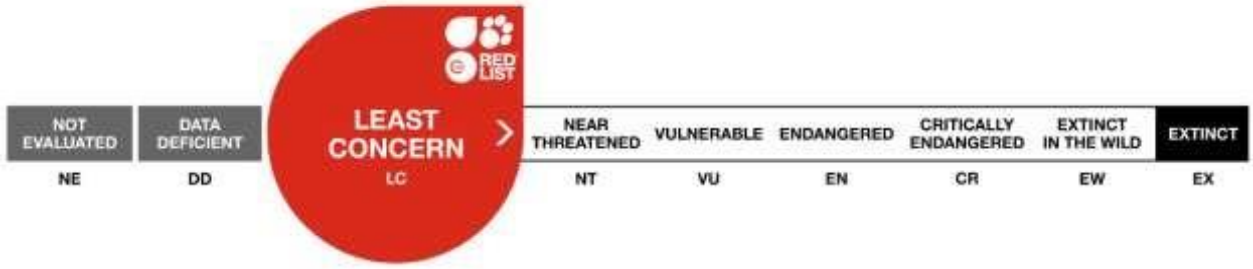
The conservation status (endemicity and IUCN conservation threat categories) of plant species was evaluated by using an online source (https://www.iucnredlist.org/species/). The plant species of the area were assessed by using the following IUCN threat categories. Furthermore, the conservation status of a species will be marked in red as seen below.



The local abundance of species was determined in in the field as common and rare.

Fauna Species Classification

The conservation status of wildlife and bird species of the project area was assessed based on an online information source, i.e., https://www.iucnredlist.org/species/. The following IUCN conservation threat categories were used in this assessment. Furthermore, the conservation status of a species will be marked in red as seen below.



Key Biodiversity Area Assessment

Key Biodiversity Areas (KBAs) of the project area were assessed by using Integrated Biodiversity Assessment Tool (IBAT) - https://www.ibat-alliance.org/ and https://www.protectedplanet.net/ (UNEP-WCMC and IUCN, 2021). This tool provides information on KBAs of the project area. Layers of site of biodiversity importance were used to visualize KBAs of the project area. A map of the KBAs of the project area was taken from this online resources. The current status of the plant communities and species diversity and threats were identified in the field.

To understand qualitative changes in the vegetation of the project area and the KBAs, historical Google Earth images were compared with the current images. For historical qualitative vegetation assessment, year 1985 was selected because its relatively higher resolution. Year 2020 was used to assess qualitative changes of the vegetation from year 1985 – 2020. This comparison will give visual comparison of the extent of vegetation of the study area in 1985 andits current status.

Critical/Sensitive Habitat Assessment

Critical/sensitive habitats assessment was conducted considering the following approach: (i) literature review and stakeholders consultations to understand the biodiversity values in the

project road area of influence, (ii) field data collection and verification of available information of plant species, communities, and faunal diversity, and (iii) critical habitats determination. The critical habitat area of analysis was considered as an ecologically relevant area surrounding and including the anticipated project area of influence on the biodiversity. Discrete management units were assessed when there is a clear demarcated boundary within which the biological communities and management issues have more in common with each other than they do with those in adjacent areas.

Critical/sensitive habitats along the project road corridor and its area of influence were determined considering the following criteria (in line with ESS6 and IFC GN6):

- **Criterion 1** - Habitat of significant importance to Critically Endangered or Endangered species, as listed in the IUCN Red List

  Critically endangered species face an extremely high risk of extinction in the wild while endangered species face a very high risk of extinction in the wild. The IUCB Red List is considered to identify if a species is critically endangered or endangered.

- **Criterion 2** - Habitat of significant importance to endemic and restricted-range species

  For terrestrial vertebrates and plants, restricted range species are defined as those species that have an extent of occurrence less than 50,000 km^2.

- **Criterion 3** - Habitat supporting globally or nationally significant concentration of migratory or congregatory species

  Migratory species are any species of which a significant proportion of its members cyclically and predictably move from one geographic area to another, including within the same ecosystem. Congregatory species are species whose individuals gather in large groups on a cyclical or otherwise regular and/or predictable basis.

- **Criterion 4** - Highly threatened or unique ecosystems

  Since formal IUCN assessment has not been performed for the project area, national/regional level assessments carried out by recognized institutions/organization has been considered. Criteria considered for evaluation are (i) reduction in geographic distribution, (ii) restricted geographic distribution, (iii) environmental degradation, (iv) disruption of biotic processes or interactions, and (v) quantitative analysis that estimates the probability of ecosystem collapse.

- **Criterion 5** - Ecological functions or characters that are needed to maintain the viability of critically endangered, endangered, endemic, or restricted-range species.

Structural attributes of a habitat (such as topography, geology, soil, temperature, and vegetation) that influence the viability of critically endangered, endangered, endemic, or restricted-range species.

Critical habitats along the road corridor are identified by scrutinizing them against these criteria.

3.2. Water Resources Assessment

3.2.1. Desk Study

Desk study conducted include collection and review of information/data on topographic gradients and features, drainage patterns, meteorological conditions, land use, soil types, runoff parameters, and hydrogeology and aquifer characteristics of the project area of influence.

3.2.2. Field Study

During the field study surface water resources were identified including river substrate identification and river channel cross sections assessment. Further, water samples were collected from some of the surface water resources for physio-chemical water quality laboratory analysis.

3.2.3. Stakeholder Consultations

The objective, approach and results of the stakeholder discussions are presented under Section 3.1.3 above. Stakeholder discussions with local communities and woreda officials indicate that the perennial rivers crossing the project area are important sources of water for the local communities, both for domestic use and animal watering.

3.2.4. Data Analysis and Interpretation

Water Flow and Discharge

The velocity of water flow of the rivers/streams of the project area used information in thetable below as a guiding principle.

Substrate type	Particle size (diameter) of substrate in mm	Current velocity in cm/sec
Mud (silt and clay)	0.2	10
Sand	1.3	25
Gravel	5	50
Coarse gravel	11	75
Pebbles	20	100
Small stones	45	150
Stones	80	200
Small boulders	180	3000
Large boulders	>200	5000

Water Quality Analysis

Water quality analysis was run by using ZEEnit 700 P (Analytikjena)-Flame AAS analytical instrument. Four calibration points were used for every trace metal. Samples were run in triplicate and the average values have been taken.

Groundwater Recharge - WetSPASS

WetSpass model was used to estimate the recharge of groundwater.

Water Risk Assessment Based on Aqueduct

The global database Aqueduct Water Risk Atlas was used to collect information on the baseline and future water risk.

Mapping

ArcGIS 10.5 was used for mapping studies.

3.3. Assessment of Impact on Biodiversity, Mitigation, and Management Plan

Based on the assessment conducted and project activities, the impact of the project on biodiversity of the project area has been assessed. The cumulative impact on biodiversity is assessed in a separate document (Annex A (ii)). Mitigation measures for the identified impact has been recommended. An indicative biodiversity management and monitoring plan has been developed.

4. Biodiversity Assessment

4.1. Flora

4.1.1. Plant Species Diversity

A total of 194 plant species were recorded from the project area (Annex 3). Out of this, 98 are herbs and 88 are shrubs and trees. Except for the two Aloe species (*A. harlana* and *A.pubescens*), all the remaining species have not immediate conservation concerns, i.e., they are categorized as IUCN category of Least Concern (LC) – Table 1. These plant species were recorded from the direct and secondary impact zones of the project area. Project activities such as vegetation clearance and excavation along the Right-of-Way (RoW) negatively affect these rare endemic plants. The IUCN conservation status of these species is given below.

Table 1. Plant species of the project area assessed for the IUCN categories

Species	IUCN category	Habit	Population trend
Acacia bussei	LC	Tree	Decreasing
Acacia etbaica	LC	Tree	Unknown
Acacia mellifera	LC	Tree	Stable
Acacia nilotica	LC	Tree	Unknown
Acacia oerfota	LC	Tree	Stable
Acacia robusta	LC	Tree	Stable
Acacia senegal	Not accessed	Tree	Unknown
Acacia seyal	LC	Tree	Stable
Acacia tortilis	LC	Tree	Stable
Acalypha fruticosa	LC	Shrub	Stable
Adenia venenata	Not accessed	Shrub	Unknown
Aloe harlana	EN	Shrub	Decreasing
Aloe pubescens	NT	Shrub	Stable
Aloe megalacantha	LC	Shrub	Decreasing
Aloe pirottae	LC	Shrub	Unknown
Azadirachta indica	LC	Tree	Stable
Balanites aegyptiaca	LC	Tree	Stable
Berchemia discolor	LC	Tree	Stable
Cadaba farinosa	LC	Shrub	Stable
Capparis fascicularis	LC	Shrub	Unknown
Carissa spinarum	LC	Shrub	Stable
Catha edulis	LC	Shrub	Unknown
Combretum molle	LC	Tree	Stable
Cordia monoica	LC	Tree/Shrub	Stable
Croton dichogamus	LC	Tree	Stable
Ehretia cymosa	LC	Tree	Decreasing
Euclea divinorum	LC	Shrub	Stable

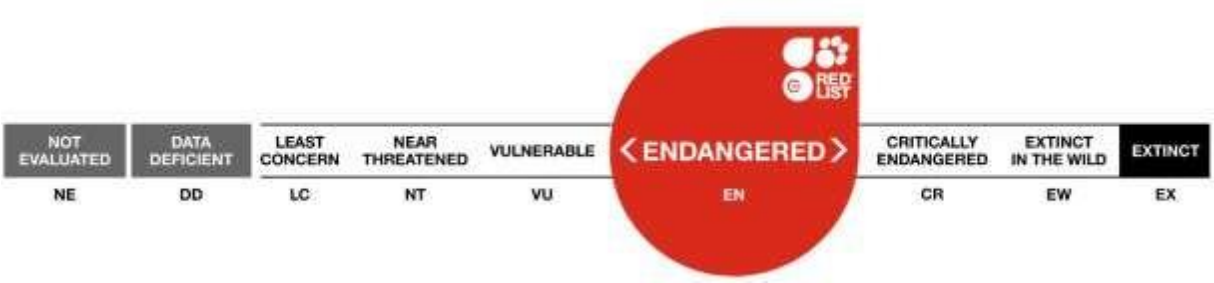
Species	IUCN category	Habit	Population trend
Euphorbia tirucalli	LC	Shrub	Stable
Grewia flavescens	LC	Shrub	Stable
Grewia mollis	LC	Tree	Stable
Grewia villosa	LC	Shrub	Stable
Jatropha curcas	LC	Shrub	Stable
Kleinia dolichocoma	LC	Shrub	Unknown
Lycium shawii	LC	Shrub	Unknown
Mimusops kummel	LC	Tree	Stable
Opuntia ficus-indica	DD	Shrub	Unknown
Parkinsonia aculeata	LC	Tree	Stable
Rhus natalensis	LC	Shrub	Stable
Tamarindus indica	LC	Tree	Stable
Tamarix nilotica	LC	Shrub	Unknown
Terminalia brownii	LC	Tree	Stable
Ziziphus mucronata	LC	Tree	Stable
Ziziphus spina-christi	LC	Tree	Stable

4.1.2. Endemics and Threatened Plant Species

Two endemic plant species were recorded from the direct and secondary impact zones of the project area. The IUCN conservation status of these species is given below.

I. *Aloe harlana* Reynolds (Family: Aloaceae)

*Aloe harrlana*is an endangered species (IUCN category: B1ab(iii)) and its populations are decreasing.



Habitat: This species is a stemless succulent growing on sparsely vegetated grassy slopes, often on limestone. It flowers from April – May and sometimes from September – October.

Fig. 1. *Aloe Harlana* in its natural habitat

Threats: Ecosystem degradation is one of the major threats to the long-term persistence of this species. Anthropogenic influences are degrading the habitats of *Aloe harlana*. These anthropogenic impacts are agricultural expansion and heavy grazing and browsing, which exposes the plant to trampling by animals and reduces its regeneration potential.

Population status: The population trend of *Aloe harlana* is continuously decreasing. There is a continuing decline of mature individuals. It occurs in restricted areas (2-3 mature individuals per 100 m^2) in its natural habitats and the populations are highly fragmented.

Uses: The saps of the leaves of this species used locally by women. They cover their faces with saps to keep their skin young and treat prickles (Observation during the field work).

Conservation: *Aloe harlana* is not included in the protected area network of Ethiopia (Fig. 1). This species has been collected from 5 locations in Ethiopia (Fig. 2). It occurs in an altitudinal range of 1500 – 2100 m asl.

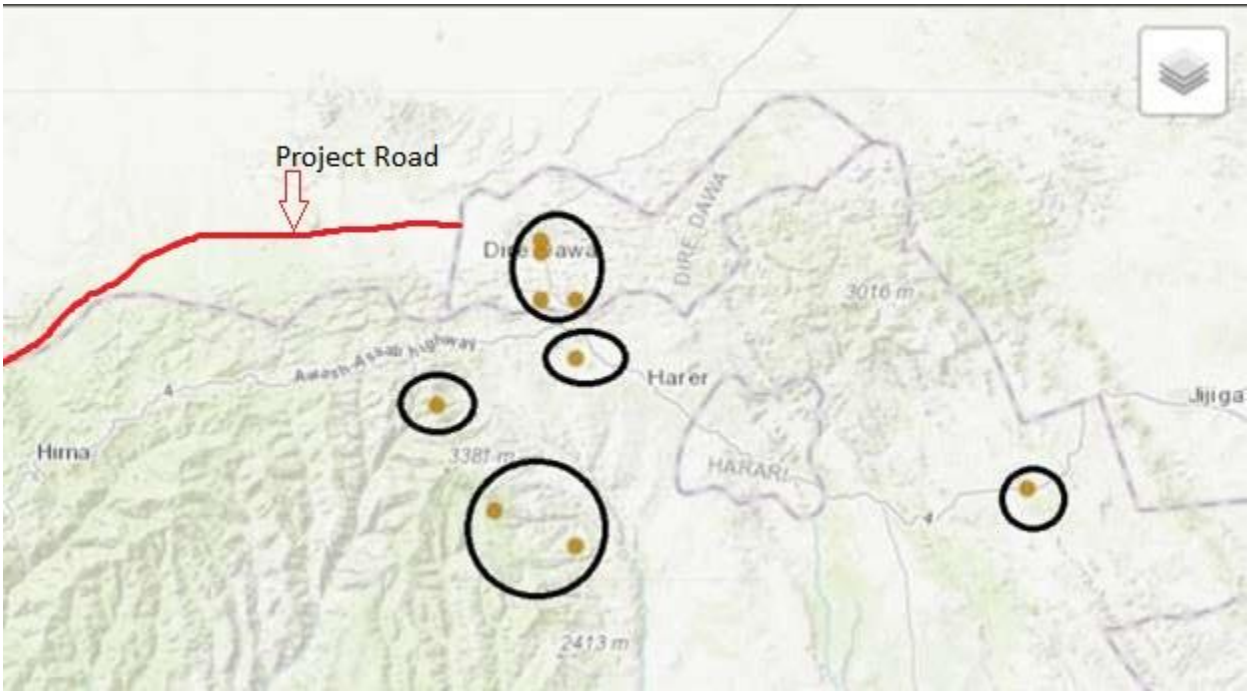


Fig. 2. Distribution of *Aloe harlana* in Ethiopia

II. *Aloe pubescens* Reynolds (Family: Aloaceae)

Aloe pubescens is a near threatened species (IUCN category: NT) and its populations are stable.

Habitat: *Aloe pubecens* grows along rocky places in open shrubland and stream/riverbanks and fieldmargins. It is a stemless species. It flowers from February – May.

Threats: The major threats are ecosystem stress and species stress due to anthropogenic influences. Agricultural expansion and Agro-industry farming are resulting in ecosystem and habitat degradation. Overgrazing and browsing by livestock is another major threat to the degradation of natural habitats of *Aloe pubescens* in the project area.

Population status: The population trend of Aloe pubescens is stable but they are fragmented. The mature individuals are continually declining. There are 5-15 individuals per square meter. *Aloe pubescens* also reproduce vegetatively (easily sucker) in addition to sexual reproduction.

Uses: The sap of *Aloe pubescens* is used by women to cover their faces for rejuvenation of dead skins and treatment of prickles 9observation during the field work). Flowers and buds of this species are used as a medicine for humans and livestock. The leaf bud and flower are concocted to treat stomachache in humans and anthrax in livestock. Also used to treat wounds and muscle cramps (https://www.iucnredlist.org/).

Conservation: Any of the subpopulations of *Aloe pubescens* occur in the Protected Areas network of Ethiopia (Fig. 3). This species is listed in CITES Appendix II. The need for initiating community education and conservation programs of Aloes in Ethiopia and their ecosystem and medicinal uses was proposed (Kelbessa, 2008).

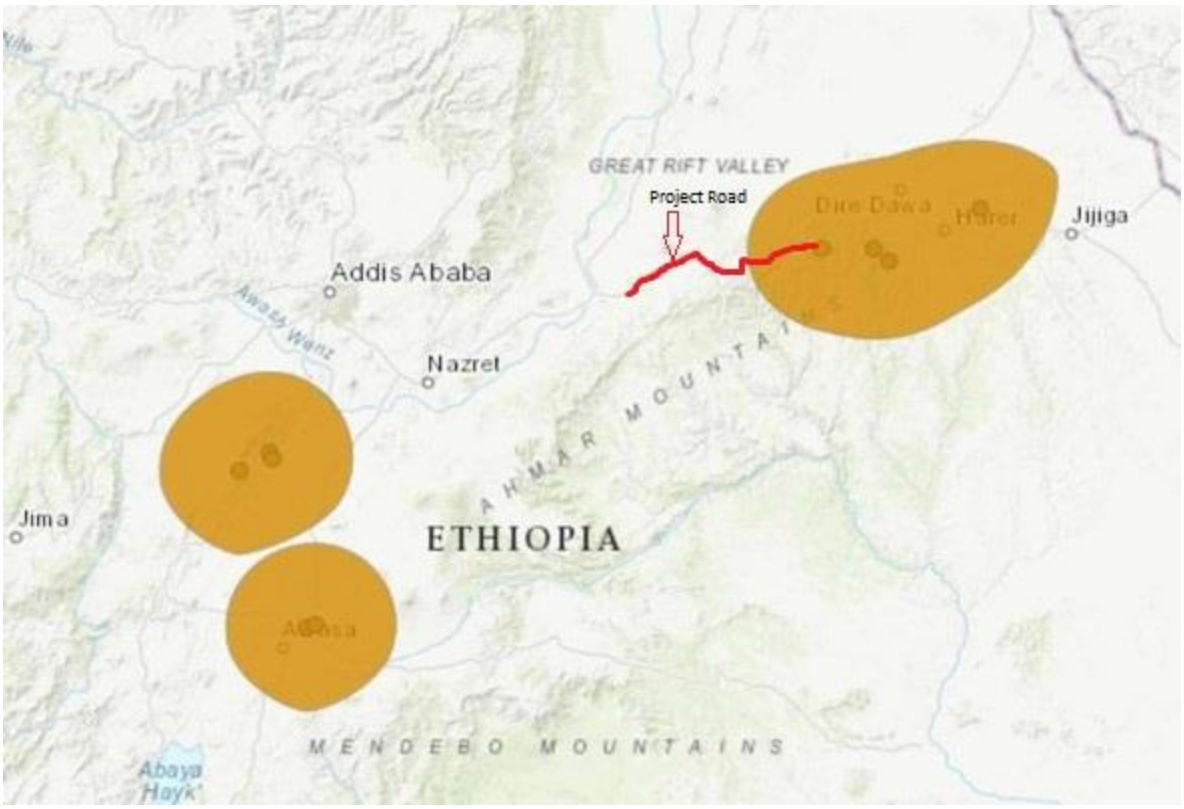


Fig. 3. Distribution of *Aloe pubescens* in Ethiopia

III. *Caraluma* species

Three Caraluma species (Fig. 4) were recorded from the project area. These are as follows.

- *Caralluma acutangula* (Decne.) NE Br.
- *Caralluma priogonium* K. Schum.
- *Caralluma speciosa* (NE Br.) NE Br.

These species are locally rare. Their conservation status has not been assessed (cf. https://www.iucnredlist.org/) but their rarity is very distinct in the project area. They were also collected at limited sites along the entire section of the Mieso – Dire Dawa Expressway.

Fig. 4. *Caraluma* species in the project area, locally rare plant species in the project area.

IV. *Klenia dolichocoma* C. Jeffrey

This succulent species (Fig. 5) is locally rare in the project area. It occurs in other parts of Ethiopia and Kenya as well. Its yellow flower distinguishes it from the other *Klenia* species, *Klenia squarrosa* Cufod. that also occurs in the project area.*K. squarrosa* has red flowers and is relatively common in the project area. *K. dolichocoma* was assessed as Least Concern (LC).

Fig. 5. *Klenia dolichocoma*, locally rare (seen only once along the whole stretch of the Mieso – Dire Dawa Expressway)

4.2. Plant Communities of the Study Area

The vegetation of the project area can be broadly categorized as *Acacia* woodland, *Acacia* shrubland (Friis et al., 2010). Plant communities were identified along the entire stretch of the Mieso – Dire Dawa Expressway. Four major characteristics of these plant communities are discernible for all of them. These are:

- They are all species poor.
- The vegetation cover of all communities is degraded.
- They are highly overgrazed and over browsed by goats, sheep and camels.
- They are repeat themselves throughout the whole stretch of the Expressway.

The plant communities were recorded from the direct and secondary impact zones (Project Area of Influence) of the Mieso – Dire Dawa Expressway project. Vegetation clearance alongthe RoW and access roads and construction of camps will negatively affect these plant communities.

4.2.1. Plant Communities Along the Expressway

Plant communities of the project area were characterized and named. The types of plant communities along the route of the Mieso – Dire Dawa Expressway are described below. A table summarizing the plant communities is also provided below.

Table 2. Plant Communities along the Project Road

No.	Plant Community	Spatial Extent	Conservation Status	Remark
Terrestrial Plant Community				
1	*Acacia mellifera - Croton dichogamous*	In Mieso town, i.e., beginning of the project road, and repeats itself along the RoW and ancillary facility sites	Least concern	Species poor plant community
2	*Euclea divinorum*	Common along the RoW and ancillary facility sites	Least concern	Species poor plant community
3	*Acacia tortilis - Opuntia ficus-indica - Acalypha fruiticosa*	Common along the RoW and ancillary facility sites	Least concern	Species poor plant community and grows in a disturbed area
4	*Acacia seyal - Acacia nilotica*	Common along the RoW and ancillary facility sites	Least concern	Species poor plant community
5	*Opuntia ficus-indica - Acacia nilotica*	Common along the RoW and ancillary facility sites	Not assessed	*Opuntia ficus-indica* is invading open sites within the community following anthropogenic disturbances
6	*Acacia tortilis - Prosopis juliflora*	Common along the RoW and ancillary facility sites	Least concern	Grows on a degraded area, community has potentially **invasive species**
7	*Acacia tortilis - Opuntia ficus-indica*	Common along the RoW and ancillary facility sites		Grows on open, non-vegetated places
8	*Acacia senegal - Acacia tortilis*	Common along the RoW and ancillary facility sites	Least concern	Abundant along the entire stretch of the RoW
9	*Aloe megalacantha - Acacia mellifera*	Common along the RoW and ancillary facility sites	Great conservation concern	Has two **endemic Aloe species,** i.e., *Aloe harlana* and *Aloe pubescens*
Riverine Plant Community				
1	*Balanites aegyptica - Acalypha fruiticosa*	Common along the RoW and ancillary facility sites	Least concern	Highly degraded and species poor, Grows at Wangayo River
2	*Acacia nilotica - Balanites Aegyptica*	Common along the RoW and ancillary facility sites	Least concern	Grows on degraded banks of *Doba* river
3	*Prosopis juliflora*	Common along the RoW and ancillary facility sites	Least concern	*Prosopis juliflora* expansion along seasonal riverbanks, **invasive species**

I. Terrestrial Plant Communities

1) *Acacia mellifera – Croton dichogamous* plant community (located at the beginning of the Expressway in Mieso town; GPS point 059)

This plant community is located at the beginning of the Expressway in Mieso town (Fig. 6). There are open, rocky places which are not covered by vegetation. This plant community is common along the RoW and access roads to material sources of the project area. The species composition of this plant community is given below.

Cyphostemma rotundifolia	*Acacia etabaica*
Opuntia ficus-indica	*Acalypha fruticosa*
Caralluma speciosa	*Parkinsonia aculeata*
Barleria eranthemoides	*Jasminum grandiflorum* L.subsp. *floribundum*
Euclea divinorium	*Acacia seyal*

This community is species poor. *Acacia seyal*, which is a good charcoal tree, is locally rare. There are 3-5 individual young trees in 100 m x 100 m area in this plant community. The height of the individuals of this species ranges from 0.5 m – 1.5 m. Mature trees of *A. seyal* are absent in this community. *Cyphostemma roundifolia* forms very dense stands throughout this plant community. Furthermore, *O. ficus-indica* is invading this plant community and it will homogenize it in the near future. All species of this plant community are of least conservation concern. However, *Caralluma* species are locally rare.

Fig. 6. *Acacia mellifera - Croton dichogamous* plant community. A, overview of the community; B, open, non-vegetated rocky places inside this community.

2) *Euclea divinorum* plant community (located at the beginning of the Expressway in Mieso town; GPS point 059)

This plant community is entirely dominated by *Euclea divinorum* and occupies the flat plain at the beginning of the Mieso – Dire Dawa Expressway (Fig. 7). It is species poor and the community

grows in a disturbed area. There are, however, scattered individuals of *Acalypha fruiticosa, Acacia mellifera, Opuntia ficus-indica, Croton dichogamous* and *Cyphostemma rotunidifolia*. All of these species are of least conservation concern. *Euclea divinorum* usually invade disturbed natural habitats and become dominate vegetation. This plant community is common along the RoW and access roads to material sources of the project area.

Fig. 7. *Euclea divinorum* plant community

3) *Acacia tortilis - Opuntia ficus-indica - Acalypha fruiticosa* plant communities (GPS = 076436, 1042906)

This plant community repeats itself in the project area (Fig. 8). It is species poor and grows in a disturbed area. This plant community is common along the RoW and access roads to material sources of the project area. The following species were recorded from this plant community.

Acacia tortilis	*Acalypha fruiticosa*
Opuntia ficus-indica	*Grewia villosa*

Cyphostemma rotundifolia

Balanites aegyptica

Sansevieria ehrenbergii

Acacia mellifera

Plectranthus sp.

Crotalaria pycnostachya

The species of this plant community are of least conservation concern. It is species poor and grows on disturbed area. Although not recorded inside this community, *Prosopis juliflora* was recorded at its margin. There is a potential invasion of this plant community by *Opuntia ficus-indica* and *Prosopis juliflora* in the near future.

Fig. 8. *Acacia nilotica - Opuntia ficus-indica - Acalypha fruiticosa* plant community

4) *Acacia seyal - Acacia nilotica* plant community (GPS 065, 066)

This community grows on a flood plain (Fig. 9). This is species poor and none of the species of this community are of least conservation concern. This plant community is common along the RoW and access roads to material sources of the project area. The species of this community are:

Acacia seyal

Acacia nilotica

Acacia etabaica

Acacia Mellifera

Opuntia ficus-indica

Cyphostemma quandriangularis

Cyphostemma rotundifolia

Klenia squarrosa

Klenia dolichocoma

Klenia dolichocoma is locally rare in this plant community and the entire project area.

Fig. 9. *Acacia seyal - Acacia nilotica* plant community on a flood plain

5) *Opuntia ficus-indica - Acacia nilotica* plant community (GPS 066)

This plant community repeats itself throughout the stretch of the Mieso – Dire Dawa Expressway (Fig. 10). It is species poor and *Opuntia ficus-indica* is invading open sites within the community following anthropogenic disturbances, e.g., cutting mature trees of *A. nilotica*. If the current trend (cutting mature trees of *A. nilotica*) continues, this plant community will be homogenized and can be entire replaced by a pure stand of *O. ficus-indica*. This plant community is common along the RoW and access roads to material sources of the project area. The species of this community includes, *Acalypha fruiticosa, Balanites aegyptiaca, Kleinia squarrosa, Sansevieria ehrenbergii* and *Physalis ixocarpa*.

Fig. 10. *Opuntia fiscus-indica - Acacia nilotica* plant community

6) *Acacia tortilis - Prosopis juliflora* plant community (GPS = 070)

This plant community grows on a degraded area and dominated by scattered trees of *Acacia tortilis* and relatively dense stand of alien invasive *prosopis juliflora* (Fig. 11). This plant community is common along the RoW and access roads to material sources of the project area. The following species were recorded in this community.

Acacia tortilis
Prosopis juliflora
Opuntia ficus-indica
Balanites aegyptica
Parthenium hysterophorus
Acalypha fruiticosa
Grewia villosa
Cissus quadriangularis
Abutilon fruticosum
Ziziphus spina-christi
Senna occidentalis
Cissus rotundifolia
Berchemia discolor
Sida urens

This community has three potentially invasive species, i.e., *Prosopis juliflora*, *Parthenium hysterophorus* and *Opuntia ficus-indica*. This community may be replaced by *Prosopis juliflora* since this species form dense stands and due to its high competitiveness through its allelopathic effects (suppressing the growth of other species close to it).

Fig. 11. *Acacia tortilis - Prosopis juliflora* plant community

7) *Acacia tortilis - Opuntia ficus-indica* plant community (GPS = 071)

This plant community is dominated by *Acacia tortilis* and *Opuntia ficus-indica* (Fig. 12). There is open, non-vegetated places. This plant community is common along the RoW and access roads to material sources of the project area. The following species were recorded in this community.

Acacia tortilis

Opuntia ficus-indica

Acacia oerfota

Acacia Mellifera

Abutilon fruiticosum

Celosia polystachia

Balanites aegyptica

Parthenium hysterophorus

Withania somnifera

Acalypha fruiticosa

Prosopis juliflora

Fig. 12. *Acacia tortilis - Opuntia ficus-indica* plant community

8) *Acacia senegal - Acacia tortilis* plant community (GPS = 076)

This plant community grows on rocky places on a hill (Fig. 13) and repeats itself along the entire stretch of the Mieso – Dire Dawa Expressway on hilly slopes. This plant community is common along the RoW and access roads to material sources of the project area. The following species were recorded in this community.

Acacia senegal

Acacia tortilis

Abutilon fruiticosum

Sedera sp.

Barleria eranthemoides

Commicarpus pedunculosus

Aerva javanica

Hibiscus aponeurus

Balanites aegyptica

Acacia seyal

Ruellia patula

Dobera glabra

Cissus rotundifolia

Boscia sp.

Grewia schweinfurthii

The species of this plant community are of least conservation concern and they also occur in abundance along the entire stretch of the Expressway.

Fig. 13. *Acacia senegal - Acacia tortilis* plant community

9) *Aloe megalacantha –Acacia mellifera* plant community (GPS 139)

This plant community is dominated by Aloe megalacantha and Acacia mellifera (Fig. 14). There is a highly level of browsing of Acacia mellifera and a footprint of high anthropogenic disturbances such as cutting Acacia trees for household uses. This community has two endemic Aloe species, i.e., *Aloe harlana* and *Aloe pubescens*. Furthermore, *Caralluma spiciosa* is also locally rare in the project area and is part of this community. This plant community is common along the RoW and access roads to material sources of the project area. The following species were also recorded in this plant community.

Acacia tortilis

Balanites aegyptica

Prosopis juliflora

Cissus rotundifolia

Caralluma acutangula

Caralluma spiciosa

Adenia venenata

Caralluma priogonium

Kleinia squarrosa

Kleinia dolichocoma

Caralluma speciosa

Grewia villosa

The two endemic Aloe species, *A. harlana* and *A. pubescens* are of a great conservation concern.The occurrence of *Prosopis juliflora* in this plant community is a threat since it could gradually invade this community and replace it with its dense stands.

Fig. 14. *Aloe megalacantha* – *Acacia mellifera* plant community

II. Riverine vegetation

1) *Balanites aegyptica* - *Acalypha fruiticosa* plant community (at Wangayo River) – Fig. 15. GPS: 0709538, 1036400

This riverine plant community is highly degraded and species poor. This plant community is common along the RoW and access roads to material sources of the project area. It speciesare:

Balanites aegyptica

Acalypha fruiticosa

Combterum molle

Opuntia ficus-indica

Acacia totilis

Ficus sp.

Cordia monoica

Capparis tomentosa

Acacia senegal

Cyphostemma rotundifolia

Klenia squarrosa

Acacia mellifera

Acacia oerfota

All species of this riverine plant community are of least conservation concern.

Fig. 15. *Balanites aegypitica - Acalypha fruiticosa* plant community at the banks of Wangayo River

2) *Acacia nilotica - Balanites Aegyptica* plant community (Doba River, GPS: 0710797, 1036839)

This plant community grows on degraded banks of Doba river (Fig. 16). This plant community is common along the RoW and access roads to material sources of the project area. It is species poor and the following species were recorded in this community.

Acacia nilotica

Balanites aegyptica

Ziziphus spina-christi

Opuntia ficus-indica

Acalypha fruiticos

Cissus rotundifolia

Fig. 16. *Acacia nilotica - Balanites aegyptical* plant community at Doba river

3) *Prosopis juliflora* dominated plant community at Erer River (GPS = 101, 114)

This riverine plant community is highly dominated by dense stands of *Prosopis juliflora* (Fig. 17). It has been noted that there is an expansion of this invasive species along both seasonal river banks. The local people, birds and vervet monkey are using this seasonal river for washing and drinking. The native species, e.g., *Mimusops kummel*, *Dobera glabra* and *Cordia monoica* are heavily pruned for firewood and other household uses. Part of the riverine vegetation is rocky and highly degraded. This plant community is common along the RoW and access roads to material sources of the project area. The following species were recorded in this riverine plantcommunity.

Prosopis juliflora

Mimusops kummel

Dobera glabra

Cordia monoica

Cissus quadriangularis

Withania somnifera

Lantana camara

Acacia nilotica

Acacia senegal

Acacia tortilis

Aerva javanica

Euphorbia polyacantha

Justicia flava	*Grewia villosa*
Sansevieria ehrenbergii	*Sterculia rhynchocarpa*
Tamarindus indica	*Cissus rotundifolia*

All these species of this riverine plant community are of least conservation concern. This plant community could be overtaken by invasive species, namely, *Prosopis juliflora* and *Lantana camara* in the future.

Fig. 17. *Prosopis juliflora* dominated riverine vegetation of Erer River

4.2.2. Plant Communities at Ancillary Sites

The nine terrestrial plant community types described above [(section 4.2.1 (1)] characterize all the ancillary sites (quarry sites, borrow pits and gravel sources). Sand sources for the construction of the Expressway are located in the riverine plant communities. All these plant communities repeat themselves all along the entire section of the Mieso – Dire Dawa Expressway and all burrow pits and gravel source sites (e.g., Fig. 18). Except for locally rare species such as *Caralluma acutangula, Caralluma priogonium. Caralluma speciose, Kleinia squarrosa*, and the endemic Aloe species (*Aloe harlana*and *Aloe pubescens*), all the remaining recorded plants species of the project area are of least conservation concern.

Fig. 18. The different plant communities of the project area repeat themselves across the entire section of the Mieso – Dire Dawa Expressway in reference to the Right-of-Way and ancillary sites. BP_1 = borrow pit-1; SS_1 – sand source-1; SS-2 = sand source-2.

Access roads to the material sites, i.e., quarry sites, borrow pits, gravel source and sand source, cross the same plant communities indicated above. Fig. 19 shows an example of an access road to borrow pit-2 (BP_2).

Fig. 19. Access roads crossing plant communities of the project area (cf. 4.2.1 and 4.2.2)

4.3. Fauna

4.3.1. Faunal Diversity of the Project Area

The following wildlife were recorded based on interviews with the local community and natural resources experts of Woredas.

I. Species list

A. Mammals

Table 3. Fauna Species in the Project Area

No	Local name	Common English name	Scientific name	IUCN category	Population trend
1.	Zinjero/ዝንጀሮ	Hamadryas baboon	*Papio hamadryas*	Least Concern	Increasing
2.	Tinchel/ጢንቸል	Abyssinian Hare	*Lepus habessinicus*	Least Concern	Decreasing
3.	Aner /አነር	Serval cat	*Leptailurus serval*	Least Concern	Stable
4.	Ensho/ድክድክ	Dikdik salts	*Madoqua saltiana*	Least Concern	Stable
5.	Ensho/ድክድክ	Dikdik gunthers	*Madoqua guentheri*	Least Concern	Stable
6.	Jib tekateko/ጅብ	Spoted hayena	*Crocuta crocuta*	Least Concern	Decreasing
7.	Jib balemesmer/ጅብ	Striped hayena	*Hyaena hyaena*	Near Threatened	Decreasing
8.	Karkaro/ከርከሮ	Warthogs	*Phacochoerus africanus*	Least Concern	Stable
9.	Jeedala/ቀበሮ	Black jakal	*Canis mesomelas*	Least Concern	Stable
10.	Gadamsa guddaa/yekola agazen/የቆላአጋዝን	Greater kudu	*Tragelaphus strepsiceros*	Least Concern	Stable
11.	Gadamsa xinnaa	Lesser kudu	*Tragelaphus imberbis*	Near Threatened	Decreasing
12.	Tiring/ጥርኝ	African civet	*Viverra civetta*	Least Concern	Unknown
13.	Midako/kuruphoo ሚዳቆ	Duicker	*Philantomba monticola*	Least Concern	Decreasing
14.	Ses/ሰስ	Klipspringer	*Oreotragus oreotragus*	Least Concern	Stable
15.	Dalga ambessa/ዳልጋአንበሳ	Caracal	*Caracal caracal*	Least Concern	Unknown
16.	Nebr/ ነብር	Leopard	*Panthera pardus*	Vulnerable	Decreasing
17.	Ambessa/አንበሳ	Lion	*Panther leo*	Vulnerable	Decreasing
18.	Tota/Qamale/ ጦጣ	Vervet monkey	*Chlorocebus pygerythrus*	Least concern	Decreasing
19.	Gadamsa/ጋዳማሳ	Thomson's gazelle	Eudorcas thomsonii	Least concern	Decreasing
20.	Xaddee/jaart/ጃርት	Crested Porcupine	*Hystrix cristata*	Least concern	Unknown
21.	Mongoose	Mongoose	*Herpestidae*	Least Concern	Unknown
22.	Aboshemane/አቦሸማኔ	Cheetah	*Acinonyx jubatus l/r*	Vulnerable	Decreasing

B. Reptiles

Five species of reptiles were recorded based on interviews with the local communities and natural resources experts of Woredas. One of these, the African Spurred Tortoise was

assigned an IUCN conservation category of Endangered. This species was recorded only at a single location during the field work.

Table 4. Reptile Species in the Project Area

No	Amharic/oromic name	English or common name	Scientific name	IUCN category	Population trend
1.	Eli/ ኢሊ	African spurred Tortoise	*Centrochelys sulcata*	Endangered	Decreasing
2.	Bofa/እባብ	Snakes	*Serpentes*	Not assessed	Unknown
3.	Enshlalit/ እንሽላሊት	Lizard	*Lacertilia*	Not assessed	Unknown
4.	Isist /እስስት	Smooth chameleon	*Chamaeleo laevigatus*	Least Concern	Unknown
5.	Zendo/ዘንዶ	African Python	*Python sebae*	Not assessed	Unknown

II. Threatened animal species of the project area

1. Panthera pardus

Common local name: ነብር

Common English name: Leopard

Scientific name: *Panthera pardus*

Population trend: Decreasing

Conservation status:

Threats to this species in the project area: degradation of the *Acacia* shrubland due to overgrazing by goats& camels, expansion of settlement and agriculture.

Distribution of Panthera pardus in the project area: It occurs in parts of the project area (Fig, 20). Its population trend is decreasing. The project area is *Acacia* shrubland, which is one of the multiple natural habitats of this species.

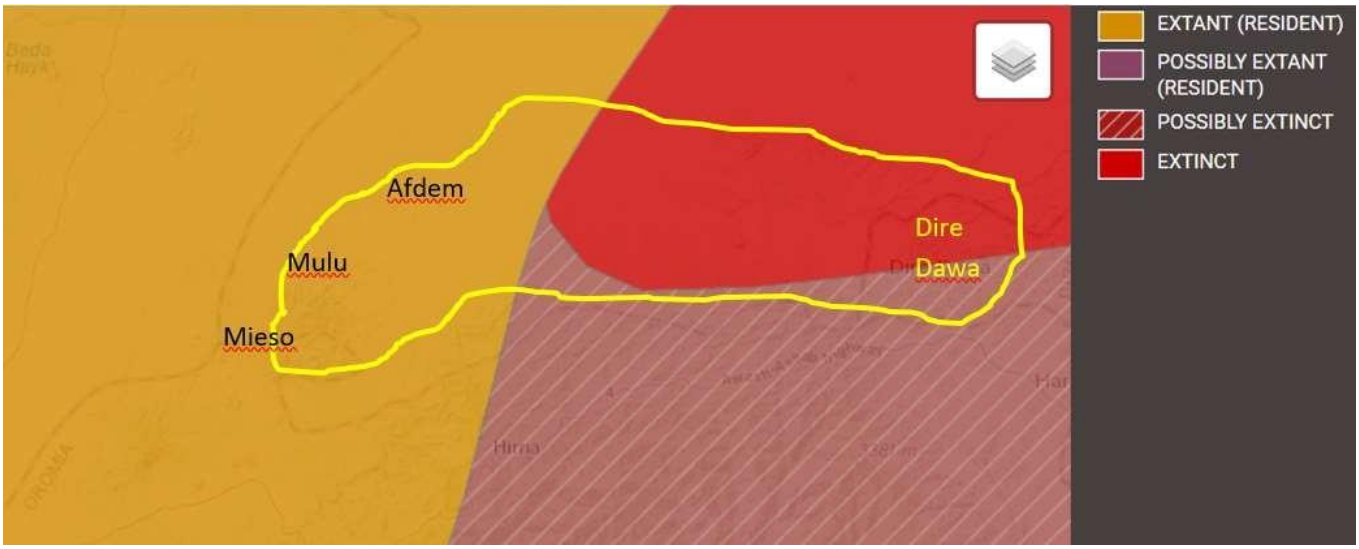


Fig. 20. Geogrpahic range of Panthera pardus (Leopard in the project area).

Source: https://www.iucnredlist.org/species

2. *Hyaena hyaena*

Common local name: ጅብ

Common English name: Stripped Hyaena

Scientific name: *Hyaena hyaena*

Population trend: Decreasing

Conservation status:

*Threats to this species in the project area:*degradation of the *Acacia* shrubland due to overgrazing by goats &camels, expansion of settlement and agriculture.

Distribution of Hyaena hyaena in the project area: throughout Ethiopia

3. *Tragelaphus imberbis*

Common local name:

Common English name: Lesser Kudu

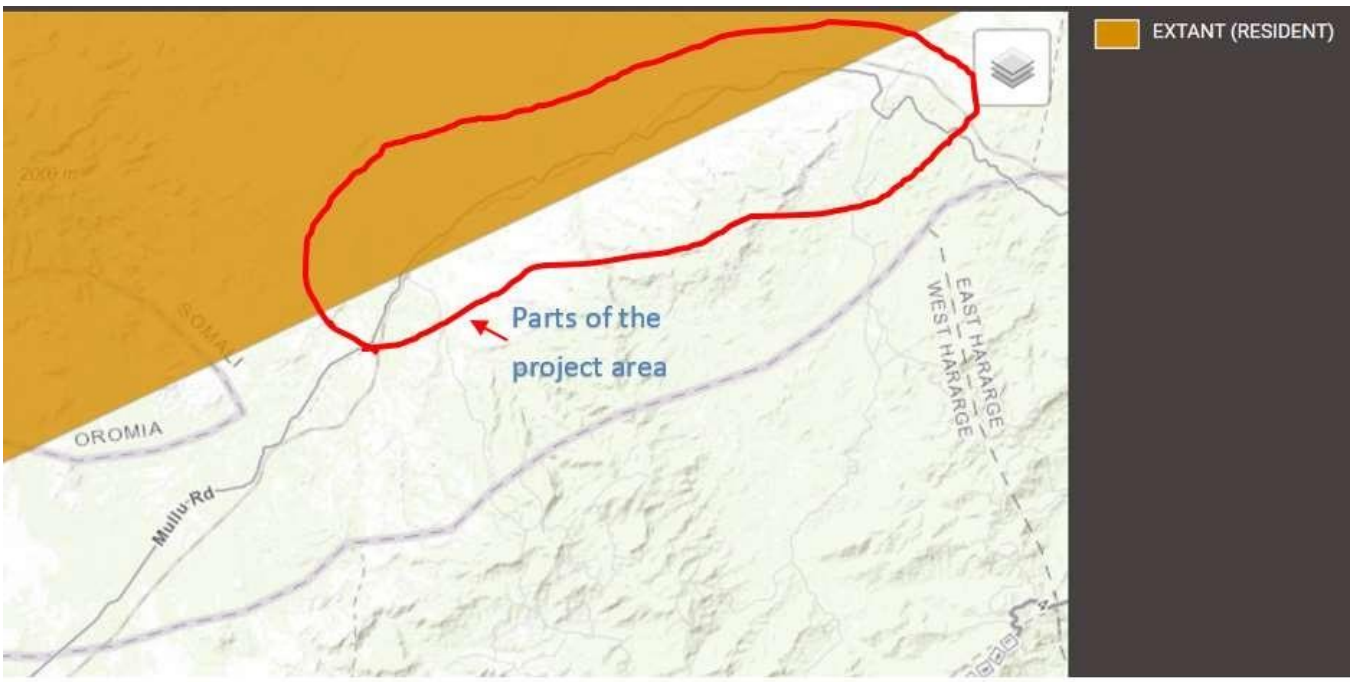
Scientific name: *Tragelaphus imberbis*

Population trend: Decreasing

Conservation status:

Threats to this species in the project area: degradation of the *Acacia* shrubland due to overgrazing by goats& camels, expansion of settlement and agriculture.

Distribution of Tragelaphus imberbis in the project area:



4. *Centrochelys sulcata*

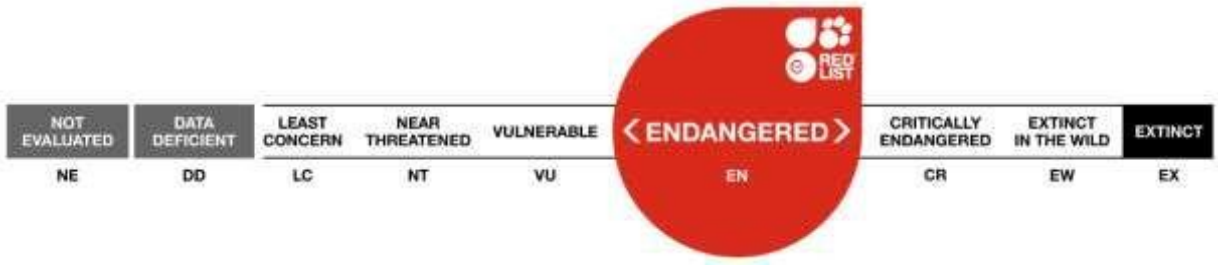
Common local name: ኤሊ

Common English name: African spurred Tortoise

Scientific name: *Centrochelys sulcata*

Population trend: Decreasing

Conservation status:



Threats to this species in the project area: The natural habitats of this species are shrubland and grassland. The continuous decline of the area, extent and quality of their habitats are major threats to this survival of this species. It has a generation year of 30 years, and it is assessed as endangered due to the degradation of its habitats, ongoing desertification and its decreasing populations.

4.3.2. Bird Diversity of the Project Area

Bird species diversity

A total of 43 bird species were recorded from the project areas. The red list category recorded for most bird species is Least Concern (LC) although the population trends are different, i.e., increasing in some and decreasing in others in others (Table 5). The population trends of some least concern speciesare stable. These species were recorded along the RoW and access roads of the project area.

Table 5. IUCN red list of bird species of the project area

No	English or common name	Scientific name	Population trend	IUCN conservation category
1.	Abyssinian roller	*Coracias abyssinicus*	Increasing	Least Concern
2.	Little Bee-eater	*Merops pusillus*	Decreasing	Least concern
3.	Superb starling	*Lamprotornis superbus*	Unknown	Least concern
4.	Greater Blue-eared Starling	*Lamprotornis chalybaeus*	Stable	Least Concern
5.	Ruppell's Starling	*Lamprotornis purpuroptera*	Not Assessed	Not assessed but it is widely distributed in different parts of Ethiopia
6.	Red-billed hornbill	*Tockus erythrorhynchus*	Stable	Least concern
7.	Eastern Yellow-billed hornbill	*Tockus flavirostris*	Decreasing	Least concern
8.	Red-cheek Cordon-bleu	*Uraeginthus bengalus*	Stable	Least concern
9.	Namaqua dove	*Oena capensis*	Increasing	Least concern
10.	Ruppell's Weaver	*Ploceus galbula*	Unknown	Not assessed but it is commonly found in dry areas (*Acacia* shrubland) and cultivated areas (cf. https://ebird.org/species/ruewea1)
11.	White-browed Coucal	*Centropus superciliosus*	Stable	Least Concern

12.	Emerald-spotted wood Dove	*Turtur chalcospilos*	Stable	Least Concern
13.	Cinnamon-breasted Bunting	*Emberiza tahapisi*	Stable	Least Concern
14.	Cut-throat Finch	*Amadina fasciata*	Stable	Least Concern
15.	Bristle-crowned Starling	*Onychognathus salvadorii*	Stable	Least Concern
16.	Red-billed Qealea	*Quelea quelea*	Stable	Least Concern
17.	Northern Red Bishop	*Euplectes franciscanus*	Stable	Least Concern
18.	White-browed Coucal	*Centropus superciliosus*	Stable	Least Concern
19.	Ring-necked Dove	*Streptopelia capicola*	Increasing	Least Concern
20.	Red-eyed Dove	*Streptopelia semitorquata*	Increasing	Least Concern
21.	Nile Valley Sunbird	*Hedydipna metallica*	Stable	Least Concern
22.	Yellow-breasted Barbet	*Trachyphonus margaritatus*	Stable	Least Concern
23.	Northern White-crowned Shrike	*Eurocephalus ruppelli*	Stable	Least Concern
24.	White-crested Helmetshrike	*Prionops plumatus*	Stable	Least Concern
25.	Sombre rockchat	*Oenanthe dubia*	Unknown	DD (Data Deficient)
26.	White-throated Bee-eater	*Merops albicollis*	Stable	Least Concern
27.	Striolated Bunting	*Emberiza striolata*	Increasing	Least Concern
28.	Grey-headed Kingfisher	*Halcyon leucocephala*	Stable	Least Concern
29.	Hamerkop	*Scopus umbretta*	Stable	Least Concern
30.	Little ringed Plover	*Charadrius dubius*	Stable	Least Concern
31.	White-bellied Go-away-bird	*Criniferoides leucogaster*	Stable	Least Concern
32.	Black-bellied sunbird	*Cinnyris nectarinioides*	Stable	Least Concern
33.	Eurasian Hoope	*Upupa epops*	Decreasing	Least Concern
34.	Red-billed Oxen Pecker			
35.	Chestnut-naped Francolin	*Pternistis castaneicollis*	Stable	Least Concern
36.	Augur Buzzard	*Buteo augur*	Stable	Least Concern
37.	Fork-tailed Drongo	*Dicrurus adsimilis*	Stable	Least Concern
38.	Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	Stable	Least Concern
39.	Abyssinian Scimitarbill	*Rhinopomastus minor*	Decreasing	Least Concern
40.	Abyssinian Ground-hornbill	*Bucorvus abyssinicus*	Decreasing	Vulnerable
41.	Common Bulbul	*Pycnonotus barbatus*	Increasing	Least Concern
42.	White-headed Buffalo-weaver	*Dinemellia dinemelli*	Stable	Least Concern
43.	Red-billed Buffalo-weaver	*Bubalornis niger*	Stable	Least Concern

Migratory corridors and Important Bird Areas of Ethiopia

In Ethiopia, there are 69 Important Bird Areas covering at least 47,757 km^2 but there are no Important Bird Areas inside the project area (Fig. 21).

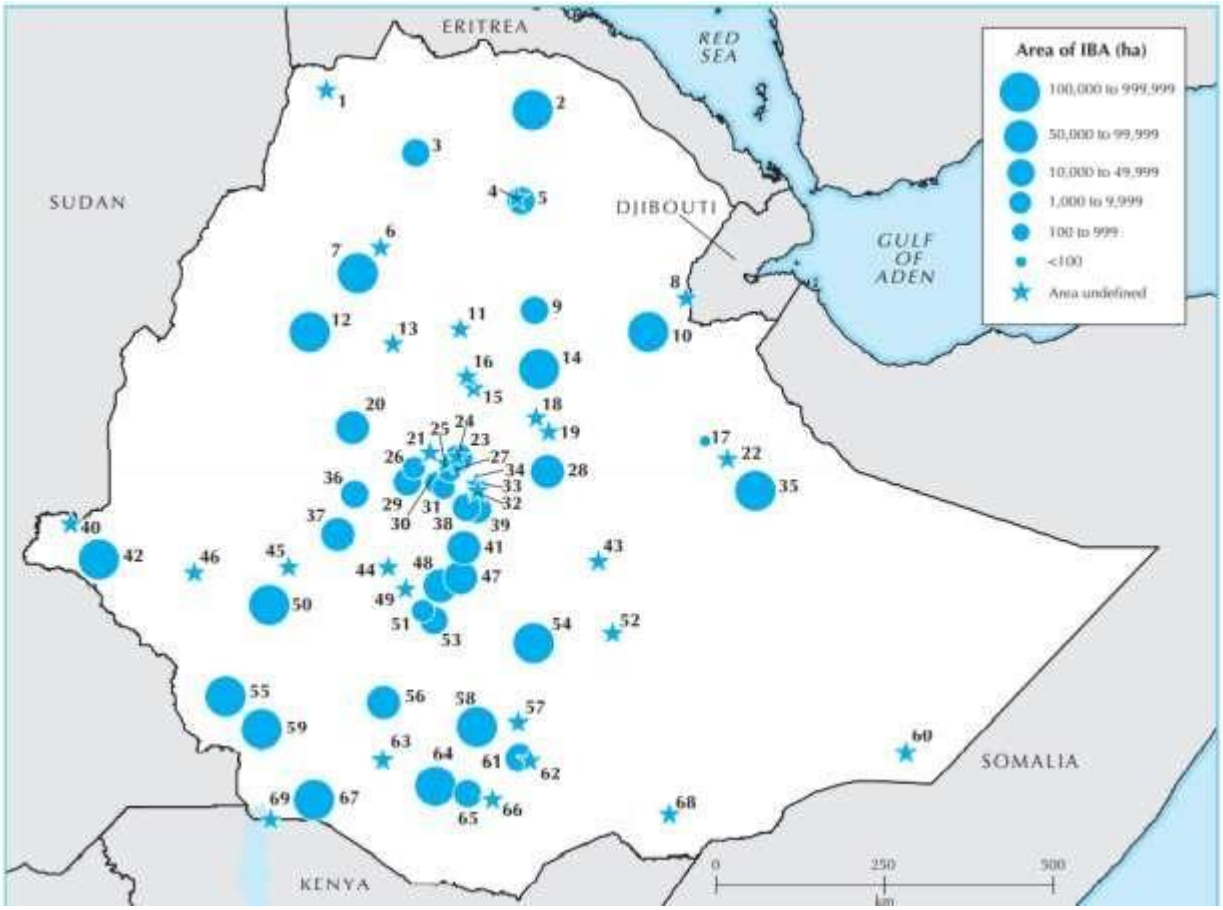


Fig. 21. Important Bird Areas of Ethiopia

Globally, there are 8 major migratory bird flyways. The East Asia – East Africa Flyway passes through Ethiopia and used as a major passage for a number of bird species (https://www.birdlife.org/worldwide/programmes/migratory-birds). Detailed literature survey and field records show that there are no non-breeding sites for migratory birds in the project area. One of major non-breeding sites for migratory bird in Ethiopia are the Great Rift Valley Lakes and their surrounding habitats (e.g. a Palaearctic– African migrant, Willow Wabler, *Phylloscopus trochilus,* Fig. 22). Lake Tana, Lake Chalalaka and other areas in Ethiopia are also non-breeding sites for migratory birds.

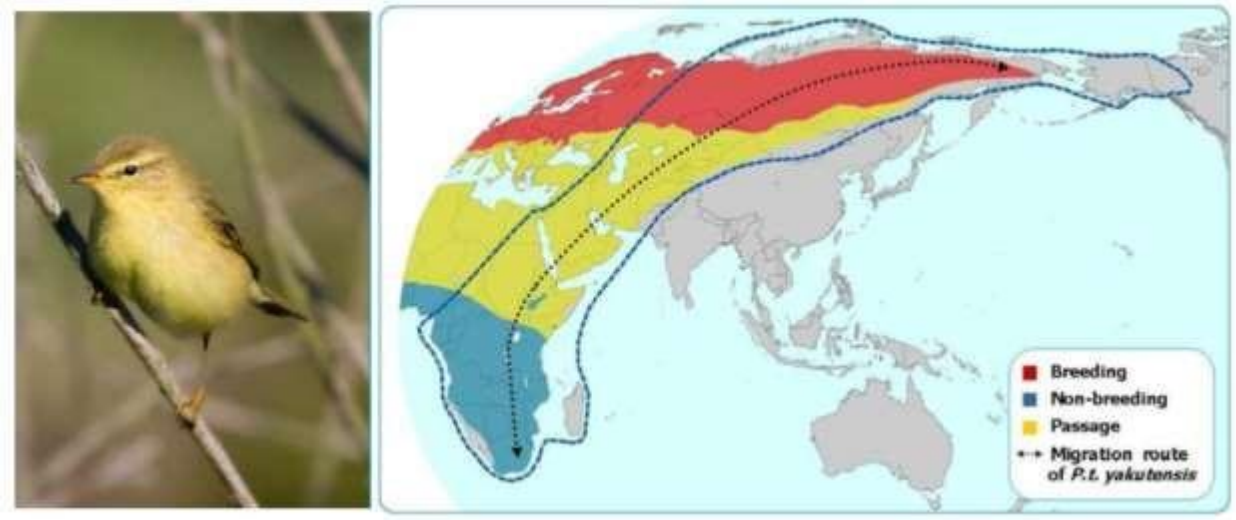


Fig. 22. Major East Asia-East Africa Flyway – breeding and non-breeding sites of Willow Wabler(*source*: Microsoft Word - East Asia - East Africa Factsheet.doc (birdlife.org))

There are intra-African and Intra-Ethiopian migratory birds. The observation of black-bellied sunbird in the study area during the field work exemplifies intra-Ethiopian migration, i.e., northward migration of this species. Furthermore, the project area is also a passage for some intra-African migratory bird, for example, Diederik Cuckoo, *Chrysococcyx caprius* (Fig. 23). This species is also native breeding in some parts of Ethiopia. However, the red list IUCN category of this species is Least Concern because of its large range, i.e., its Extent of Occurrence is 30,000,000 km^2 (Birdlife International, 2021).

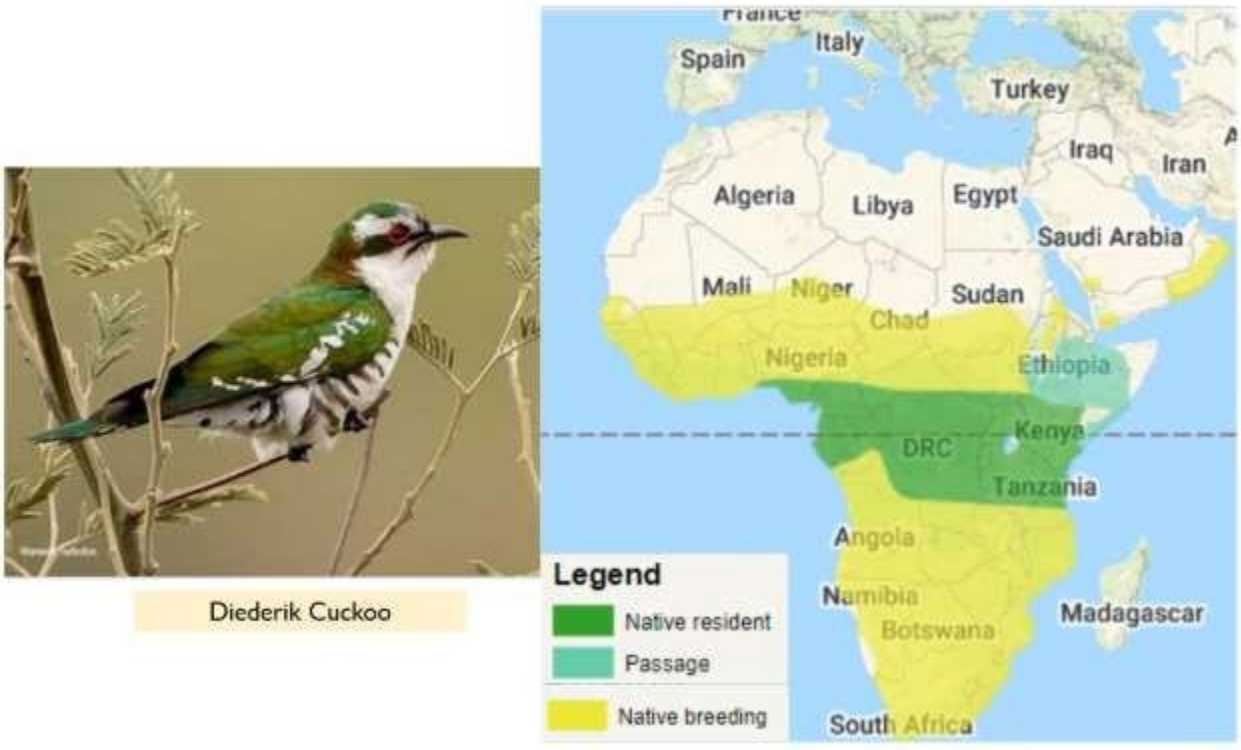


Fig. 23. Intra-African migratory bird, Diederik Cuckoo (source: modified after Birdlife International, 2021).

4.3.3. IUCN Conservation Status of Birds of the Project Area

Most of the bird species of the project area (75%) have stable population trend (Fig. 24). Whereas some species of least concern (9%) have a decreasing population trend, others (16%) are characterized as with an increasing population trend. Noteworthy is that none of the recorded bird species of the study show any immediate conservation concern.

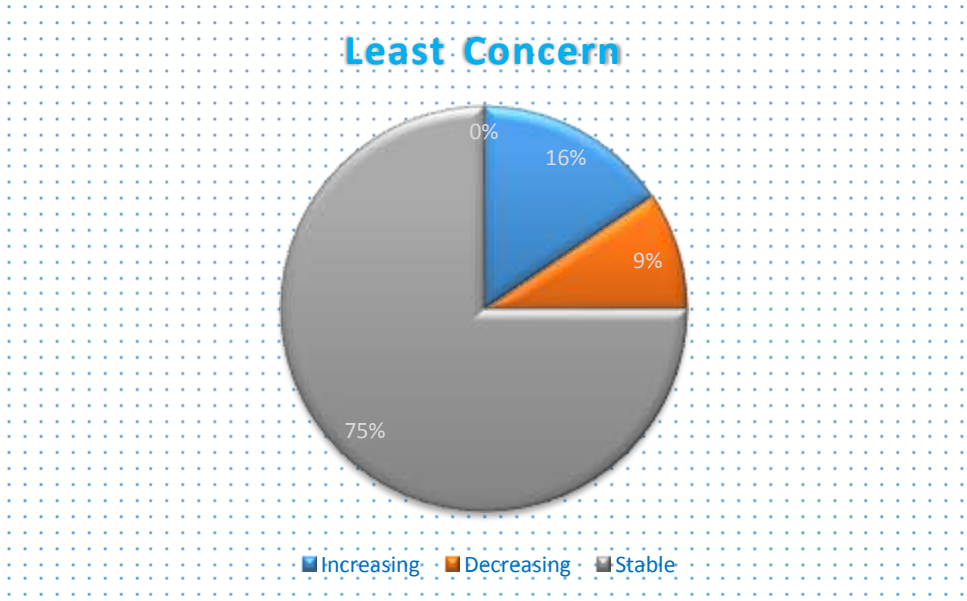


Fig. 24 Population trend of bird species with IUCN status of Least Concern

4.4. Key Biodiversity Area (KBAs) of the Project Area

There are two Key Biodiversity Areas (KBAs) in the project area (Fig. 25). These are the Afdem – Gewane Controlled Hunting Area and the Dengago – Melka Jebdu National Forest Priority area. Sections of the Mieso – Dire Dawa Expressway crosses these KBAs. Parts of theproject area of influence (both direct and secondary impact zones) falls inside KBAs.

Fig. 25. Key Biodiversity Areas of the project area.

4.4.1. The Afdem – Gewane Controlled Hunting Area

One Key Biodiversity Areas of the Project area is the Afdem – Gewane Controlled Hunting area (Fig. 26). The Mieso – Dire Dawa Expressway crosses this KBAs falling between Mieso and Erer. This KBA was designated as Protected Area and classified as IUCN Management category.

The IUCN Management Category VI is characterized as a protected area with sustainableuse of natural resources. This Afdem – Gewane controlled Hunting Area was designated to conserve ecosystems and habitats with associated cultural values and traditional natural resources management. This type of KBA is usually large with most portions in natural conditions. However, the current status and threats of the Afdem – Gewane Controlled Hunting Area are given below.

Fig. 26. Afdem – Gewane Controlled Hunting Area

Historical and Current status of the Afdem - Gewane Controlled Hunting Area

A series of historical Google Earth images of the project area have shown a visible qualitative changes of the vegetation cover of the project area (Fig. 27). The main causes are overgrazing and over browsing, agricultural expansion, expansion of urban settlement and expansion of rural settlement due to increased population.

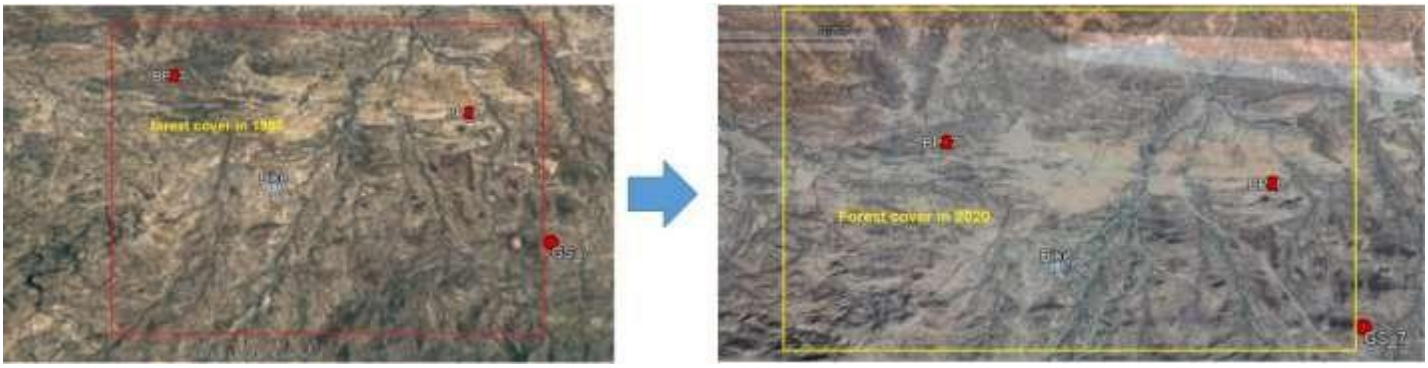


Fig. 27. An example of qualitative change of the vegetation cover of Afdem – Gewane Controlled Hunting Area around Bike area in 1990 and 2020.Key: BP_7 = Borrow pit-7; BP_8 = Borrow pit-8; GS_7 = Gravel source-7

In 2020, the part of the Afdem – Gewane Key Biodiversity Area has been degraded due tourban expansion

The Afdem – Gewane Controlled Hunting Area from Mieso – Mulu towns was relatively dense and in a natural condition in 1990 (Fig. 28). The expansion of urban settlement and agriculture have played key roles for the degradation of the vegetation cover of this KBA.

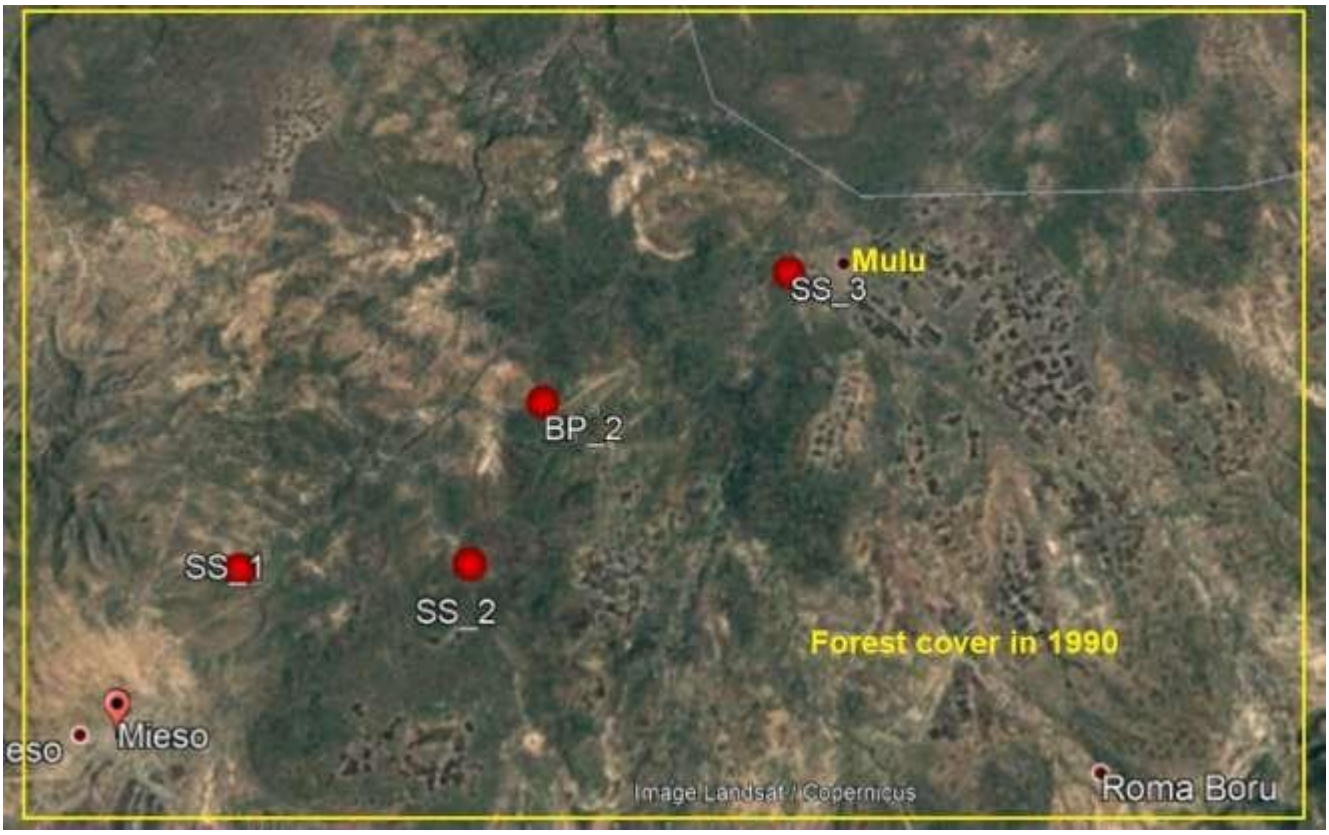


Fig. 28. Historical vegetation cover of Afdem – Gewane Controlled Hunting Area and current condition from Mieso – Mulu towns in 1990. Key: SS-1 = sand source-1; SS-2 – sand source-2; SS-3 = sand source-3; BP-2 = Borrow pits-2

In 2020, the vegetation cover of this section of the Afdem – Gewane Controlled Hunting area has been degraded due to the expansion of urban settlement and agriculture (Fig. 29). There was also a high level of charcoal extraction from the Afdem – Gewane Controlled Hunting Area from Mieso – Mulu towns in the 1990s up until 2015 (interview with Mulu and Mieso Woreda Natural Resources Expert). Charcoal trade has been so extensive that the local communities have used camels to travel to Chiro and other parts to sale their charcoal products. Local vendors have also used Mieso as their center for buying and storing charcoal for national market. In addition to urban and agricultural expansion, unprecedented charcoal production in the Afdem – Gewane Controlled Hunting Area is believed to have contributed significantly to the degradation of the vegetation cover and selective cutting of big *Acacia* trees.The absence of charcoal production in this section of the KBA of the project area is entirely because all mature trees of *Acacia* species are totally cut.

Fig. 29. Historical vegetation cover of Afdem – Gewane Controlled Hunting Area and current condition from Mieso – Mulu towns 2020.Key: SS-1 = sand source-1; SS-2 – sand source-2; SS-3 = sand source-3; BP-2 = Borrow pits-2

Charcoal production and firewood collection were recorded in the other section of the KBA of the project area (Fig. 30). This activity will result in the cutting of all, highly scattered mature trees of *Acacia* species from the Afdem – Gewane Controlled Hunting Area of the project.

Fig. 30. Charcoal production between Bike and Erer towns; A, Charcoal; B, firewood

Currently, the vegetation cover of the Afdem – Gewane Controlled Hunting Area from Mieso – Mulu towns has been highly degraded and dominated by a succulent, weedy plant species called *Opuntia ficus-indica* (Fig. 31). This species is economically important fruit and fodder crop. In areas where this species is dominant, there is a homogenization of the composition of the plant communities of the project area, i.e., reduction in species diversity. There is a noticeable invasion of the plant communities of the project area by Opuntia ficus-indica. If this trend continues, the species composition of the current plant communities of the project area will be negatively affected. This unabated invasion of this KBA by *O. ficus-indica* will result in homogenized plant communities in the project area with depauperated native flora and biodiversity.

Fig. 31. Vegetation cover between Mieso – Mulu towns dominated by a weed plant species, *Opuntia ficus-indica*.

Threats to the Afdem - Gewane Controlled Hunting Area

The portion of this KBA falling in the influence zone of the Mieso – Dire Dawa Expressway is highly degraded due to two major anthropogenic driven threats. These are described as follows.

a. Overgrazing and over browsing of the vegetation

The project area is home to pastoral communities with a large herd of livestock. The local communities keep a large number of goats, sheep and camel. This project area has experienced heavy overgrazing and over browsing over years, which has degraded the vegetation and negatively affected natural regeneration (Fig. 32).

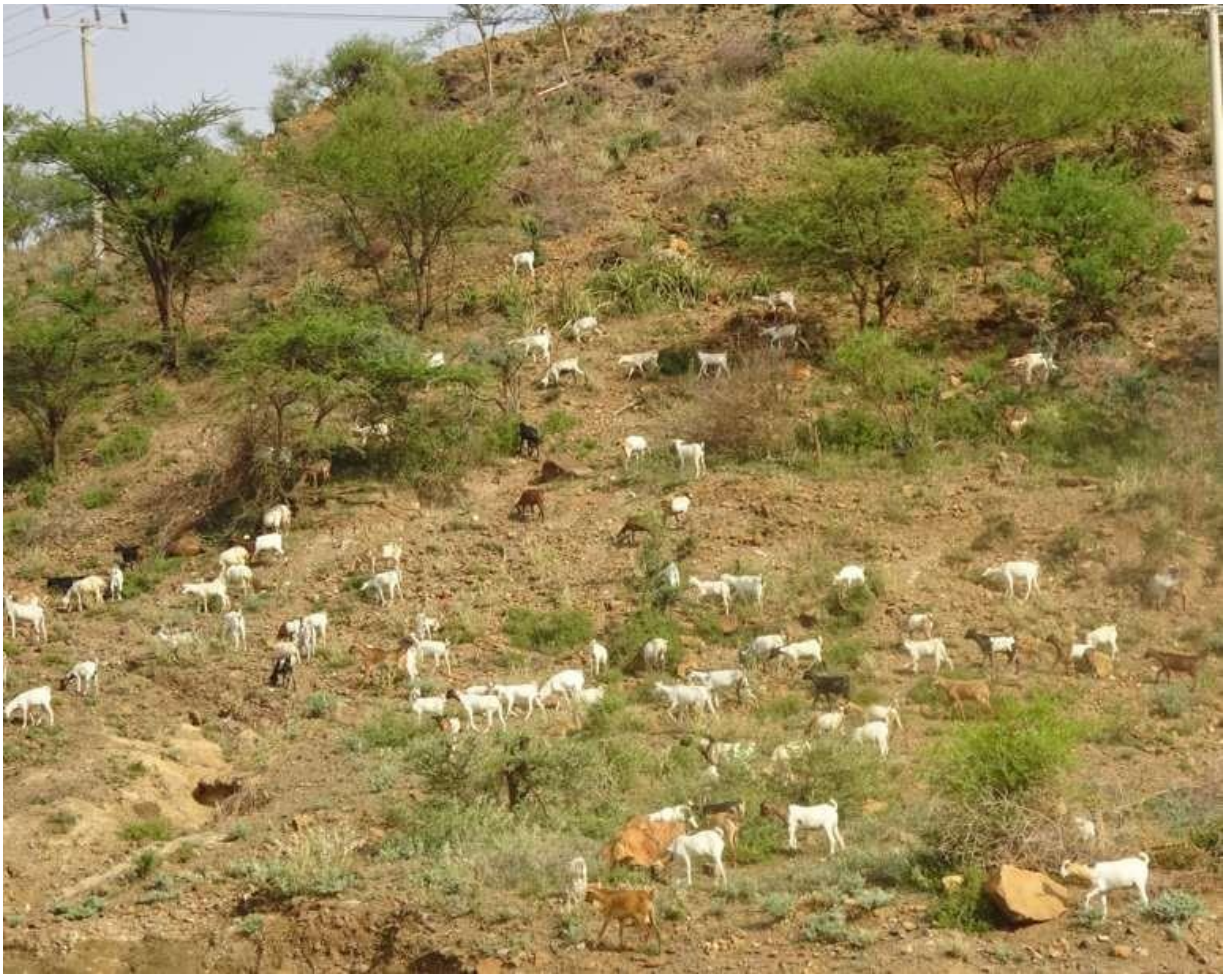


Fig. 32. A large number of goats browsing in the project area

Plant species of the project area were heavily over browsed. Such over browsing has negatively affected coppicing, i.e., repeated over browsing coppiced shrubs and trees has induce stunted growth and degradation of vegetation cover.

b. Alien invasive species

Some areas of the Afdem – Gewane Controlled Hunting Area have been infested with an alien invasive species, *Prosopis juliflora* (Fig. 33). This species is an evergreen shrub which causes degradation of native biodiversity and grazing areas in the arid environment such as the Mieso – Dire Dawa Expressway project area. It is a native plant to Mexico, central and northern South America. It was introduced to Ethiopia to increase wood availability and restoration of degraded areas. A recent study in Afar region has revealed the new dimension of the impacts ofthis aggressive invasive species on livelihoods, i.e., it diminishes water resources (Shiferaw et al., 2021). This study has reported the following findings.

- The transpiration of an individual tree is 7 L/day.
- The average evapotranspiration of a dense stand of *Prosopis juliflora* is 3.7 (±1.6) mm per day.

- With an area cover of 1.18 million ha, water use of *Prosopis juliflora* was estimated to be 3.1 – 3.3 m^3/year. This volume of water can irrigate a total of 460,000 ha of cotton or 330,000 ha of sugar cane. The total economic impact will be 320,000 US Dollars of cotton value or 420,000 US Dollars for sugar cane.

With the current rate of the expansion of *Prosopis juliflora*, most of the areas of the Afdem – Gewane Controlled Hunting Area will be covered by thick, impenetrable thickets of this species. As of result of this, this species will seriously reduce water resources of the project area affecting livelihoods and degraded native biodiversity and rare, endemic plants of the project area. Therefore, the rapid expansion of *Prosopis juliflora* affects ecosystem services such as water availability of the project area, results in ecosystem degradation, changes species composition and alters functioning of the terrestrial ecosystem of the project area.

Fig. 33. Portion of the Afdem – Gewane Controlled Hunting Area infested with alien invasive species, *Prosopis juliflora*

c. Expansion of urban settlement and agriculture

There is a steady increase in the expansion of urban settlement and agriculture in the portion of Afdem – Gewane Controlled Hunting Area falling in the project area (Fig. 34). In 1990, this KBA was in its natural condition with less anthropogenic disturbance as evidenced by spare settlement both in the urban and rural areas. In 2020, there was an increase in urban settlement and agriculture inside the Afdem – Gewane Controlled Hunting Area in the project area, e.g. Mieso town and its surroundings. This has led to degradation of vegetation cover due to anthropogenic impacts.

Fig. 34. Urban settlement and Agriculture inside Afdem – Gewane Controlled Hunting Area around Mieso. A, overview of Mieso town; B, Sorghum field close to the beginning stretch of the Mieso – Dire Dawa Expressway at Mieso town.

At around the beginning of point of the Mieso – Dire Dawa Expressway, agricultural expansion and settlement has converted the Afdem – Gewane Controlled Hunting Area into a simplified landscape with scattered tree (Fig. 35). These scattered trees of Grewia mollis is a source for food for birds. Furthermore, local communities use to store dry hay for their livestock.

Fig. 35. View of the altered vegetation of the Afdem – Gewane Controlled Hunting Area due to anthropogenic impacts at around Mieso town

4.4.2. The Dengego – Melka Jebdu National Forest Priority Area

The Dengego – Melka Jebdu National Forest Priority Area (NFPA) is one of the 58 NFPAs of Ethiopia (Fig. 36). Some section of the Mieso – Dire Dawa Expressway crosses part of this NFPA. The historical vegetation cover of this NFPA and its threats are describes below.

Fig. 36. The Dengego – Melka Jebdu National Forest Priority Area in the project areas.

The blue Circle represents (Fig. 36) relative location of the part of the Dengego – Melka Jebdu NFPA in the project area that has been severely affected by expansion of urban settlement and agriculture and invasion by *Prosopis juliflora* between 1985 and 2020. The reported area of this NFPA is 536.19 km^2 (UNEP-WCMC and IUCN, 2021).

Historical and Current status of the Dengego - Melka Jebdu National Forest Priority Area

The vegetative cover of the portion of the Dengego – Melka Jebdu National Forest Priority Area falling inside the project area was relatively dense in 1985 (Fig. 37). The vegetation coverwas relatively dense and settlements were confined to a small area in Melka Jebdu village. DireDawa town was confined to areas well below the forest cover indicated in the circle.

Fig. 37. Vegetation cover of the Dengego – Melka Jebdu NFPA in 1985 based on historical Google Earth Image

In 2020, the vegetation cover of the Dengego – Melka Jebdu has been significantly reduced (Fig. 38). The vegetation was replaced by the expansion of urban settlement and agriculture. The major driving factor for the degradation of the part of this NFPA close to Dire Dawa is the expansion of urban settlement and agriculture. Currently, the part of the Dengego – Melak Jebdu NFPA in the project area is a degraded *Acacia* woodland with open spaces and scatteredtrees. Currently, the part of this NFPA in the project area is degraded and replaced by dense stands of *Prosopis juliflora*, settlement and Sorghum fields.

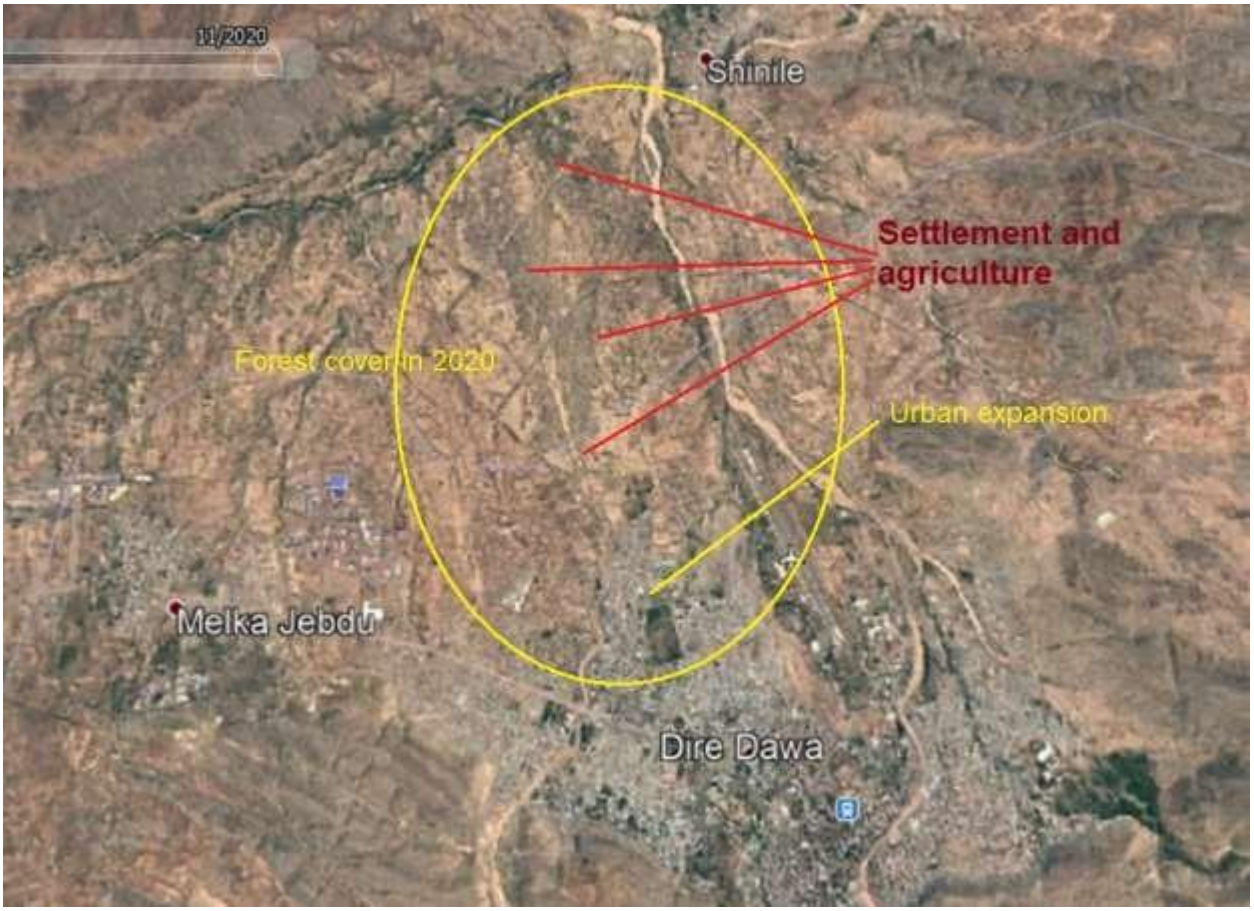


Fig. 38. Current vegetation cover of portion of Dengego – Melka Jebdu NFPA in the project area (Google Earth Image)

Threats to the Dengego - Melka Jebdu National Forest Priority Area of the project area

The following threats were recorded during the field visit.

a. Expansion of an invasive *Prosopis juliflora*

This aggressive alien invasive species is overtaking the natural vegetation. Details of environmental and livelihood impacts of the expansion of *Prosopis juliflora* are given above.

b. Overgrazing and over browsing of the vegetation

There are large populations of livestock in the area. Overgrazing and browsing is another major factor negatively affecting the health of the natural habitats and native biodiversity.

c. Expansion of urban settlement and agriculture

There is unprecedented expansion of urban settlement into the part of this NFPA falling inside the project area. The combined effects of these anthropogenic factors have resulted in degradation and complete deforestation of the portion of this NFPA of the project area.

4.5. Biodiversity Corridors

The first 30 – 35 km of the project road, particularly the Mieso – Mulu section is comparatively

dense, and it is in its natural state. This section is close and contiguous to other protected habitats (outside of the project influence area), namely the Aledeghi wildlife reserve and the Awash national park. This part of the project road could be a potential biodiversity corridor and should be given due attention. Further, surface water bodies (whether perennial or intermittent) have comparatively dense vegetation and can serve as a steppingstone for wildlife movement. Moreover, the comparatively dense habitats can also serve as refuges.

The existing conservation status of these potential biodiversity corridors, however, is similar to the entire project influence area, which is affected by over grazing and browsing, expansion of smallholders rainfed agriculture, and urban expansion resulting in habitat degradation and fragmentation. For instance, historical satellite image comparison for the Mieso – Mulu sections shows a significant reduction in vegetation cover over the last two decades. This is due to agricultural and urban expansion. Also, charcoal production is widely practices in this area, resulting in further exploitation of the vegetation cover.

At the backdrop of the current condition of the potential biodiversity corridors (which can be described as deteriorating due to years of anthropogenic intervention), implementation of the project road could exacerbate the situation if not properly managed. The main anticipated impacts on the biodiversity corridors include:

- Fragmentation of the biodiversity corridors through construction of an access controlled expressway, link roads, and also during operation of ancillary facilities. Vegetation clearing for the road RoW and ancillary facilities will fragment the corridors into parts or patches which may not be viable as individual ecosystems and species with in them could be significantly affected. The project components will cut-off the biodiversity corridors into pieces which could lead to breakdown of ecological processes such as species movement, migration, dispersal, interbreeding/crossbreeding and genetic variability, gene flow, recycling of nutrients, food availability, maintenance of biodiversity, and functions which are vital for the viability of the corridors.
- Fragmented biodiversity corridors could ultimately lead to reduction in species population, and potential extinction of plant and animal species.
- Implementation of the project road is expected to affect the water resources available in the project area, both in terms of quantity and quality. Potential use of water for construction activities and consumption by the project workers could compete and reduce water availability for ecological purposes. Further, construction activities could compromise the quality of surface and groundwater resources through sedimentation and contaminant transfer. Surface water sources where vegetation is comparatively thick are expected to serve as biodiversity corridors for both terrestrial and aquatic organisms. Impact on these water bodies will affect the ecological processes which makes them a viable ecological corridors.

The following table summarizes the potential impacts on biodiversity corridors due to project implementation in comparison with the baseline conditions of the corridors.

Table 6. Summary of With and Without Project Effects on Biodiversity Corridors

	Without Project (Baseline)	With Project (If not properly managed)
Existing conditions	- Over grazing and browsing, expansion of smallholders rainfed agriculture, and urban expansion resulting in habitat degradation and fragmentation - Also, charcoal production has significantly affected the potential ecological corridors	- The existing conditions of potential ecological corridors is expected to be further affected by project activities if not properly managed
Major impacts	- The current anthropogenic interventions and destruction of habitats will continue due to population pressures and unsustainable resources utilization	- Habitats fragmentation - Habitats loss/destruction - Impact on water resources, both in terms of quantity and quality
Ecological processes	- Species movement - Migration - Dispersal - Interbreeding/crossbreeding - Gene flow and genetic viability - Recycling of nutrients (water, carbon, nitrogen, etc) - Food availability - Escape route for predators	- Restricted species movement - Restricted migration - Limited dispersal - Inbreeding and reduced viability - Restricted gene flow - Affected nutrient equilibrium and ecosystem functions - Limited food availability and competition for food - Modification of animal behavior (altered movement pattern, reproductive success, escape response, and physiological state

4.6. Critical/Sensitive Habitats

The critical/sensitive habitats assessment considered areas with high biodiversity value. This includes areas that meet the following criteria:

- Criterion 1 - Significant importance to critically endangered or endangered species
- Criterion 2 - Significant importance to endemic or restricted range species
- Criterion 3 - Support migratory or congregatory species
- Criterion 4 - Highly threatened or unique ecosystems
- Criterion 5 - Ecological functions or characteristics needed to maintain the viability of biodiversity values.

Further details of the above criteria are provided under Section 3.1.4. The following table summarizes analysis made to determine the presence of critical habitats in the two KBAs and in the project area of influence outside the two KBAs.

Table 7. Summary of Critical Habitats Assessment in the Project Area of Influence

Criteria	Road Corridor within or near the Afdem – Gewane KBA	Road Corridor within the Dengego – Melka Jebdu KBA	Road Corridor outside of the Two KBAs
1. Critically endangered or endangered species	*Centrochelys sulcate* (African spurred tortoise) is an endangered species based on the IUCN classification and extant in shrubland and grassland habitats common to the KBA. It is difficult to determine the discrete management unit(s) due to the wide range of the species in the KBA.	*Aloe harlana* is an endangered species based on the IUCN classification and its population is decreasing. It is mostly available in the Dengego – Melka Jebdu KBA which can be considered as a discrete management unit.	*Centrochelys sulcate* is extant in shrubland and grassland habitats common to the project area of influence. It is difficult to determine the discrete management unit(s) due to the wide range of the species in project area of influence.
2. Endemic or restricted range species	No endemic or restricted-range species identified in this KBA	*Aloe harlana* and *Aloe pubescens* are endemic species available mostly in the Dengego – Melka Jebdu KBA and adjoining areas. The KBA can be considered as a discrete management unit for these species.	No endemic or restricted-range species identified in the project road area of influence outside of the two KBAs.
3. Migratory or congregatory species	There are no non-breeding sites for migratory birds in the project area. However, the project area is a passage for some inter-African migratory birds such as Diederik Cuckoo (this species is of least concern based on IUCN Red List). There is no migratory or congregatory animal route or areas in the project area of influence.		
4. Highly threatened or unique ecosystems	Although data is insufficient, this KBA is possibly highly threatened due to environmental degradation and disruption of biotic processes / interactions because of anthropogenic activities (such as over grazing / browsing, urban and agricultural expansion) and invasive species. Also, the *Balanites aegyptica* – *Acalypha fruiticosa* riverine plant community (such as at Wangayo river) is high degraded and species poor.	The *Aloe megalacantha* – Acacia mellifera plant community near the end of the project road is of great conservation concern. The community has the two endemic Aloe species. The occurrence of *Prosopis juliflora* in a threat to this plant community. Although data is insufficient, this area is possibly highly threatened due to environmental degradation and disruption of biotic processes.	The project area of influence outside of the two KBAs has either similar conservation status, particularly with the Afdem – Gewane KBA, or has been significantly converted by anthropogenic activities and thus doesn't represent unique ecosystems.
5. Ecological functions or characteristics needed to maintain the viability of biodiversity values	Landscape with high spatial heterogeneity and environmental gradients, which are one of the driving forces for speciation and high species diversity, are not common to or available in the KBA. On the other hand, the KBA is connected with other KBA namely the *Alledeghi* wildlife reserve from the west and the *Yangudi Rassa* national	Part of the KBA overlapping with the project area of influence has no significant landscape heterogeneity and environmental gradient. Further, the KBA is not connected with other habitats of significance. *Aloe harlana* and *Aloe pubescens* species often grows on limestone which is available near the end of the project road. This may	The project area of influence outside the two KBAs has no significant landscape heterogeneity and environmental gradient. It has no measurable characteristics to maintain viability of biodiversity values.

Criteria	Road Corridor within or near the Afdem – Gewane KBA	Road Corridor within the Dengego – Melka Jebdu KBA	Road Corridor outside of the Two KBAs
	park from the north (even though these KBAs are considerably far from the project road area of influence). The section of the KBA which overlaps with the first 30 – 35 km of the project road can be considered as a potential biological corridor which ensures species migration and gene flow.	have resulted in the edaphic interfaces which may led to the formation of the plant community characterized by endemism.	

The results of critical habitats assessment indicated in the above table can be summarized as:

- Section of the project road area of influence in the Dengego – Melka Jebdu KBA can be considered as critical habitat since it triggers Criteria 1 (due to presence of *Aloe harlana* endangered species), Criteria 2 (presence of *Aloe harlana* and *Aloe pubescens* endemic species), Criteria 4 (the *Aloe megalacantha – Acacia mellifera* plant community near the end of the project road has two endemic Aloe species, and its status is of great conservation concern), and potentially Criteria 5 (the presence of limestone and potential edaphic interfaces).
- Sections of the project area of influence in the Afdem – Gewane KBA (particularly areas overlapping with the first 30 – 35 km of the road) can be considered critical habitats since it triggers potentially Criteria 1 (due to the presence of *Centrochelys sulcate* endangered species), Criteria 4 (possibly highly threatened due to environmental degradation and disruption of biotic processes/interactions because of anthropogenic activities), and Criteria 5 (it can be considered as a potential biological corridor).
- Further to the above, the habitat where the endemic species (namely the *Aloe harlana* and *Aloe pubescens*) occur is highly affected by the invasive species *Prosopis juliflora*. The habitat does not provide protection to the endemic species from *Prosopis juliflora*.
- In general, the bulk of the project road (~75%) is aligned either within or in close proximity to the two KBAs. Critical/sensitive habitats are located within these KBAs considering the criteria set above. Although information is insufficient, section of the project road area of influence outside the two KBAs may contain the *Centrochelys sulcate* which could potentially trigger Criteria 1. This section of the road, however, does not satisfy the other criteria.

4.7. Biodiversity Indices

Plant species diversity of the project area has been assesses based on studies conducted within or near the project area of influence. *Shannon's index (H')*, *evenness (H'/Hmax)*, and *Species richness* are used to assess the plant species diversity. The higher the value of Shannon's index the higher the diversity of species in a particular community. Higher values of evenness indicate

higher levels of evenness of species diversity. Evenness value close to 1 indicates all species have the same relative abundance. Higher value of species richness indicates high species diversity.

Tessema et al (2022) conducted plant species diversity assessment along altitudinal gradient in the Dengego area which is part of the Dengego – Melka Jebdu KBA. The average overall vegetation species diversity and evenness were 3.1 and 0.8, respectively.

Table 8. Average Plant Species Diversity, Richness, and Evenness of Dengego – Melak Jebdu Area

Altitude Type	Shannon Diversity Index (H')	Evenness (H'/Hmax)	Species Richness
Lower Altitude	2.8 ±0.8	0.88 ±0.023	17.3 ±7.50
Middle Altitude	3.3 ±0.7	0.84 ±0.03	21.6 ±8.63
Upper Altitude	3.1 ±1.3	0.83 ±0.06	26.2 ±9.83

Based on the above results, the species diversity shows significant difference across the altitude gradient while the evenness is more-or-less close. The lowest diversity index and richness registered for the lower altitude (which is a reflective of the section of the KBA overlapping with the project area of influence) is due to interference by anthropogenic activities such as urban and agricultural expansion, and over browsing/grazing. It could also be due to disturbance in nutrients and moisture which can be influenced by human interference and climatic factors. Anticipated impacts during project implementation and operation, including vegetation clearing and habitats fragmentation due to road RoW and ancillary facilities) could further lower the species diversity and richness in the Dengego – Melka Jebdu KBA if not sufficiently managed.

Mekonnen et al (2012) conducted plant species diversity in Asebot dry Afromontane Forest which is in the Afdem – Gewane KBA, near the start of the project road, i.e., Mieso town. The study shows that species richness in the study area is low compared to other similar habitats. The southeast and northeast habitats of the Asebot forest are close to the project start point and their altitude and vegetation cover are more related to the KBA compared to the others. Species diversity of the Asebot Afromontane Forest is generally low and project activities should not exacerbate the current situation. Construction material extraction sites are often located at hilly areas such as the Asebot forest. Material extraction activities will adversely affect the species diversity of such habitats and should be managed appropriately.

Table 9. Species Diversity in Asebot Forest

Habitat	Shannon Diversity Index (H')	Species Richness
Northeast (Acacia wooded grassland)	0.5271	25
Southeast	0.5590	18
Plateau	0.5179	29
North	0.4862	24

Shiferaw et al (2019) assessed the *Prosopis juliflora* invasion in Afar region, in an area contiguous with the Afdem – Gewane KBA with similar ecological characteristics. The habitats with *Prosopis* invasion generally show lower diversity and richness compared to non-invaded habitats. This is testament to the effect of *Prosopis juliflora* (which is an alien invasive species) on habitat biodiversity. Using results of the study, it can be inferred that the Afdem – Gewane KBA, where most of the project road area of influence lies, has lower species diversity and

richness compared to the Dengego – Melka Jebdu KBA. Moreover, *Prosopis juliflora* further affected species diversity. Project implementation and operation will result in clearing of vegetation, habitats fragmentation, and propagation of invasive species and thus could further deteriorate the species diversity in the KBA if not properly managed.

Table 10. Effect of *Prosopis juliflora* Invasion on Soil Seed Bank Patterns in South Afar Region

Altitude Type	Shannon Diversity Index (H')	Evenness (H'/Hmax)	Species Richness
Prosopis thicket (PT) which contained 25 – 100% of *Prosopis*	1.18 ±0.03	0.93 ±0.01	3.94 ±0.15
Mixed (*Prosopis* + native woody species) < 25% were *Prosopis* individual stems with native species	1.19 ±0.04	0.94 ±0.01	3.83 ±0.013
Non-invaded woodland	1.46 ±0.04	0.93 ±0.01	5.13 ±0.15
Open grazing land as non-invaded habitats without *Prosopis*	1.30 ±0.05	0.94 ±0.01	4.30 ±0.17

Ahmed et al (2015) assessed rangeland browse woody species diversity in Shinile area which can be taken as a representative of the area between and outside of the Afdem – Gewane and Dengego – Melka Jebdu KBAs. The assessment area lies between 9 – 10 latitude and 41 – 42 longitude.

Table 11. Effect Production System on Woody Species Diversity, Evenness, and Richness in Shinile Area (outside of the two KBAs)

Factor Levels and Interaction Effect	Shannon Diversity Index (H')	Evenness (H'/Hmax)	Species Richness
Pastoral Production System			
Riverside grazing	1.08	0.80	4.1
Enclosure grazing	0.88	0.72	3.5
Communal grazing	1.10	0.78	4.2
Agro-pastoral Production System			
Riverside grazing	1.15	0.79	4.3
Enclosure grazing	0.75	0.60	3.7
Communal grazing	1.00	0.74	3.9

Results in the above table can be interpreted as:

- Species diversity and richness in areas outside of the two KBAs are generally lower compared to the those within the KBAs (particularly for habitats that are not affected by *Prosopis juliflora*).
- The pastoral and agro-pastoral production system have more-or-less similar species diversity and richness.
- Anthropogenic interference through over browsing/grazing, and urban and agricultural expansion has adversely affected the species diversity and richness.

Similar to the two KBAs, implementation and operation of the project road will result in vegetation clearing, habitats fragmentation, propagation of invasive species, etc. which in turn

could adversely affect species diversity in areas outside of the two KBAs, if not properly managed. Clearing of vegetation by project activities will result in habitats destruction and ultimately to reduction in biodiversity. Fragmented habitats result in isolated species population with restricted gene flow and interaction. Project activities and disturbed habitats are favorable for spread of alien invasive species. Fragmented and isolated habitats have lower chance of surviving the effects of invasive species.

Ahmed et al (2021) also assessed herbaceous biodiversity in the same area (Shinile area). The result of their assessment is indicated in the below table.

Table 12. Effect Production System on Herbaceous Species Diversity, Evenness, and Richness in Shinile Area

Factor Levels and Interaction Effect	Shannon Diversity Index (H')	Evenness (H'/Hmax)	Species Richness
Pastoral Production System			
Riverside grazing	1.51	0.88	5.68
Enclosure grazing	1.48	0.88	5.55
Communal grazing	1.43	0.81	5.62
Agro-pastoral Production System			
Riverside grazing	1.12	0.72	4.18
Enclosure grazing	1.57	0.81	6.90
Communal grazing	1.16	0.73	4.05

The herbaceous diversity and richness are comparatively better than the woody species in the study area. However, the current status of habitats and the effect of the project remain the same.

4.8. Ecosystem Services

The local communities residing in the project area of influence are mainly pastoralists and agro-pastoralists. Their livelihood is mainly livestock rearing which depends on grazing and browsing of their livestock in the woodlands of the project area. Also, firewood collected from the woodlands and charcoal are the primary source of energy for household activities. Further, the communities collect incense and sell it in the market to earn income to support their livelihoods. The local communities collect water for livestock watering and human domestic consumption from the available surface and groundwater resources. The local communities, therefore, value the habitats and biodiversity in the project area as their livelihoods depend on them. In addition, the habitats provide regulating services such as climate, soil erosion, and water quality regulations. The local communities indirectly benefit from these regulating services. The planned road project will impact the ecosystem services the local communities' livelihoods depend on.

4.9. Aquatic Diversity

Diatom diversity of the rivers of the project area that contain water during the field work was found to be comprised of 9 families and 12 genera. Table 13 give details of the species of this algal group based on field data.

Family	Species name	Habitat	Images (source: www.algaebase.org; www.algaterra.org)
Naviculaceae	*Navicula tripunctata* (O. F.Müller) Bory	Freshwater	
	Craticula cuspidata (Kutzing) D.G.Mann		
Cymbellaceae	*Cymbella* sp.		Most diverse genus and valves asymmetrical about the apical axis 
Cymbellaceae	*Cymbella tumida* (Brébisson) Van Heurck	Freshwater	
Ulnariaceae	*Ulnaria ulna* (Nitzsch) Compère	Freshwater	

Table 13. Diversity of Diatoms of the project area based on field data and Further Information such as photographs were also collected from www.alagebase.org

Rhopalodiaceae	*Epithemia* sp.	Freshwater Bentic hard-water habitat	
Catenulaceae	*Amphora pediculus (Kützing) Grunow*	Freshwater	
Catenulaceae	*Amphora ovalis (Kütz.) Kütz.*	Freshwater	
Fragilariaceae	Fragilaria *sp.*	Freshwater	
Rhopalodiaceae	*Rhopalodia operculata* (C.Agardh) Håkanasson	Freshwater	
Achnanthaceae	*Achnanthes* sp.	Freshwater	
Bacillariaceae	*Nitzschia linearis* W.Smith	Freshwater	

5. Water Resources Assessment

5.1. Water Quality

The amount of Cadmium, Chromium and Lead in all water samples is below their detection level. Laboratory result of different trace metals in all water samples of the project area is given.

Table 14. Water Quality Test Result

Sample	Concentration in part per million					
	Calcium	Manganese	Zinc	Copper	Magnesium	Nickel
AG-1	1.651	1.266	0.2589	0.9585	0.9237	2.296
BK-2	1.934	1.365	0.2576	1.045	0.5102	2.18
DB-1	1.079	2.332	1.415	0.9952	0.611	1.91
DL-1	2.119	4.49	0.2412	0.7658	0.5313	1.775
DR-1	2.683	1.415	0.2391	0.3163	0.7107	3.789
ED-1	2.927	1.462	0.3226	0.582	0.9111	1.186
ERG-1	1.226	3.592	0.2392	0.8817	0.605	2.152
ERW-1	4.034	2.637	0.2567	0.6174	0.5103	3.977
GD-1	1.251	2.619	0.2518	0.1603	0.7215	1.995
GJ-1	2.406	1.542	0.2666	0.324	0.8344	3.667
GT-1	5.17	2.638	0.3001	0.7212	0.6529	1.973
GT_1	5.174	2.742	0.2889	0.7426	0.7441	1.88
HA-1	7.285	3.72	0.251	0.4812	0.5218	2.679
HD-1	6.125	1.827	0.2429	0.5935	0.6145	2.742
KR-1	2.709	2.219	0.2964	0.4736	0.7275	3.996
LF-1	1.717	4.165	0.24	0.8794	0.6426	2.074
LH3	2.724	3.231	0.2518	0.7212	0.7948	2.897
LR-1	2.313	2.04	1.461	0.2635	0.5257	3.226
M1	2.661	3.251	0.2455	0.3737	0.8102	1.885
M2	2.257	2.327	0.2396	0.4603	0.5293	3.633
M3	3.024	2.261	0.251	0.3151	0.7135	2.441
M4	2.141	2.38	0.2567	0.68	0.54	3.697
M5	4.079	3.419	0.2422	0.334	0.5321	3.539
M5	4.058	3.5427	0.2505	0.3907	0.5525	3.459
MA-1	3.85	1.569	0.2394	0.8765	0.7108	2.985
MF-1	2.912	2.721	0.2459	0.6112	0.6204	2.039
MM-6	1.965	2.709	0.2347	0.3253	0.6393	3.214
OD-1	1.899	2.878	1.415		0.6732	1.7301

Poor water quality has potential impacts on the natural environment. Water quality deterioration could result from sedimentation (turbidity) and presence of harmful chemicals/compounds. Construction activities, particular those involving earthwork, often results in aggravating erosion and sedimentation. Surface and groundwater resources could be polluted through vehicle exhaust emissions, pavement wear, tire wear, spillage/drippage of petroleum products, and corrosion of metals used in construction. Potential impacts of poor water quality on the natural environment include:

- Sedimentation results in turbid water which prevents natural aquatic vegetation growth.
- Turbidity disrupts the natural food chain by destroying habitats where aquatic organisms live.
- Harmful chemicals in surface waters ingested by animals can travel through the food chain and affect wildlife/animals depending on it.
- Eutrophication due to nutrients abundance ultimately results in reduction of dissolved oxygen and affects aquatic organisms.
- Chemicals often affect the breeding pattern of animals, sometimes resulting in loss of entire species.
- Poor water quality affects aquatic species diversity and richness.

5.2. Classification of Rivers of the Project Area

5.2.1. Number and Altitudinal Variation of Rivers/Streams of the Project Area

A total of 84 rivers and small streams were recorded from the project area. These rivers andstreams vary in their altitude and Fig. 38 shows this variation.

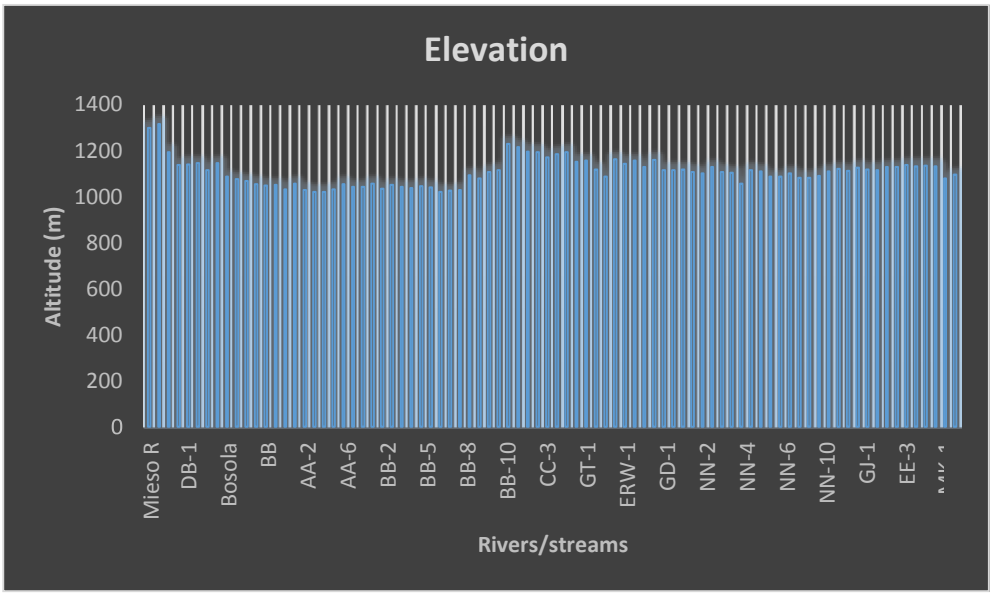


Fig. 39. Altitudinal variations of the streams of the project area.

Most of the rivers and streams of the project area are seasonal. Whereas only 5 (about 6%) of them are perennial, the remaining 79 rivers and streams flow only for a short period[1] (from Mid-July – Mid-September).

5.2.2. Slope of the Project Area

The project area lies at the lower part of the surrounding highlands (Fig. 40). The rivers and streams of the project area depend on the extent and quantity of the rainfall of the surrounding highland areas. The slope of the project area falls in the range of 0 – 15%.

[1] The field was conducted in July 2021 but these streams were dry. The team has asked the local communities and they latter said that the rivers usually flow from July – Mid September.

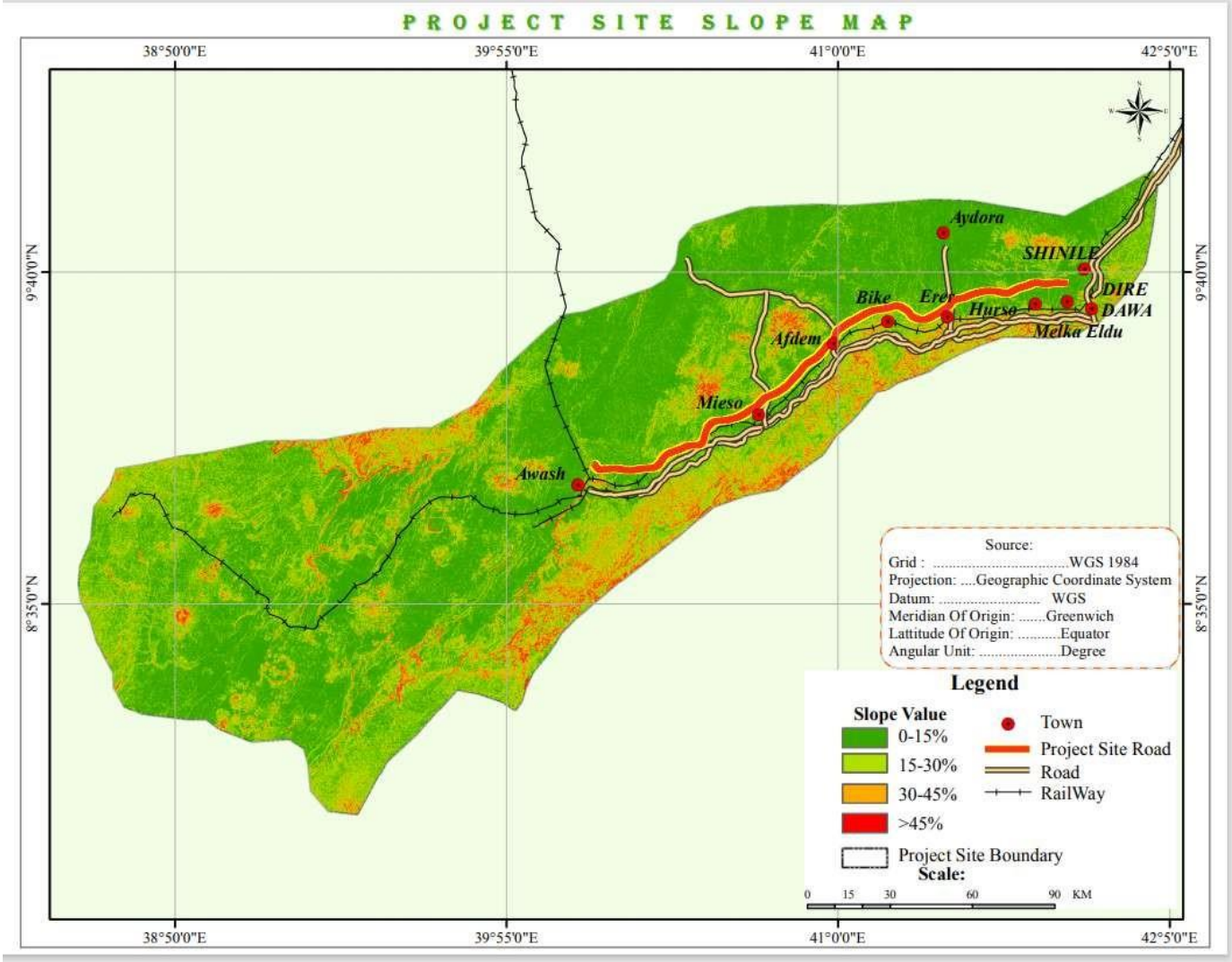


Fig. 40. Slope map of the project area

The drainage map including the project area is given in Fig. 41. The frequency and amount of rainfall in the highlands surrounding the project area affects the availability of surface water. Furthermore, the extraction of surface water for different purposes in these highland areas decrease the quantity of perennial rivers of the project area.

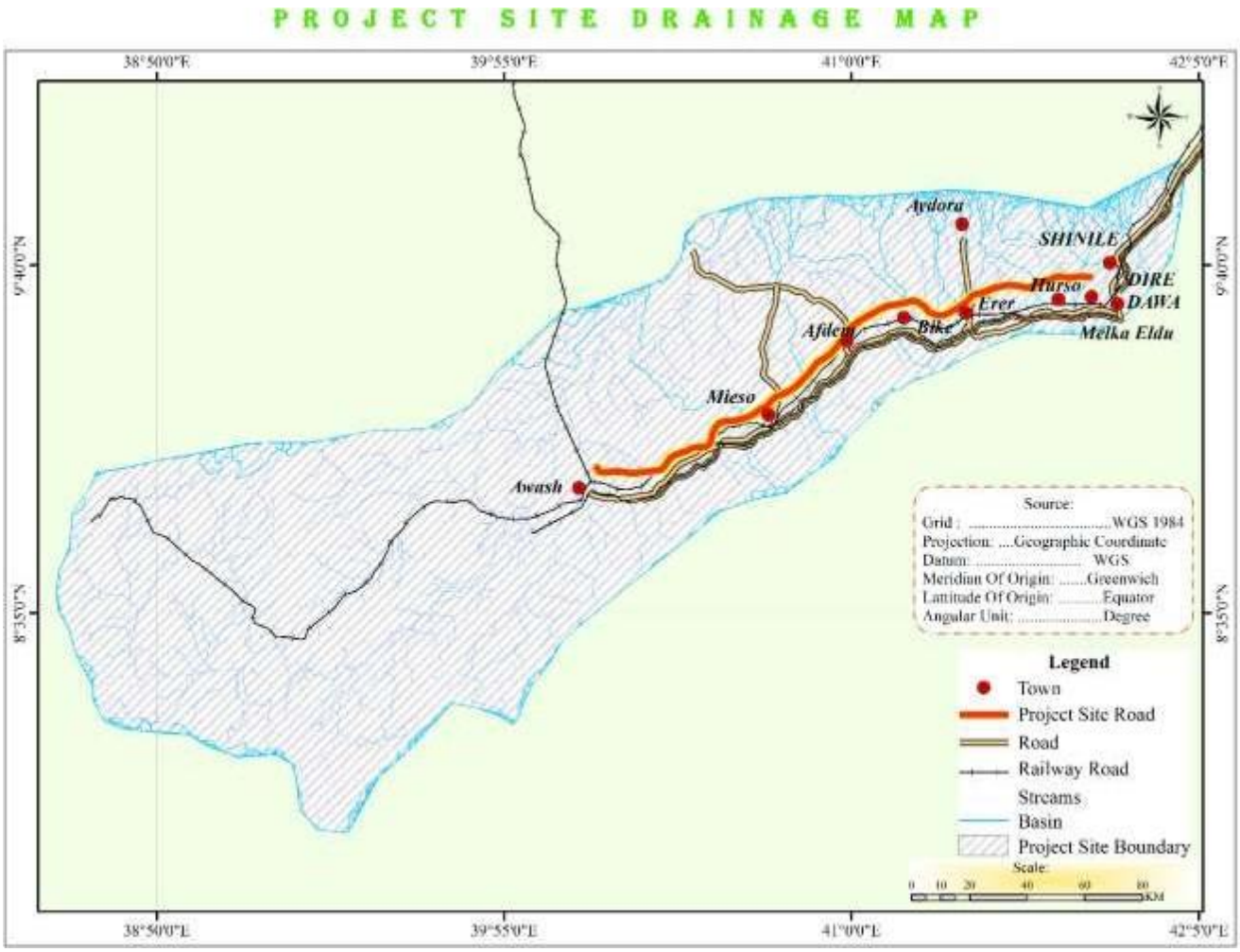


Fig. 41. Drainage map of the project area

5.2.3. Types of Substrates of the River/Stream Bed and Water Flow

The rivers/streams of the project area have different substrates. A total of 19 types of substrates of these rivers//streams have been recorded (Fig. 42). The majority of the rivers/streams (26) of the project area have sand substrate. A total of 15 rivers/streams of the project area has fine sand substrate and this is followed by 6 rivers/streams which have big boulders. Furthermore, some rivers have a gradation of substrates, i.e., silt – sand, mud – sand, mud – pebbles, sand – pebbles and sand – gravel.

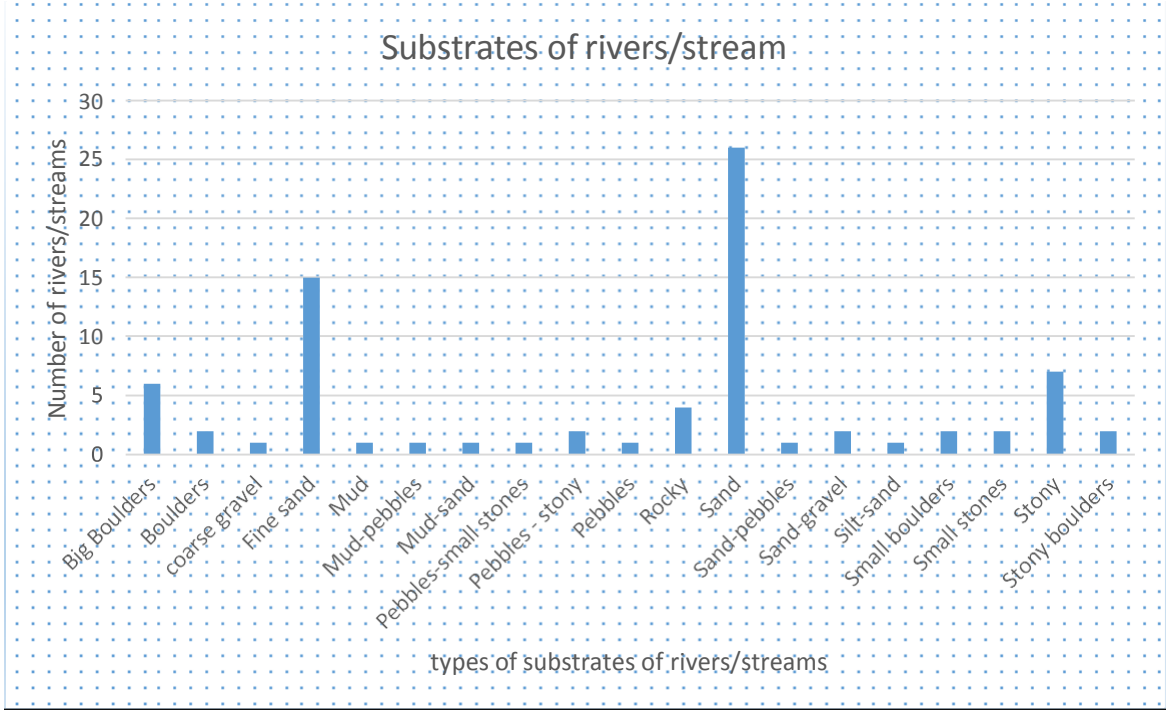


Fig. 42. Materials of river/stream beds of the project area

5.2.4. Spatial Distribution of Rivers/Streams of the Project Area

The spatial locations of the rivers/streams of the project area are given in Fig. 43. The drainage information from the EthioGIS hasbeen used as the base map to locate GPS points of the rivers/streams collected during the field work.

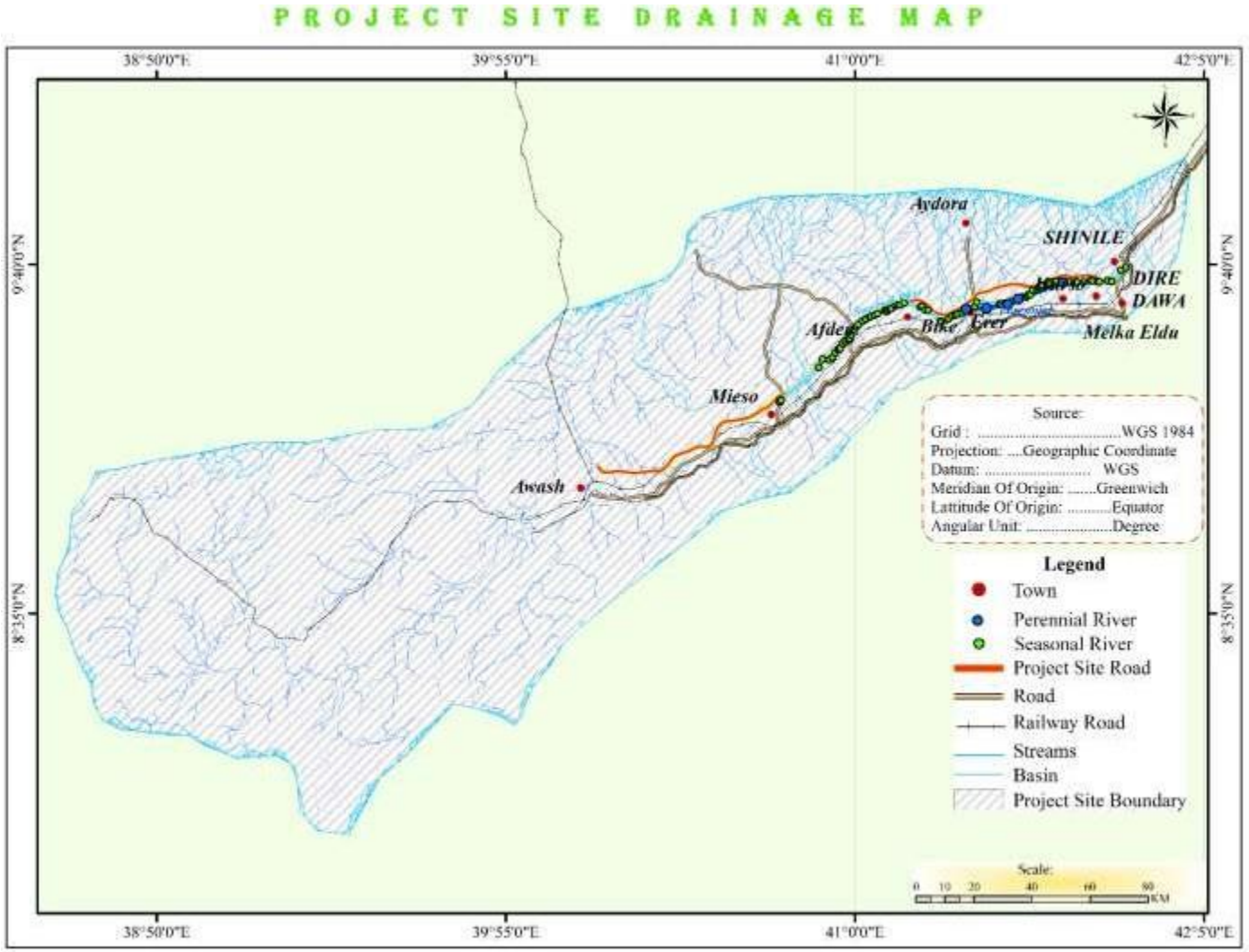


Fig. 43. Spatial locations of rivers/streams of the project area. Note that the types of these rivers/streams (seasonal and perennial) are given in different colors for distinction.

A close-up of Fig. 44 is given below to show details of the rivers/streams relative to geographic reference points, e.g. name of towns. Green circles denote seasonal rivers/streams and blue circle are perennial rivers/streams.

Fig. 44. A close-up a section of rivers/stream map of the project area

All rivers/streams between Mieso and Erer (up until Gota River) are seasonal. There is a remarkable scarcity of surface water in these areas and the communities use boreholes for drinking purposes. The communities in Bike town have faced scarcity of groundwater and there is an effort currently to develop a borehole 10 km away from Bike. The 5 perennial rivers (blue circles) arelocated between Gota River and Dire Dawa.

5.2.5. Water Discharge, Water Flow and Uses

The surface water sources of the project area are given below (Table 15). These rivers cross the Mieso – Dire Dawa Expressway (direct impact zone). They are also sources of construction materials, e.g., sand for the project area. They are located in the project area of influence (direct and secondary impact zones). Water is a limited resource in the project area and use of these existing scarce resource by the project will exert negative impacts on the local communities.

The type of substrates is used to measure the velocity of water flow. As a rule, riverbeds filled with big boulders have much higher velocity (water flow in m/s) compared to, for example, those with sand and fine sands. In cases where the rivers are actively flowing, very small amountof water flows, the values following direct measurements of water flow are given in Table 15.

The highest volume of discharge (6,000 m^3/s) was recorded for U-1 while the lowest volume(0.2 m^3/s) was obtained for NN-6 and NN-7 streams (Table 15).

In all cases, the velocity of water flow for all rivers/streams of the project area was calculated based on width and depth (height) of their channels. Table 15 gives the values of the velocity of water flow of these rivers/streams. The potential impacts of the velocity of water flow on infrastructure (flood hazard) is also given in the same table and Fig. 45.

Table 15. Current water flow (cm/s), estimated discharge, water uses and potential impacts.

No.	Code	Name of rivers/streams	Dry/wet condition (Channel dimensions: width, depth in m) *	Substrate type**	Discharge estimate (m^3/sec) ***	Current flow (cm/s)	Water uses	Possible impact or use to Project ****
2	M1	Kerkarale/ Laga Mieso	Wet for 3 months	sand	Slow to medium	-	Bathing Sand mining	Sand building material
3	M2, M3	Mulu River	Wet perennial	Silt to sand		-	drinking	Camp water supply
4	MM6	Meiso-Moulu	Deep well	NA	NA	NA	Drinking	Camp water supply
5	OR1	Orongogu (OR) Jerigara (SOM)	Dry river bed (25,2)	Pebble - small stones	50 m^3/s	-	Drinking	Effect insignificant
6	WN-0	Wangeyu	Dry channel (12,6)	stones	144 m^3/s		Drinking	Potential hazard
7	DB-1	Doba River	Wet and flowing	Mud - pebble	Past flow - fast	53.5cm/sec	Drinking	
8		Birale River	Dry (6, 2)	sand	3.0 m^3/s		Drinking	Sand material Effect insignificant
9	DL-1	Deladu point	Wet				Drinking	Water

							point for cattle, people	supply
10		Bosola	Dry (3,2)	Rocky bed	18 m^3/s	-		Effect insignificant
11	RB	Rocky bottom at 1102 alt	Dry (3,2)	rocky	18 m^3/s	-		Effect insignificant
12	GB-1	Gobi	Dry (3,1)	stony	3.0 m^3/s	-		Effect insignificant
13	GA	Gobi-Afdem	Dry (3,2)	stony	18 m^3/s	-		Effect insignificant
14	BB	Broken bridge Alt. 1050	Dry (10, 2)	Sand-gravel	10 m^3/s	-		Effect insignificant
15	HD	Hula Dimo dry bed at 1049 alt	Dry (50,10)	stony	750 m^3/s	-		Possible flash flooding
16	AFW-1	Afewyni	Dry (10, 1.5)	Stony-boulder	240.0 m^3/s	-		Potential hazard
17	AF-1	Afdem town well	NA	NA	NA	NA	drinking	Camp water supply
18	AA-1		Dry (10,4)	Sandy - gravel	20 m^3/s	-		Effect insignificant
19	AA-2		Dry (15,3)	sandy	10.3 m^3/s	-		Sand material Effect insignificant
20	AA-3		Dry (3, 0.5)	fine sand	0.37 m^3/s	-		Effect insignificant Fine sand material
21	AA-4		Dry (20,1)	sand	5 m^3/s	-	Sand mining	Sand material
22	AA-5	Ford bridge	Dry (8, 1.5)	Large boulders	600 m^3/s	-		Potential hazard
23	AA-6		Dry (2,1)	Rocky substrate	60 m^3/s	-		Fast runoff but Effect insignificant
24	AA-7	Dry ford	Dry (12,0.5)	boulder	180 m^3/s			Potential hazard
25	KR-1	Keraba River bed	Wet (40,4)	Big boulder	800 m^3/s	4.76	Not much used	Potential hazard Water source
26	BB-1	Small stream and ford crossing	Dry (1, 10)	sand	2.5 m^3/s	-	Rocky bed	Effect insignificant
27	BB-2	Ford bridge	Dry (20,4)	boulder	2400 m^3/s	-	Broken ford bridge due to fast flow	Potential hazard
28	DLA-1	Dere-ela water	Dry				Watering	Water

		point					point for cattle, people	source
29	BB-3	Ford bridge	Dry (5,3)	stony	30 m^3/s	-	Broken bridge due to fast flow	Effect insignificant
30	BB-4	Wahajsa ford crossing	Dry	Large boulders				Potential hazard
31	BB-5	Ford bridge	Dry (17,1)	sandy	4.3 m^3/s	-		Effect insignificant
32	GD-1	Gedereat water tower					Water to be pumped to Bike 15 km	
33	BB-6	Large floodplain	Dry (20,2)	sandy	10 m^3/s	-		Sand source Effect insignificant
34	BB-7	Ford bridge	Dry (20,5)	sandy	25 m^3/s	-		Damage pipeline?
35	BB-8	Large floodplain	Dry (30,0.5)	sandy	3.75 m^3/s	-		Sand source Effect insignificant
36	BK-1	Bike River and town	Dry (50, 3)	Coarse gravel	112.5 m^3/s		Reduced flow at present due to abstraction from Chercher	Large volume of water – needs big bridge?
37	BK-II	Bikigerefi	Wet	Rocky bed	fast			Some
38	BB-9	Ford crossing	Dry (5,2)	sand	2.6 m^3/s	-		Effect insignificant
39	BB-10	River bed	Dry (8,1)	Fine sand	2.0 m^3/s	-		Effect insignificant
40	CC-1	Dry bed	Dry (1.5,1)	Fine sand	0.37 m^3/s	-	Water tower for village	Effect insignificant
41	U-1	Unidentified wet point	Wet (80, 25)	Small boulder	6,000 m^3/s	-	Flows over rocky bed	Potential hazard
42	CC-2	Dry bed	Dry (50, 2)	sandy	25 m^3/s	-		Sand source Effect insignificant
43	CC-3	Dry bed	Dry (3,0,5)	Fine sand	0.37 m^3/s	-		Effect insignificant
44	CC-4	Dry bed	Dry (10, 0.5)	Mud-sand	0.5 m^3/s	-		Effect insignificant
45	CC-5	Dry bed	Dry (5,1)	mud	0.5 m^3/s	-	Fast flow below bridge	Effect insignificant
46	AG-1	Abrach-Gota village	dry					Water source

47	GT-1	Gota River	Wet (50,1)	stony	100 m^3/s	4.37	Washing drinking	Significant hazard during high flood season
48	CC-6	Dry bed	Dry (5,2)	stony	20 m^3/s	-	Broken ford bridge	Effect insignificant
49	CC-7	Dry bed	Dry (50,2)	sand	25 m^3/s	-	Abandoned sand dam project	Sand source Effect insignificant
50	HD-1	Hado River	Wet	sandy	Slow	18.9	washing	Effect insignificant
51	ERW-1	Erer River (Kenteras)	Wet (50, 3)	Stony-boulders	4,500 m^3/s	12.5	High human pressure	Potential hazard
52	CC-8	Dry bed	Dry (8, 0.5)	Fine sand	1.0 m^3/s	-		Effect insignificant
53	DRB-1	Dry bed		Sand to pebble	Slow to fast			Effect insignificant
54	CC-9	Ford crossing	Dry (5,1)	Fine sand	1.25 m^3/s	-		Effect insignificant
55	GD-1	Gendisa River	Wet	Big boulders	Very fast			Potential hazard
56	CC-10	Ford bridge	Dry (5,1)	Fine sand	1.25 m^3/s	-		Effect insignificant
57	NN-1	Ford crossing	Dry (5,1)	pebbles	5.0 m^3/s	-		Effect insignificant
58	GARM-1	Garmam River	Wet (30, 3)	Small stones	135 m^3/s	25.92	Water supply	
59	NN-2	Ford crossing and catchment joining	Dry (7, 0.5)	Fine sand	0.9 m^3/s	-		Effect insignificant
60	LF-1	Lege Farso and joining streams	Dry narrow	Big boulders	Very fast	-	Algal (diatom)	Potential hazard
61	DFC-1	Dry ford crossing	Dry	Fine sand	Slow	-		Effect insignificant
62	NN-3	Wet ford crossing	Wet (20, 1)	sand	5.0 m^3/s	-		Effect insignificant
63	ERG-1	Errer town					drinking	
64	NN-4	Ford crossing	Dry (3, 3)	Big boulders	270 m^3/s	-		Potential hazard
65	SMFC-1	Small ford crossing	Dry	sand				Effect insignificant
66	MA-1	Megala Adi (near Harsho village)	Wet with rocky bottom (30, 2)	Small boulder	180 m^3/s	-	Italian bridge Water source	Potential hazard
67	NN-5	Ford crossing	Dry (6, 0.5)	Fine sand	0.75 m^3/s	-		Effect insignificant
68	NN-6	Ford crossing	Dry (1.5, 0.5)	Fine sand	0.20 m^3/s	-		Effect insignificant
69	NN-7	Ford crossing	Dry	Very fine	0.20 m^3/s	-		Effect

			(1.5, 0.5)	sand				insignificant
70	NN-8	Ford crossing	Dry (15, 0.5)	Fine sand	1.85 m^3/s	-		Effect insignificant
71	NN-9	Ford crossing	Dry (28,2)	Fine sand	14.0 m^3/s	-		Effect insignificant
72	NN-10	Lafito dry bed	Dry (5,1)	Fine sand	1.25 m^3/s	-		Effect insignificant
73	EE-1	Ford crossing	Dry (40, 4)	small stones	240 m^3/s	-	Ford bridge broken	Potential hazard
74	LH-3	Lege Hurso	Wet (5,3)	Pebble to stony	22.5 m^3/s	-	Drinking water	Effect insignificant
75	EE-2	Dry river bed	Dry (30, 2)	sand	15.0 m^3/s	-		Effect insignificant
76	GJ-1	GerbeJijeba	Dry	sandy			Cattle drink	
77	GF-1	Gundefeto River (Ford bridge crossing)	Dry (37,15)	Pebble to stony	832.5 m^3/s	-	Damaged bridge gabion mended	Potential hazard
78	WB-1	Warabale river	Dry (14, 10)	sandy	35.0 m^3/s	-		Effect insignificant
79	DD-1	Dire Dawa area new bridge	Wet and Dry	sandy	Slow but voluminous		Camel drinking point	Potential hazard Sand source
80	EE-3	New and old bridge crossing	Dry (25, 20)	sandy	125.0 m^3/s	-		Potential hazard Sand source
81	EE-4	Near DD Industrial area	Dry Old bridge (10, 10) New bridge (50, 10)	sandy	125.0 m^3/s	-	Crossing camel drink	Potential hazard Sand source
82	EE-5	Old and new bridge crossing in Dire Dawa	Dry Old bridge (10, 15) New bridge (20, 10)	sandy	50.0 m^3/s	-	Crossing camel drink	Sand source
83	EE-6	Old and new bridge crossing in Dire Dawa	Dry Old bridge (10, 15) New bridge (20, 10)	sandy	50.0 m^3/s Slow but voluminous	-	Crossing camel drink	Possible hazard Sand source
84	MK-1	Melka Jebdu bridge, Woreda 1	Dry (47, 10)	sandy	117.3 m^3/s	-		Potential hazard Sand source
85	GR-1	Ganda Riga new bridge (Ganda Riga or Riga Kebele)	Dry (25, 10)	sandy	62.3 m^3/s	-		Effect insignificant
86	ADW-1	Adaweyin sand bed	Dry (72, 20)	sandy	360.0 m^3/s	-		Potential hazard

								Sand source
87	MM-1	Culvert bridge	Dry (26, 3)	sandy	19.5 m^3/s	-		Effect insignificant

* Estimated channel width/height in m (bracket);
** Substrate types and flow velocity as in methodology.
*** Measurement of flow with orange method and estimate of discharge at each crossing with cross-sectional area and flow rate.
**** impact prediction based on discharge - < 100 m^3/s = effect insignificant; >100 m^3/s = potential hazard. Also, contribution to project in terms of water and sand supply at the coordinates are indicated.
NB: The dry seasons are Oct – Feb and May – June while wet seasons are July – Sep and Mar – April.

The discharge of 22 rivers/streams of the project area exceeds the limit, i.e., the discharge volume of these water is above 100 m^3/s (Fig. 45 and Table 15). Three rivers/streams have adischarge volume of above 2,000 m^3/s.

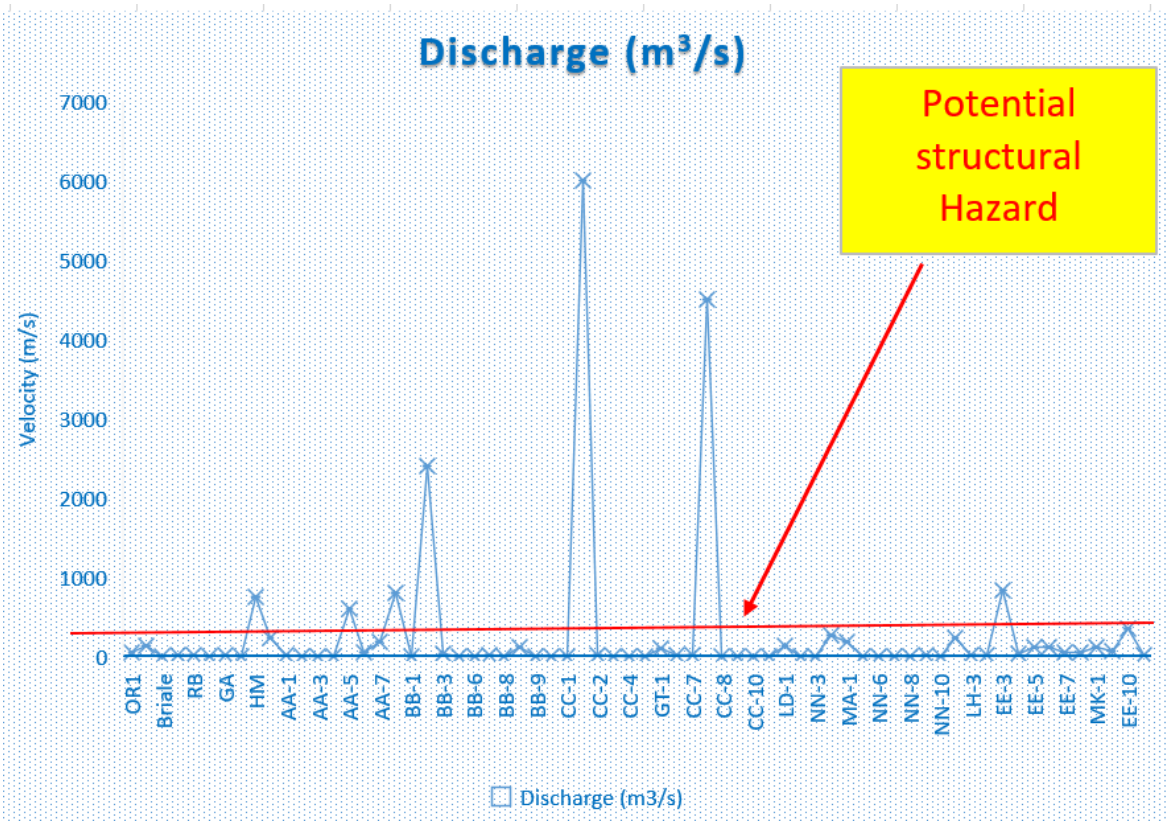


Fig. 45. Depicting discharge volume vis-à-vis potential for structural damage and/or flood risk

5.3. Groundwater Recharge Estimation by using WetSpass Model

Groundwater depth map is used to include seepage fluxes in the water balance calculations in the model. Thus, the groundwater depth of the study area was deduced from the surface topography considering the rule of thumb which suggests that the groundwater level as subdued replica of the surface topography.

It is known that meteorological conditions of a given wide and independent area affect the formation of water resources. As a result, mean annual meteorological parameters maps such as precipitation, Temperature, potential evapotranspiration and wind speed were prepared from the available meteorological stations and global sources to grasp the meteorological characteristics of the project area. These data, along with other sets of data, were used to estimate groundwater recharge of the area (Table 16). The meteorological map of the study area isgiven in Fig. 46.

Table 16: Annual Hydro-Meteorological parameters used as in put for WetSpass model in theproject area

Model Input Hydro-meteorological parameter	Min	Max	Mean	STD
Annual Precipitation (mm)	422	1351	717	274
Mean annual Temperature (°C)	14.1	26.7	23.3	4.6
Annual Potential Evapotranspiration (mm)	1034	2111	1615	310
Wind Speed (m/s)	0.7	2	1.6	0.3

Annual Mean total precipitation values for the project area were calculated from the available data in each station and FAO climate estimator. Spatial maps were produced using kriging interpolation technique from observed stations and global data. The mean annual precipitation is 717 mm. The statistical values and annual spatial distribution were given in Table 16. Generally southern portion receive higher rainfall than northern half. Highest rainfall is recorded near Asebot.

Annual mean temperature in the project area as estimated from FAO local climate estimator is

23.3 ^{o}C. The high mean temperature is observed in the west and northern portion while southeastern area near Gara Muleta enjoys lower temperature.

Since Potential evapotranspiration is not usually measured directly in most cases it is estimated by empirical methods based on other measured parameters. Generally potential evapotranspiration estimated using Pennman and monteith approach is plausible for its use of large number of meteorological data. In the study area PET estimated using this method is extracted from the New FAO climate estimator. The mean potential evapotranspiration is about 1615 mm. Higher PET is observed in the northeastern portion whereas low values are observed on the southeastern part of the project area.

Wind speed data from FAO new climate estimator is used to generate the spatial distribution of wind in the project area. Accordingly, the annual average wind speed is 1.6 (m/s). High wind

speed is observed in the eastern half of the project area.

Parameter tables

Land-use, soil type and runoff parameters have to be specified in four look-up tables required for running the WetSpass model. The two land-use attribute tables include parameters related to land-use type and soil type. The former contains parameters such as rooting depth, leaf area index and vegetation height (Batelaan and De Smedt, 2007) and which was calibrated for temperate conditions in Belgium (Al Kuisi et al. 2013). While as described in Abu-Saleem et al. (2010), Al Kuisi et al. (2013) application of this model requires some modification of lookup tables in climatologically arid regions.

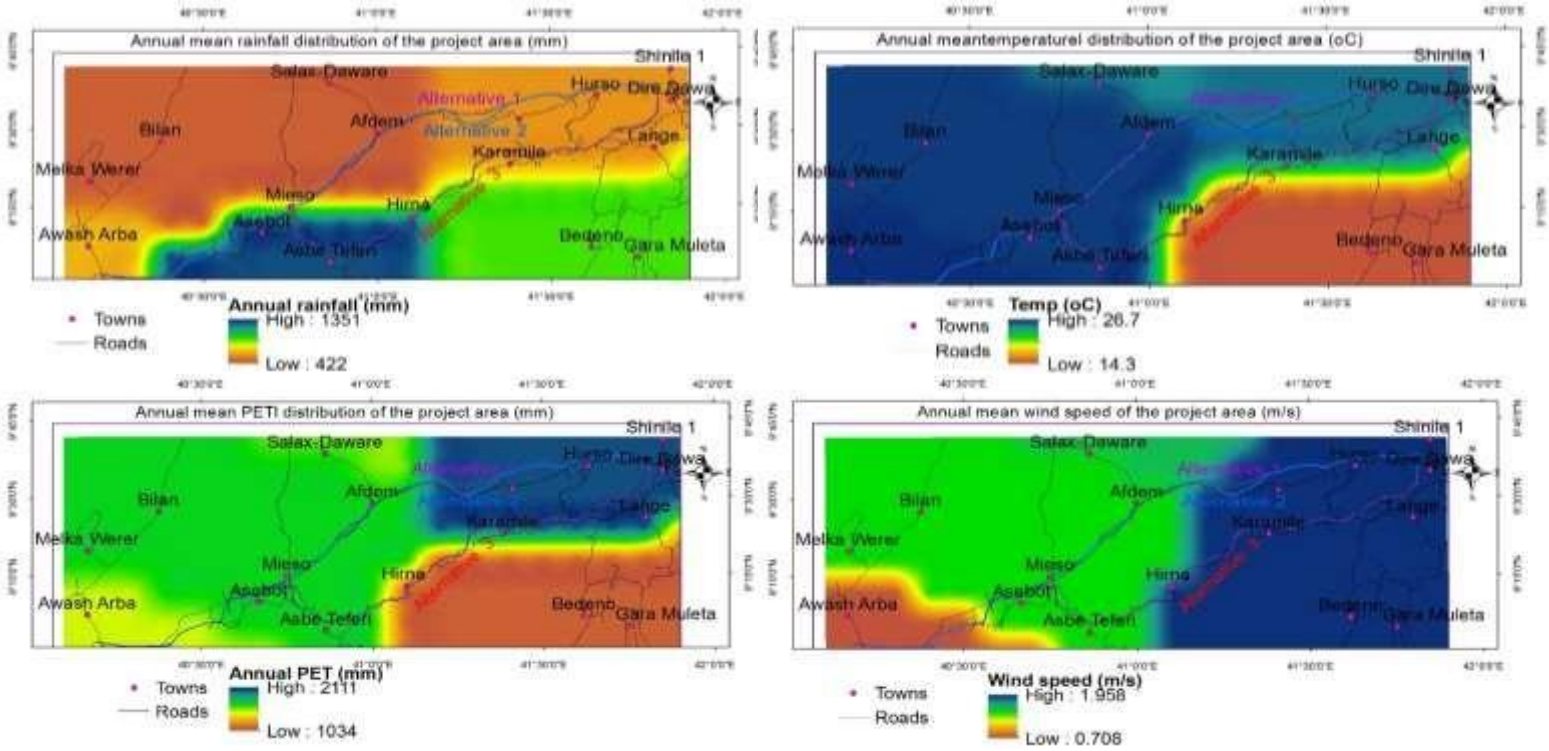


Figure 46. GIS maps of meteorological parameters used as input for the WetSpass model: Annual rainfall (mm) (Upper left), Annual total potential evapotranspiration (mm)(bottom left), average annual temperature (°C) (Upper right), average annual wind speed (m/s) (bottom right

The water balance components including actual evapotranspiration, surface runoff and groundwater recharge are estimated using WetSpass model (table 17). In hydrologic cycle, understanding the prior processes such as the spatial pattern and rate of precipitation, actual evapotranspiration and surface runoff can be used to provide the rate and distribution of ground water recharge.

As shown in Figure 47, the model simulation results produce digital raster images of the spatially distributed long-term annual average values of groundwater recharge of the project area.

Groundwater recharge is the entry of water into the saturated zone through the process of infiltration (Freeze, 1969). Recharge is an important factor in evaluating groundwater resources but is difficult to quantify (Alley et al., 2002). The WetSpass model determines the long-term average spatially distributed recharge as a spatial variable dependent on the soil texture, land-use, slope, meteorological conditions and etc. This is primarily to take into account the influence of the spatial variability of the land surface on the groundwater system (Batelaan and Woldeamlak, 2004).

The amount of infiltration into the groundwater depends on vegetation cover, slope, soil texture and rainfall amount Figure 47 and 2. The mean annual groundwater recharge for the whole area is about 82 mm, which is about 11 % of the mean annual rainfall. In general, the groundwater recharge is high in the southeastern portion of the project area whereas the northeastern part receives low to moderate recharge. Closer look at the recharge values along the proposed alignments indicates variable conditions (Figure 47). Generally, looking at the lower elevation that the alignment follows and relatively higher recharge along the Mieso –Asebot segments, favors better probability of groundwater availabilities. Successful wells sitting require a detailed geomorphological and hydrogeological investigation supported by geophysics.

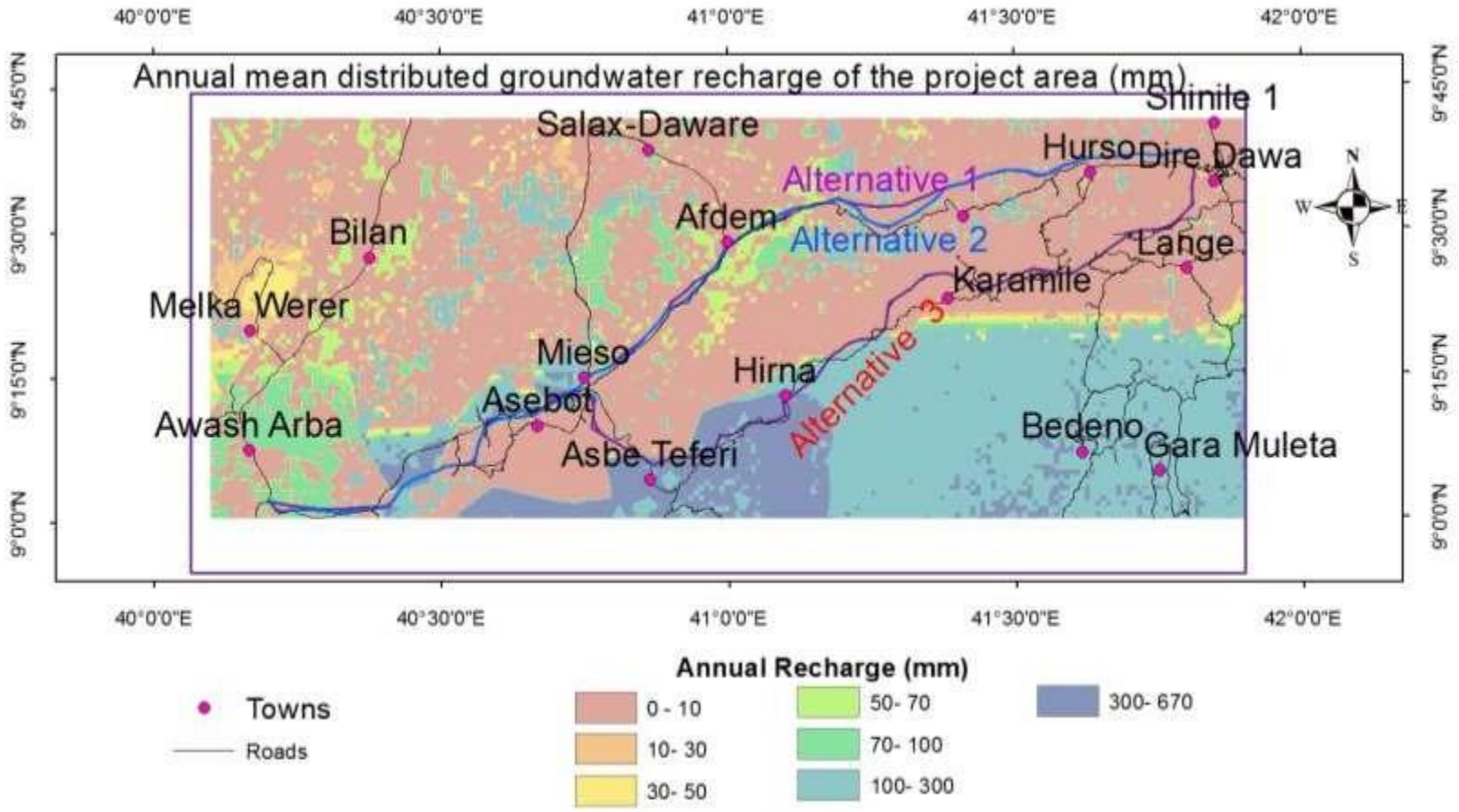


Fig. 47. Distributed annual groundwater recharge (mm) in the project area

Table 17: Annual water balance of the project area simulated with the WetSpass model.

Water balance component	Annual values (mm/yr)				
	Min	**Max**	**Mean**	Std. dev.	%ppn
Precipitation(P)	422	1351	717	274	100
Actual Evapotranspiration (mm)	113	1710	536	196	74.7
Surface runoff (S)	0	913	101	203	14
Recharge (R)	0	668	82	119	11.4
Input - Output	P – (ETO + S + R) = 0				

%ppn stand for percentage of hydrologic parameter of precipitation

5.4. Aquifer Characterization of the Project Area

One of the notable works focusing on Ethiopian Hydrogeology is the hydrogeological mapping of the country including the project area by Aquatest (Sima et.al, 2018). The project area fallsin the Dire Dawa Sheet (NC 37-12). Generally, the area is mainly characterized by Basalt (35%), Sediments (26%), Limestone (17%) and sandstone (13%) which has fissured, porous or karast porosity and permeability, resulting in moderate productivity and groundwater potential. The remaining 9 % is mainly covered by basement and acidic volcanics, which have a low or a very low potential that might serve as aquitard or aquiclude (Figure 48). The main aquifers of the project area can be grouped into four.

i. Moderately productive Porous aquifer. This is formed in lacustrine andalluvial and colluvial sediments along the main alignment segments (Alternative 1 and Alternative 2) running from Mieso to Afdem and from Hurso to Melka Jebdu as an infill of depressions on the valley floor (Fig. 48). There are limited numbers of existing boreholes. Depth of Borehole ranges from 40 to 93 meter, Static water level ranges from 20 to 82 meter and the yield ranges from 5 to 5.5 lit/sec. This implies that the aquifer has a moderate potential. Sitting well should involve further hydrogeological and geophysical investigation on the particular area of interest.

ii. Moderate productive basalt aquifers, which extend along the alignments and surrounding hills and escarpments. In a topographically suitable environment this formation has a moderate groundwater potential as evidenced by existing boreholes. The segment from Awash Arba to Mieso in alternative 1 and 2 alignments may extract groundwater from this formation (Fig. 48). There are limited numbers of existing boreholes. Depth of

Borehole ranges from 43 to 169 meter, Static water level ranges from 21 to 150 meter and the yield ranges from 0.8 to 4.8 lit/sec. This implies that the aquifer has a moderate potential. Sitting well should involve further hydrogeological and geophysical investigation on the particular area of interest.

iii. Moderate Productive, Karastic Aquifer. This is mainly composed of limestone covering southeastern portion of the project area (Fig. 48). Only alternative 3 alignments cross this aquifer. Because of its topographic location and rugged landscape, drilling wells in this area may not be feasible. One borehole in this formation has a depth of 133.6 meter, Static water level at 19.6 and yield of 5.5 l/s. There are several springs in this formation that might be developed for either the community or the project personnel. The yield of springs in this aquifer ranges from 5 to 25 lit/sec. It is one of the main recharge zones in the project area.

iv. Moderate Productive, Fissure and porous aquifer. This is mainly composed of sandstone covering southeastern portion of the project area (Fig. 48). Only alternative 3 alignments cross this aquifer. Because of its topographic location and rugged landscape, drilling wells in this area may not be feasible. There are limited numbers of existing boreholes. Depth of Borehole ranges from 60 to 133 meter, Static water level ranges from 20 to 28 meter and the yield ranges from 3 to 5 lit/sec. This implies that the aquifer has a moderate potential. Sitting well should involve further hydrogeological and geophysical investigation on the particular area of interest. There are few springs in this formation that might be developed for either the community or the project personnel. The yield of springs in this aquifer ranges from 0.1 to 1 lit/sec. This zone is mainly found in the recharge zone of the project area.

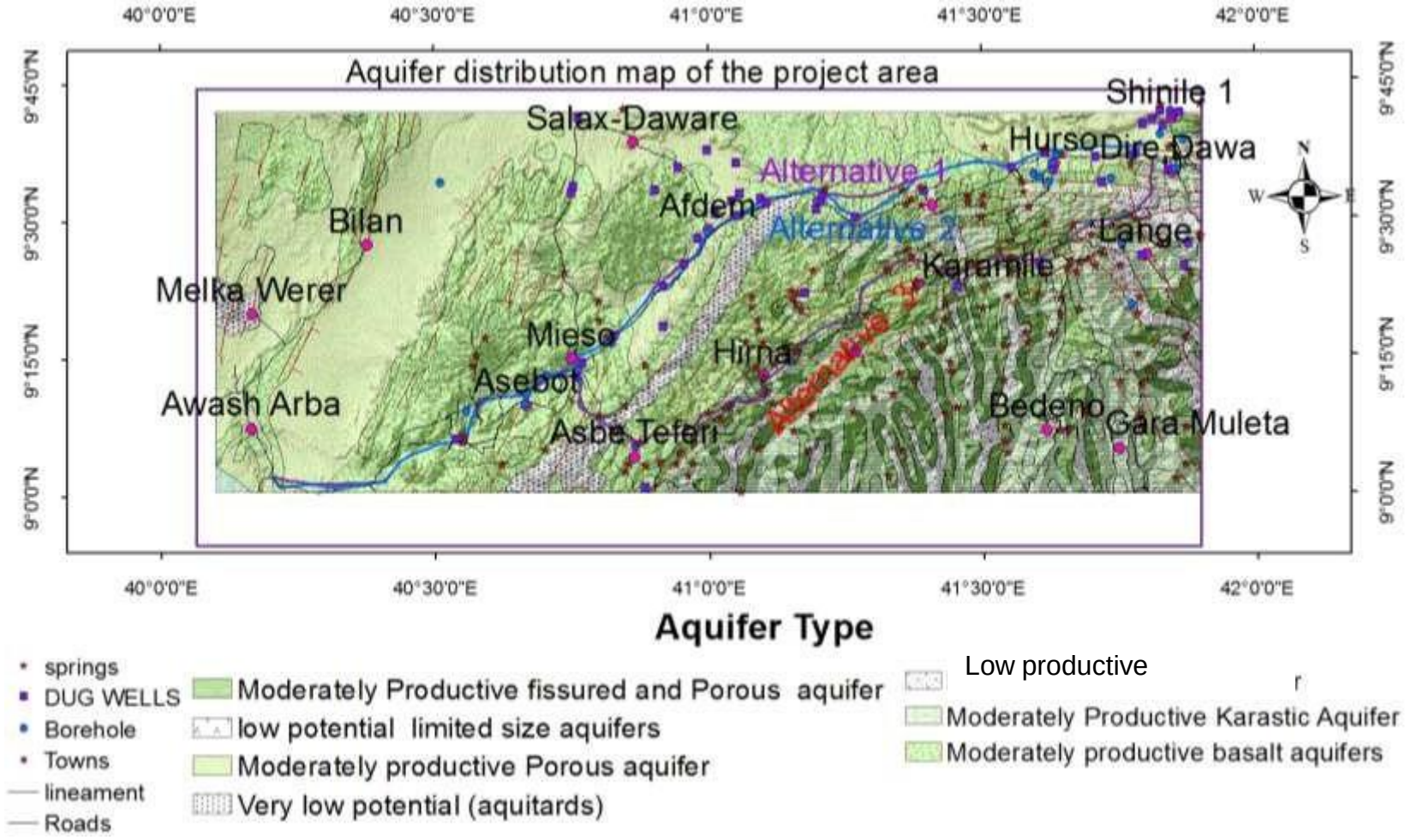


Fig. 48. Hydrogeological map of the project area

The groundwater resource potential assessment of a given area can be approached by its availability, accessibility and sustainability. In the study area, alternative 1, Alternative 2 alignments of the Mieso – Dire Dawa Expressway and the nearby zones are characterized bya discharge zone indicating the presence of both shallow and deep unconfined/confined aquifers. The escarpment and the plateau area where alternative 3 is located have recharge zones where groundwater accessibility using boreholes is difficult. The main groundwater resources in the escarpment and the plateau area are springs, which emanate at the contact between the static water level and topography break or at the contact of two variable permeability rocks.

The average annual recharge of the project area estimated using WetSpass model is 82 mm/ year. As a rule of thumb, 50% of recharge is proposed as a sustainable yield. Considering the rectangular project area shown in the recharge map, which has an area of 15,000 km^2, the sustainable yield from the rectangular zone groundwater system is about 615 MCM (Million Cubic Meters). If we narrow only within 5 km along the alignment which has an approximate length of 220 km, then the sustainable yield will be around 45 MCM. For successful and productive well sitting, a detailed hydrogeological and hydrogeophysical investigations are recommended.

5.5. Water Risk Assessment based on Aquaduct Data

Aqueduct is a global Water Risk Atlas (https://www.wri.org/applications/aqueduct/water-risk-atlas/). It provides baseline information on the different aspects of water risk of the project area. Furthermore, it can also be used to predict future water related risks. Under the baselineWater Risk conditions, the physical risk quantity is very relevant to the water resources of the project areas. The sub-categories of the physical risk quantity are given below.

Overall water risks categories	Sub-categories
Physical risks quantity	Water stress
	Water depletion
	Interannual variability
	Seasonal variability
	Ground table decline
	Riverine flood risk
	Drought risk

5.5.1. Baseline Overall Water Risk

Water stress

The baseline water stress of the project area is assessed as low for most of its section and low-medium in areas close to Dire Dawa (Fig. 49). This shows that there is relatively low level of water withdrawal in areas around Mieso, Afdem, Bike and Hurso. On the other hand, there are higher level of surface water extraction in areas close to Gota and Erer for irrigation and Dire Dawa for household consumptions and industries.

Box 1. Baseline water stress measures the ratio of total water withdrawals to available renewable surface and groundwater supplies. Water withdrawals include domestic, industrial, irrigation, and livestock consumptive and non-consumptive uses. Available renewable water supplies include the impact of upstream consumptive water users and large dams on downstream water availability. Higher values indicate more competition among users (WRI Aqueduct, 2019).

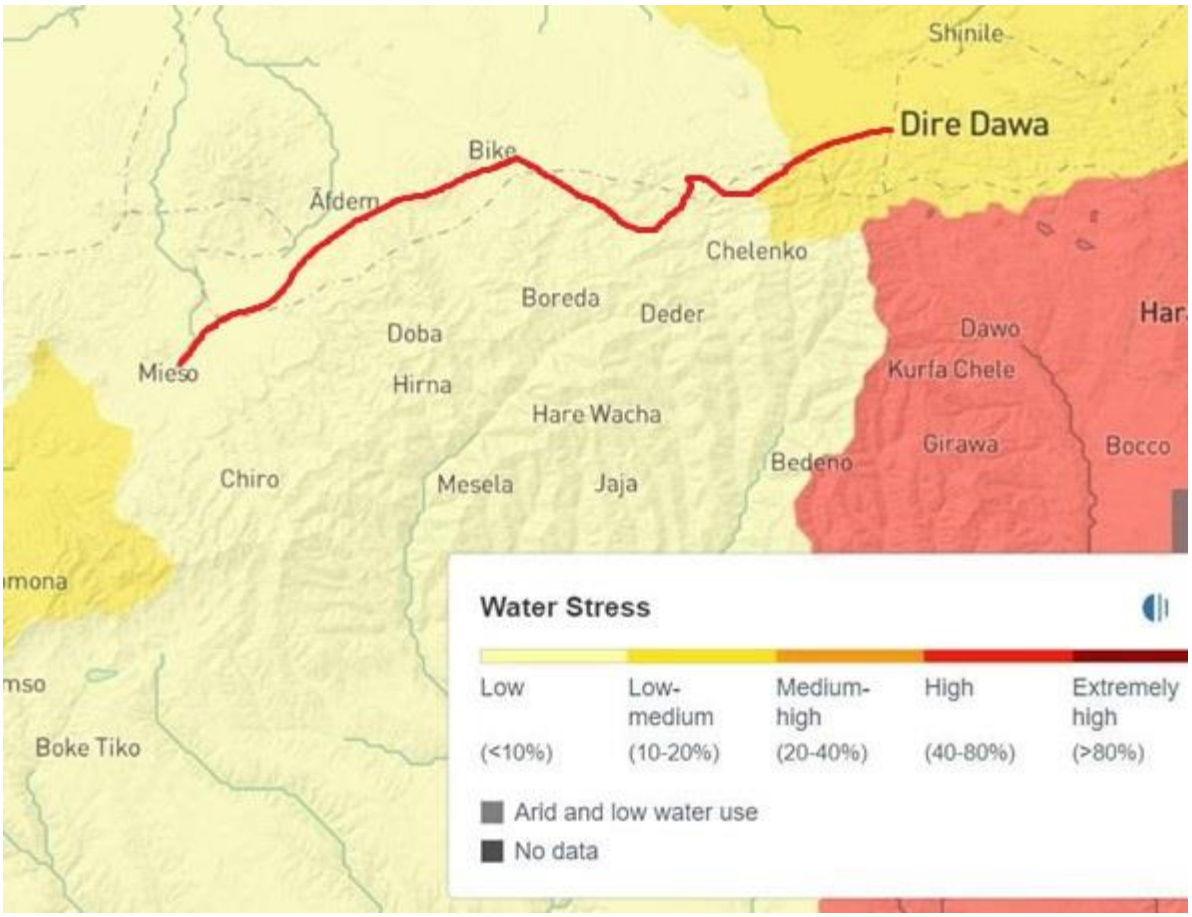


Fig. 49. Baseline water stress of the project area (source: https://www.wri.org/applications/aqueduct/water-risk-atlas/)

Water depletion

Water depletion of the project area was assessed to be low – medium (5%-25%) (Fig. 50).

Box 2. Baseline water depletion measures the ratio of total water consumption to available renewable water supplies. Total water consumption includes domestic, industrial, irrigation, and livestock consumptive uses.
Available renewable water supplies include the impact of upstream consumptive water users and large dams on downstream water availability. Higher values indicate larger impact on the local water supply and decreased water availability for downstream users. Baseline water depletion is similar to baseline water stress; however, instead of looking at total water withdrawal (consumptive plus non-consumptive), baseline water depletion is calculated using consumptive withdrawal only (WRI Aqueduct, 2019).

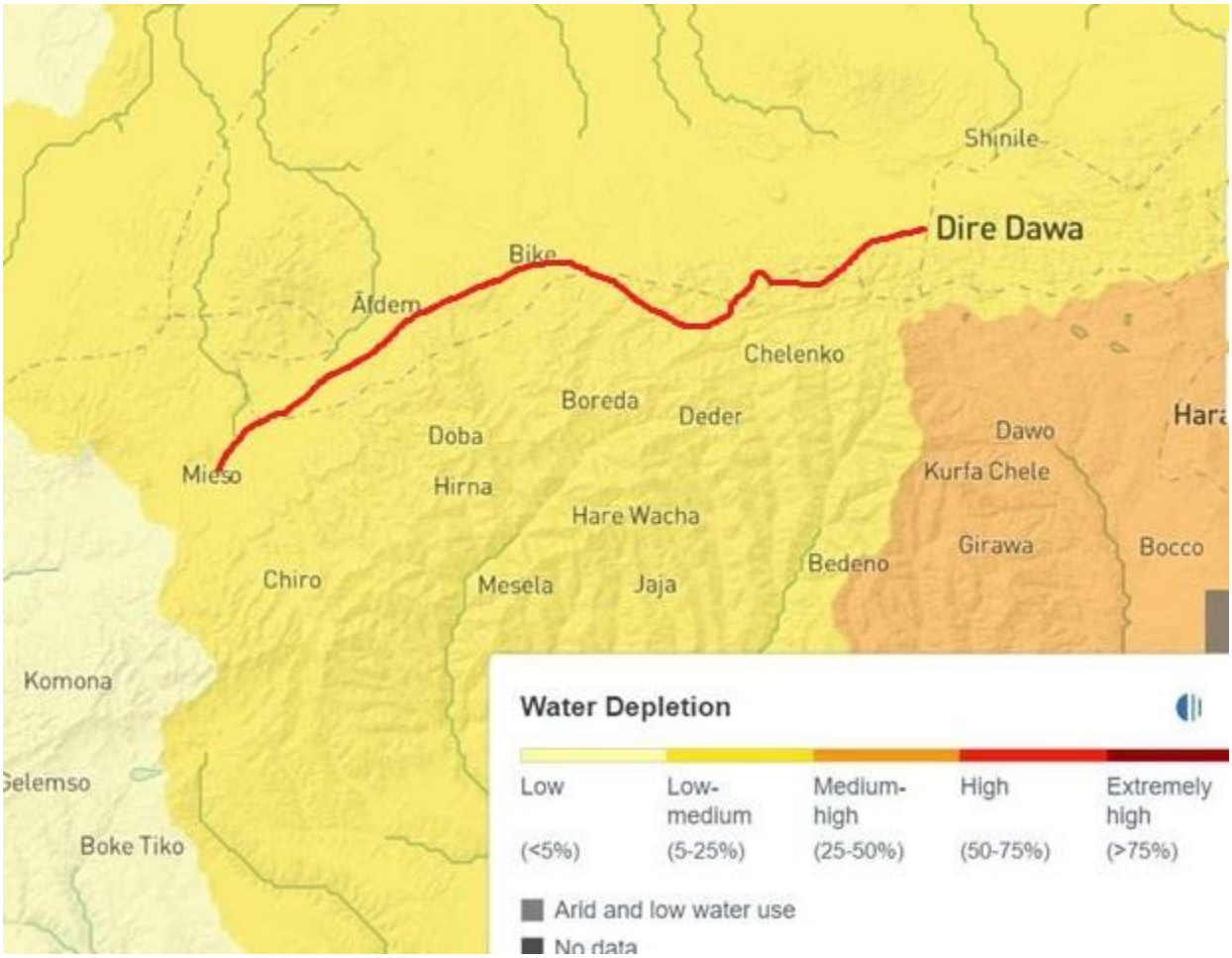


Fig. 50. Baseline water depletion risk of the project area (source: https://www.wri.org/applications/aqueduct/water-risk-atlas/)

Interannual variability

The interannual variability of available water supply of the project area is assessed as low – medium(0.25 – 05.0) (Fig. 51).

Box 3. Interannual variability measures the average betweenyear variability of available water supply, including both renewable surface and groundwater supplies. Higher values indicate wider variations in available supply from year to year (WRI Aqueduct, 2019).

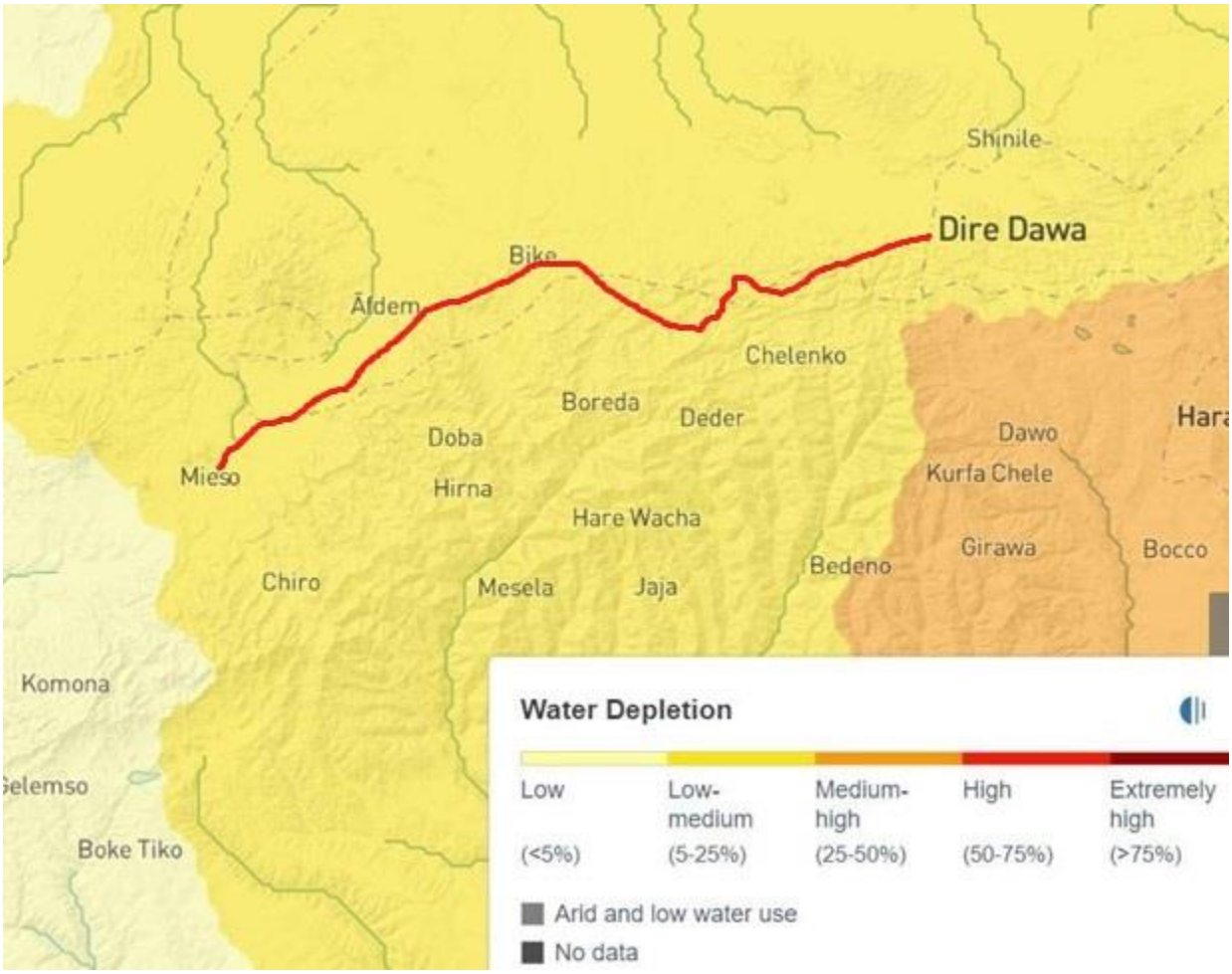


Fig. 51. Baseline interannual variability of available water supply of the project area (source: https://www.wri.org/applications/aqueduct/water-risk-atlas/)

Seasonal variability

The seasonal variability of available water supply is different along the Mieso – Dire Dawa Expressway (Fig. 52). Whereas the seasonal variability of available water supply is assessed as medium – high (0.66-1.00) from Mieso – Erer, it is low – medium (0.33-0.66) in areas of the project around Dire Dawa.

Box 4. Seasonal variability measures the average within-year variability of available water supply, including both renewable surface and groundwater supplies. Higher values indicate wider variations of available supply within a year (WRI Aqueduct, 2019).

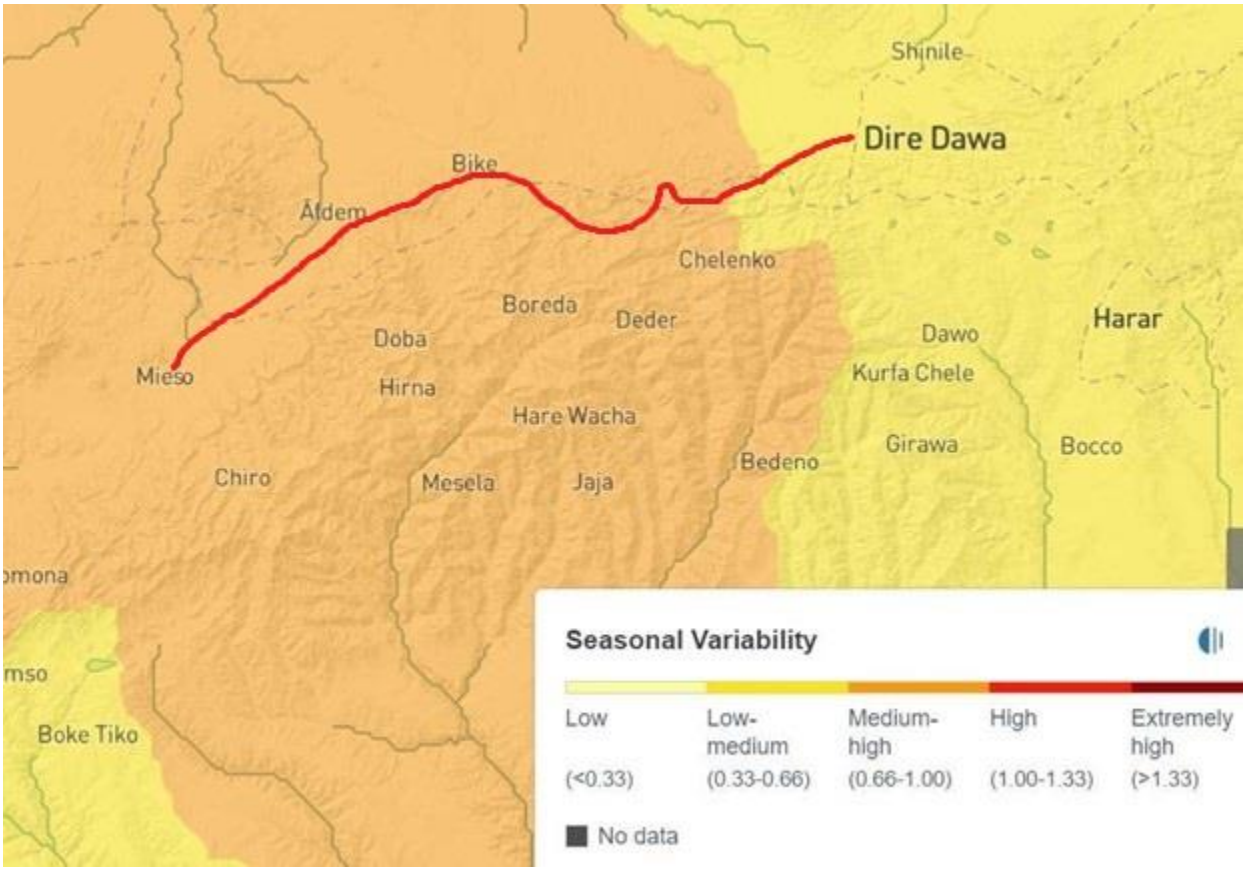


Fig. 52. Baseline seasonal variability of available water supply (source: https://www.wri.org/applications/aqueduct/water-risk-atlas/)

Groundwater table decline

There are two classes with regard to groundwater table decline of the project area (Fig. 53). The areas of the project around Mieso is characterized as with low groundwater table declines (less than 0 cm per year). A groundwater table decline was found to be insignificant for the remaining parts of the project.

Box 5. Groundwater table decline measures the average decline of the groundwater table as the average change for the period of study (1990–2014). The result is expressed in centimeters per year (cm/yr). Higher values indicate higher levels of unsustainable groundwater withdrawals (WRI Aqueduct, 2019).

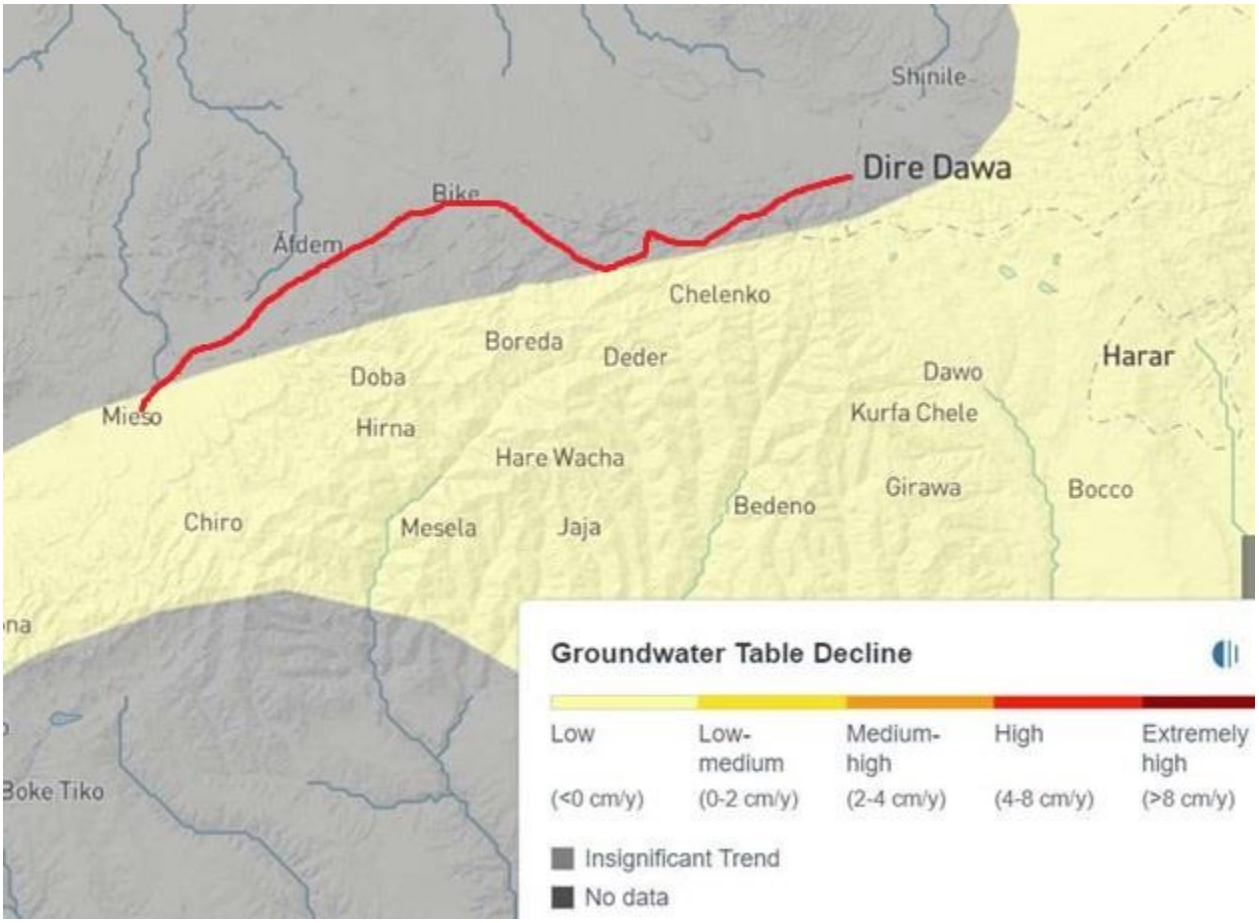


Fig. 53. Baseline groundwater table decline of the project area (source: https://www.wri.org/applications/aqueduct/water-risk-atlas/)

Riverine flood risk

The percentage of population affected by riverine flooding was assesses as low – medium (1 in 1,000 – 2 in 1,000) (Fig. 54).

Box 6. Riverine flood risk measures the percentage of population expected to be affected by Riverine flooding in an average year, accounting for existing flood-protection standards. Flood risk is assessed using hazard (inundation caused by river overflow), exposure (population in flood zone), and vulnerability.16 The existing level of flood protection is also incorporated into the risk calculation. It is important to note that this indicator represents flood risk not in terms of maximum possible impact but rather as average annual impact. The impacts from infrequent, extreme flood years are averaged with more common, less newsworthy flood years to produce the "expected annual affected population." Higher values indicate that a greater proportion of the population is expected to be impacted by Riverine floods on average (WRI Aqueduct, 2019).

Fig. 54. Baseline riverine flood risk of the project area (source: https://www.wri.org/applications/aqueduct/water-risk-atlas/)

Drought risk

The drought risk of the project area was assessed as medium (0.4 – 0.6) (Fig. 55).

Box 7. Drought risk measures where droughts are likely to occur, the population and assets exposed, and the vulnerability of the population and assets to adverse effects. Higher values indicate higher risk of drought (WRI Aqueduct, 2019).

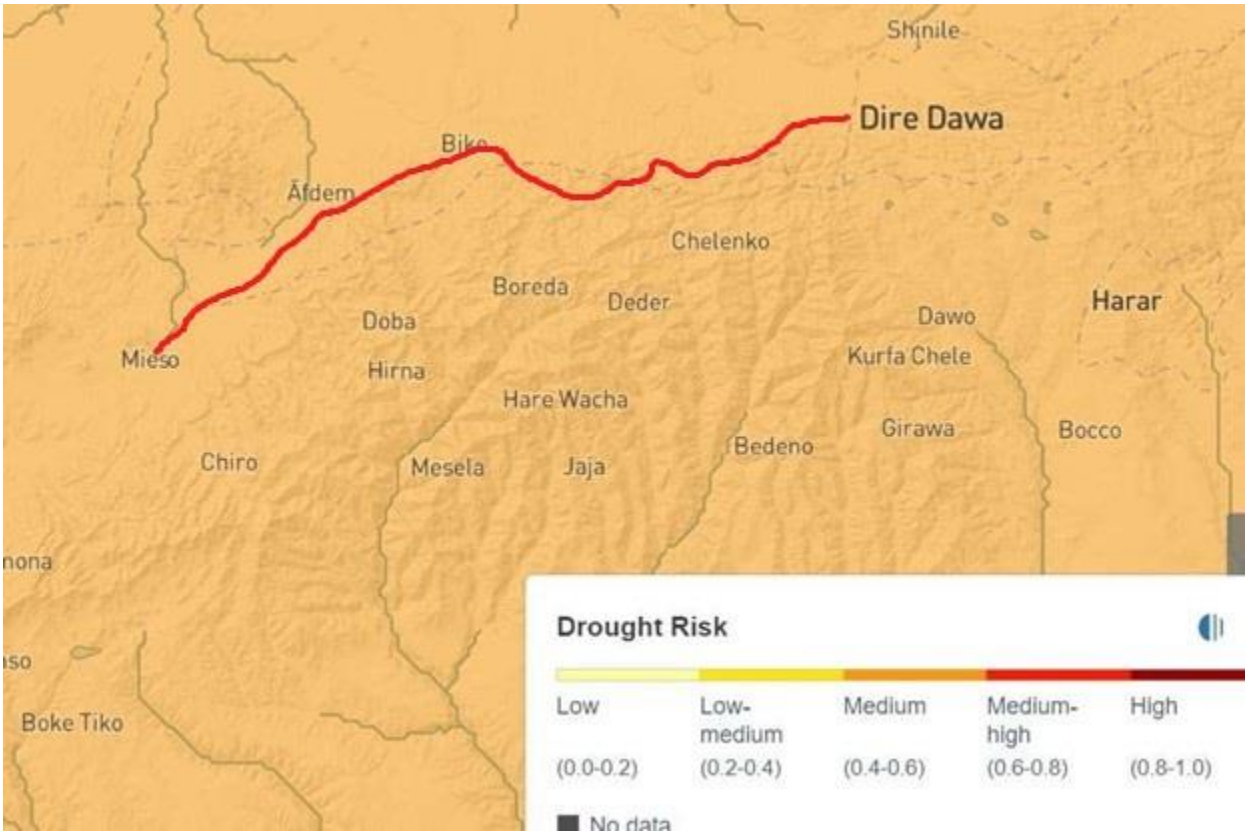


Fig. 55. Baseline flood risk of the project area (source: https://www.wri.org/applications/aqueduct/water-risk-atlas/)

5.5.2. Future Overall Water Risk

The future overall water risk is based on three scenarios (Box 8).

Box 8. Future scenarios of overall water risk (WRI Aqueduct, 2015).
Optimistic:
The "optimistic" scenario (SSP2 RCP4.5) represents a world with stable economic development and carbon emissions peaking and declining by 2040, with emissions constrained to stabilize at ~650 ppm CO_2 and temperatures to 1.1–2.6°C by 2100.
Business as usual:
The "business as usual" scenario (SSP2 RCP8.5) represents a world with stable economic development and steadily rising global carbon emissions, with CO_2 concentrations reaching ~1370 ppm by 2100 and global mean temperatures increasing by 2.6–4.8°C relative to 1986–2005 levels.
Pessimistic:
The "pessimistic" scenario (SSP3 RCP8.5) represents a fragmented world with uneven economic development, higher population growth, lower GDP growth, and a lower rate of urbanization, all of which potentially affect water usage; and steadily rising global carbon emissions, with CO_2 concentrations reaching ~1370 ppm by 2100 and global mean temperatures increasing by 2.6–4.8°C relative to 1986–2005 levels.

The timeframe 2040 was used for future overall water risk of the project area. There are four indicators for future water risk assessment. These are water stress, seasonal variability, water supply and water demand.

6. Impacts on Biodiversity and Management Plan

Based on the assessment conducted and project activities, the impact of the project on biodiversity of the project area has been assessed. The cumulative impact on biodiversity is assessed in a separate document. The impacts on biodiversity, mitigation measures, and management plan are discussed in the following sections.

6.1. Impacts on Biodiversity

6.1.1. Habitat Loss and Degradation

Impact on the natural habitats and plant communities will likely occur during project road construction activities such as clearing for road RoW, link roads, ancillary facility sites, and access to ancillary facilities. Since most of the length of the project road and ancillary facilities fall within or close to the two KBAs, the habitats to be affected are critical/sensitive habitats. Some of the plant communities have endemic and IUCN red list species which are of greater conservation concern. Habitat loss due to project activities is both temporary and permanent. In addition to habitats loss and degradation due to land take and clearing of vegetation, accidental spill or release of hazardous substances and waste from construction camp and ancillary facilities will pose a risk to the habitats.

6.1.2. Habitat Fragmentation and Edge Effect

The linear road construction project and associated vegetation clearance has the potential to cause habitat fragmentation. Habitat fragmentation results in loss and degradation of habitats by reducing them to patches which are isolated, unsuitable for foraging and breeding, and are not ecologically viable as they are getting smaller and smaller. Habitat fragmentation also results in edge effect as the smaller patches of habitats have increased edges. Edge effect include increased light penetration, higher wind speeds, and unsuitable species spreading in from adjacent land use. The project area already has a new railway line which is almost parallel to the planned project road. Further, smallholder rainfed agriculture and urban expansion are showing increasing trends. The combination of these coupled with the project road will further fragment the natural habitat, particularly the two KBAs.

6.1.3. Loss of Rare and Threatened Species

The two endemic Aloe species i.e., *Aloe harlana* and *Aloe pubescens*, are of great conservation concern. Further, there are locally rare species such as *Caralluma acutangula*, *Caralluma priogonium*, *Caralluma speciose*, and *Kleinia dolichocoma*. Also, IUCN red list animal species in the project area include *Panthera pardus*, *Panthera Leo*, *Acinonyx jubatus I/r*, *Hyaena hyaena*, *Tragelaphus imberbis*, and *Centrochelys sulcate*. Habitats loss and degradation is expected to affect these rare or conservation concern plant and animal species.

6.1.4. Invasive Species Proliferation/Expansion

Some parts of the project area are already infested by *Prosopis juliflora* which is an evergreen shrub causing

degradation of native biodiversity and grazing areas in arid environments such as the project area. With the current rate of the expansion of *Prosopis juliflora*, most of the areas of the Afdem – Gewane KBA will be covered by thick, impenetrable thickets of this species. Also, *Opuntia ficus-indica* may pose a threat of homogenization of this natural habitat. Increased movement of project workers and vehicles during the construction period may have a risk of introduction and transfer of invasive species to plant communities that are not currently affected by the invasive species.

6.1.5. Impact on Water Resources

The project area has a limited water resources. Only five perennial rivers cross the project road. The local communities use available surface water bodies (rivers) and the groundwater resource. Construction of the project road will compete for these water resources and could also result in water quality deterioration. The project could cause sedimentation, high turbidity, and eutrophication of surface water resources. Spill and contamination of water resources by hazardous substances may affect the aquatic habitats and organisms. Human consumption of contaminated water will pose health risks.

6.1.6. Impact on Aquatic Organisms

Implementation and operation of the project expressway and ancillary facilities will affect aquatic animals in the available surface water resources. The impacts include (i) altering river/stream hydrologic regime through modification of surface and groundwater flows, levels, and cross-sections due road construction activities such as earthwork and hydraulic structures construction, (ii) altering of river/stream channels through redirecting flows, changing sediment load, and nutrients load on which aquatic organisms survival and reproduction depend on, (iii) construction of the road could destroy aquatic habitats through clearing of aquatic vegetation, dredging, and blocking of waterways by construction spoil, (iv) road crossing create barriers for movement or restrict movement of aquatic animals, (v) reduction of available water in the watershed systems due to resource competition and utilization for various construction activities, and (vi) heavy metals derived from fossil fuel, hydrocarbon, and other pollutants often end up in water bodies and affects aquatic organisms health and may even kill some aquatic organisms. Some of the above impacts occur in the direct impact zone while other affect watershed systems.

6.1.7. Loss of Ecosystem Services

The local communities main livelihood is pastoral and agro-pastoral. The local communities depend on the *Acacia* woodlands of the project area for livestock grazing/browsing, firewood collection, charcoal making, and water for livestock watering and human domestic consumption. Habitats loss and degradation will eliminate or reduce the ecosystem services on which the livelihood of the local community depend on. Food insecurity, income reduction or loss, social conflict, and increased poverty could result due to loss or reduction of household income and overall impact on their livelihood.

6.1.8. Air Quality Impact

Construction of the project road is expected to emit dust, particularly land clearing, earthwork, and materials production activities for road RoW and at ancillary facility sites. Dust accumulation on leaves can block stomata and impact photosynthesis and transpiration. Prolonged exposure to dust emission can affect plant species and could result in loss of growth or regenerative capacity of the plant species. Those plants near the source of dust emission will be affected more. Vehicle emissions such as CO, SO_2, NO_x, and particulate matter will also affect plant and animal species.

6.1.9. Noise and Vibration Impact

Noise and vibration from project machineries, plants, and vehicles could evoke a flight reaction by most fauna. Most animals are known to experience stress, increased susceptibility to diseases, reduced biological fitness, and decreased breeding success due to exposure to noise and vibration.

6.1.10. Impact due to Light

Light emitted from construction vehicles (if construction is done during night) and vehicles using the road affects certain animal species, resulting in behavioral changes such as altered feeding and roosting patterns.

6.1.11. Collision of Project Vehicles with Fauna

During the construction period, particularly during land clearing and earthwork, accidental collision with vehicles and machineries will result in injury and mortality of fauna. In particular, impact on threatened species could be most significant.

6.2. Mitigation Measures

The following mitigation measures are recommended for the identified impacts on the biodiversity of the project area based on the mitigation hierarchy of avoid, minimize, and mitigate.

6.2.1. Mitigation Measures for Impacts on Plant Species and Habitats

The following mitigation measures are recommended:

- The contractor should conduct its own biodiversity assessment in the project influence area and prepare a Biodiversity Management Plan prior project implementation.
- To the extent possible, avoid removal of endemic, rare, or threatened plant species, particularly matured trees.
- Explore the possibility of relocating endemic, rare, or threatened plant species to a suitable receptor site.
- To the extent possible, avoid important habitats and plant communities during clearing for road RoW and locating ancillary facility sites.
- Invasive species propagation procedure should be implementing including avoidance of areas with invasive species by the project workforce and washing of project machines and vehicles.
- Herbicides and fire should not be used to clear vegetation to ensure minimum impact during clearing and reduce injury and mortality of wildlife.
- The contractor should assign and seek advice from a biodiversity expert during clearing of land and vegetation.
- Vegetation clearance should be limited to the absolute necessary.
- Dust emission is kept to the minimum through watering/showering, gravel application, and sealing frequently used access roads.
- Spill or release of hazardous substances should be avoided. Spill management procedures should be developed and implemented. Also, emergency response procedures should be developed and implemented.

- Project workforce should not be engaged in collection of plant materials.
- Revegetate, rehabilitate, and restore cleared areas with native species once construction activities are completed.
- Create awareness and provide training for construction workers on protected of vegetation cover, habitats, poaching, etc.

6.2.2. Mitigation Measures for Impacts on Fauna

The following mitigation measures are recommended:

- Consider mitigation measures recommended for impact on plant species above since protection of habitats should be given attention to reduce impacts on fauna.
- Construction should be avoided at dusk, dawn, and night to avoid disturbance to fauna nocturnal and crepuscular patterns.
- Habitats clearing should be done in a progressive and sensitive manner to give time to fauna move away or relocate to surrounding areas.
- Implement speed limit during construction period to minimize collision of animals with project machineries and vehicles.
- Wildlife crossing points should be considered, where necessary.
- Noise and vibration should be limited to minimize disturbance to fauna.
- Project workers should not poach wildlife.

6.2.3. Mitigation Measures for Impacts on Water Resources and Aquatic Organisms

The following mitigation measures are recommended:

- Contractor should develop and implement a water management plan.
- Avoid or minimize soil erosion and water bodies sedimentation during earthworks, structures construction, and other construction activities.
- Avoid accidental spill and release of hazardous substance in water bodies and on land to avoid contamination.
- Project workers should not fish, hunt, and collect natural resources from aquatic habitats.
- The project should reduce water consumption to the extent possible through developing and implementing a water management plan.
- Rehabilitate or restore project affected aquatic habitats.

6.3. Biodiversity Management and Monitoring Plan

Table 18. An Indicative Biodiversity Management and Monitoring Plan

Impact on Biodiversity during Project Construction and Operation	Recommended Mitigation Measures	Responsibility for Implementing Mitigation Measures	Monitoring Responsibility	Monitoring Indicators	Monitoring Frequency
Habitat loss and degradation	<u>Mitigation Measures for Impacts on Plant Species</u> - The contractor should conduct its own biodiversity assessment in the project influence area and prepare a Biodiversity Management Plan prior project implementation. - To the extent possible, avoid removal of endemic, rare, or threatened plant species, particularly matured trees. - Explore the possibility of relocating endemic, rare, or threatened plant species to a suitable receptor site. - To the extent possible, avoid important habitats and plant communities during clearing for road RoW and locating ancillary facility sites. - Invasive species propagation procedure should be implementing including avoidance of areas with invasive species by the project workforce and washing of project machines and vehicles. - Herbicides and fire should not be used to clear vegetation to ensure minimum impact during clearing and reduce injury and mortality of wildlife. - The contractor should assign and seek advice from a biodiversity expert during clearing of land and vegetation. - Vegetation clearance should be limited to the absolute necessary.	- Project contractor and sub-contractors - Ethiopia Roads Administration (overall implementation responsibility)	- Project supervising engineer - Ethiopia Roads Administration (overall monitoring responsibility) - Federal, regional, and local environmental protection agencies - Federal, regional, and local agriculture ministry / bureaus / offices - Federal, regional, and local water ministry / bureaus / offices - Regional and local land administration bureaus / offices	- Area of vegetation cleared - Area covered by invasive species - Species diversity, richness, and evenness - Number or proportion of endemic species - Number or proportion of rare and threatened species - Habitat connectivity, patchiness	Biannual
Habitat fragmentation and edge effect					Biannual
Loss of rare and threatened species					Biannual
Invasive species proliferation					Biannual

Impact on Biodiversity during Project Construction and Operation	Recommended Mitigation Measures	Responsibility for Implementing Mitigation Measures	Monitoring Responsibility	Monitoring Indicators	Monitoring Frequency
Impact on water resources	- Dust emission is kept to the minimum through watering/showering, gravel application, and sealing frequently used access roads. - Spill or release of hazardous substances should be avoided. Spill management procedures should be developed and implemented. Also, emergency response procedures should be developed and implemented. - Project workforce should not be engaged in collection of plant materials. - Revegetate, rehabilitate, and restore cleared areas with native species once construction activities are completed. - Create awareness and provide training for construction workers on protected of vegetation cover, habitats, poaching, etc. <u>Mitigation Measures for Impacts on Animal Species</u> - Consider mitigation measures recommended for impact on plant species since protection of habitats should be given attention to reduce impacts on fauna. - Construction should be avoided at dusk, dawn, and night to avoid disturbance to fauna nocturnal and crepuscular patterns. - Habitats clearing should be done in a progressive and sensitive manner to give time to fauna move away or relocate to surrounding areas.		- Ethiopian Biodiversity Institute - Ethiopian Wildlife Conservation Authority	- Water volume consumed - Surface and groundwater quality (pH, TDS, Turbidity, EC, COD, BOD, anion, cation, heavy metals)	Biannual
Loss of ecosystem services				- Household income reduction - Poverty level	Biannual
Air quality impact				- Concentration of PM_{10}, CO, NOx, SO_2	Monthly
Noise and vibration impact				- Noise level (in dB) during daytime, nighttime	Monthly

Impact on Biodiversity during Project Construction and Operation	Recommended Mitigation Measures	Responsibility for Implementing Mitigation Measures	Monitoring Responsibility	Monitoring Indicators	Monitoring Frequency
Impact due to light	- Implement speed limit during construction period to minimize collision of animals with project machineries and vehicles. - Wildlife crossing points should be considered, where necessary. - Noise and vibration should be limited to minimize disturbance to fauna. - Project workers should not poach wildlife. <u>Mitigation Measures for Impacts on Water Resources and Aquatic Organisms</u> - Contractor should develop and implement a water management plan. - Avoid or minimize soil erosion and water bodies sedimentation during earthworks, structures construction, and other construction activities. - Avoid accidental spill and release of hazardous substance in water bodies and on land to avoid contamination. - Project workers should not fish, hunt, and collect natural resources from aquatic habitats. - The project should reduce water consumption to the extent possible through developing and implementing a water management plan. - Rehabilitate or restore project affected aquatic habitats.			- Hours worked during dusk, dawn, and night	Monthly
Collision of project vehicles with fauna				- Number of accidents, incidents, near misses recorded and response given	Daily

7. Conclusion and Recommendations

7.1. Conclusion

Detailed biological and water resources baseline study was conducted by a team of experts drawn fromdifferent relevant disciplines. The following conclusions were made based on the findings of this study.

i. Vegetation: The project area is located in *Combretum - Terminalia* woodland vegetation. The study shows that vegetation of the direct and secondary impact zones of the project were used to be intact with large mature individuals of *Acacia* species. Gradual cutting of mature trees of this vegetation through extensive charcoal has led its current level of degradation. Currently, the vegetation of the project area is converted to thickets and infected by invasive species. Furthermore, continued heavy grazing and browsing have stunted plant growth and suppressed natural regeneration.

ii. Endemism: There are a number of rare endemic plant species in the project area. These endemic plants will be negatively affected by the activities of the project, e.g., clearing of vegetation along the RoW and access roads and establishment of camps by a Contractor.

iii. Water resources. There are limited numbers of perennial rivers and most of the rivers that cross the Expressway are seasonal. The local communities use the streams along the project route and also utilize boreholes for local consumption and their livestock. The construction of the expressway project requires a considerable volume of water, which has the potential of competing with the resource available in the corridor. Therefore, it is considered that water is very limited and the use of the existing perennial rivers for the road construction would negatively affect the water demand in the project area.

7.2. Recommendation

i. Based on the assessment, activities of the project negatively affect endemic species, plants of conservation concern and the remaining scattered mature Acacia species. Therefore:
   - The contractor will assign a Biodiversity Specialist(s) who will conduct pre-construction checks, to avoid or minimize identified potential risks on natural vegetation and aquatic biodiversity to the lowest scale possible.
   - Right before the commencement of project construction activities, the contractor will be required to prepare a Biodiversity Management Plan to be a guide during construction period. The biodiversity specialist, based on the design study's ESIA and (Updating) Biodiversity and Habitat Baseline Data Report has to map out, rare species, sensitive habitat, less sensitive sites, etc… in the plan and draft a method with regard to conservation and potential replacement of negatively affected plant species.
   - Construction practice that minimizes the construction width needs to be adopted.
   - During site selection (for ancillary sites that are not identified in the design stage, such as camps, workshops, plant sites, etc…) the contractor needs to attempt to locate areas with minimal removal of vegetation and away from identified important species or sensitive areas.
   - Further, the contractor is strongly recommended to follow these, and other recommended measures as stipulated under the design study's ESIA and Terms of Reference in order to minimize the potential risks on natural biodiversity.

ii. It was also noted that, there is a scarcity of water in the project area. Hence, in order mitigate impacts of the project on the availability of the resource:
   - Prior to commencement of works, the contractor shall prepare a Management Plan to

minimize adverse impacts on water resources.

- Construction methodologies need to be demand-reducing with consideration of resource conservation and recycling of resource where possible.
- Upon utilization of water from streams, use of alternative water supply sources and scheduling the operations in a way that spreads extractions are advised in order to avoid overlap of maximum demands and of maximum competitions of use.
- Additionally, as perennial streams are limited, for the water consumption of the project, preparation of water harvesting ponds to collect from seasonal streams or extraction of underground water are recommended to fulfill the project water demand.
- The contractor, similarly, should adopt the water resource conservation measures forwarded in the ESIA to reduce potential impacts on water resources.

iii. The bidding document will be prepared in such a way that the contractor will be required to prepare the plans, and implement the activities, mentioned above as well as employ the required specialists.

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9. Annexes

Annex 1: List of experts for this study

Name	Areas of Expertise	Roles in the study
Prof. Sileshi Nemomissa	Environmentalist and Biodiversity (plants, Birds, KBAs, IUCN conservation classifications of species)	Team Leader
Prof. Seyoum Mengistou	Aquatic Ecology, algal diversity and water quality	Aquatic Ecologist
Dr. Dessie Nedaw	Hydrogeology and groundwater recharge assessment	Hydrogeologist
Dr. Bikila Warkineh	Terrestrial Ecology	Ecologist
Mr. Melaku Wondafrash	Plant Identification	Plant Identification field technical assistant
Mr. Shambel Alemu	Wildlife identification	Animal Identification field technical assistant
Mr. Fiseha Getachew	Plant and animal identification, water sampling	Overall field technical assistant

Annex 2: List of species determined from the project area. Key: * = endemics; ** = invasive species;LC = Least Concern. Not assessed means that the conservation status of the species has not been assessed (IUCN categories has not been assigned). EN = Endangered; NT = Near Threatened.

Sr. Nr.	Species	IUCN Category	Population trend	Family
1	*Barleria ventricosa* Hochst. ex Nees	Not assessed	-	Acanthaceae
2	*Barleria eranthemoides* R. Br.	Not assessed	-	
3	*Blepharis edulis* (Forssk.) Pers.	Not assessed	-	
4	*Ecbolium* sp.			
5	*Justicia flava* (Vahl) Vahl	Not assessed	-	
6	*Megalochlamys violacea* (Vahl) Vollesen	Not assessed	-	
7	*Ruellia patula* Jacq.	Not assessed	-	
8	*Zaleya pentandra* (L.) Jeffrey	Not assessed	-	Aizoaceae
9	*Aloe harlana* Reynolds*	EN	Decreasing	Aloaceae
10	*Aloe pubescens* Reynolds*	NT	Stable	
11	*Aloe megalacantha* Baker	LC	Decreasing	
12	*Aloe pirottae* Berger	LC	Unknown	
13	*Achyranthes aspera* L.	Not assessed but it is a common weed	-	Amaranthaceae
14	*Aerva javanica* (Burm.f) Schultes	Not assessed but locally common in the project area	-	
15	*Alternanthera pungens* Kunth	NA because of its marginal occurrence	-	
16	*Amaranthus graecizans* L.	Not assessed	-	
17	*Amaranthus hybridus* L.	Not assessed	-	
18	*Amaranthus lividus* L.	Not assessed	-	
19	*Celosia polystachia* (Forssk.) C.C. Townsend	Not assessed		
20	*Gomphrena celosioides* Mart.	Not assessed		
21	*Psilotrichum gnaphalobryum* (Hochst.) Schinz			
22	Pupalia lappacea (L.) A. Juss.			
23	Rhus natalensis Krauss			Anacardiaceae
24	Lannea malifolia (Chiov.) Sacl.			
25	Carissa spinarum L.			Apocynaceae
26	Phoenix dactylifera L.			Arecaceae
27	Calotropis procera (Ait.) Airf			Asclepiadaceae
28	Caralluma acutangula (Decne.) NE Br.			

29	Caralluma priogonium K. Schum.			
30	Caralluma speciosa (NE Br.)NE Br.			
31	Dregea rubicunda K. Schum.			
32	Echidnopsis sp.			
33	Leptadenia sp.			
34	Pergularia daemia (Forssk.) Chiov.			
35	Acanthospermum hispidum DC.			Asteraceae
36	Crepis sp.			
37	Kleinia dolichocoma C. Jeffrey			
38	Kleinia squarrosa Cufod.			
39	Parthenium hysterophorus L. **			
40	Pluchea dioscoridis (L.) DC.			
41	Sphaeranthus suaveolens (Forssk.) DC.			
42	Tridax procumbens L.			
43	Verbesina encelioides (Cav.) A. Gray			
44	Vernonia cinerascens Sch. Bip. in Schweinf & Asch			
45	Vernonia sp.			
46	Xanthium spinosum L.			
47	Xanthium strumarium L. **			
48	Balanites aegyptiaca (L.) Del.			Balanitaceae
49	Cordia myxa L.			Boraginaceae
50	Cordia monoica Roxb.			
51	Bourreria orbicularis (Hutch. & E.A. Bruce) Thulin			
52	Ehretia cymosa Thonn.			
53	Heliotropium aegyptiacum Lehm.			
54	Heliotropium cinerascens DC. & A. DC.			
55	Heliotropium sp.			
56	Farsetia longisiliqua Dec.			Brassicaceae
57	Farsetia stylosa R. Br.			
58	Commiphora sp.			Burseraceae
59	Opuntia ficus-indica (L.) Miller **			Cactaceae

60	Boscia sp.			Capparidaceae
61	Cadaba farinosa Forssk			
62	Cadaba rotundifolia Forssk.			
63	Capparis fascicularis DC.			
64	Capparis tomentosa Lam.			
65	Cleome scaposa DC.			
66	Carica papaya L.			Caricaceae
67	Catha edulis (Vahl) Forssk. ex Endl.			Celasteraceae
68	Combretum molle R. Br. ex G. Don			Combretaceae
69	Terminalia brownii Fresen.			
70	Commelina diffusa Burm.f			Commelinaceae
71	Seddera bagshawei Rendle			Convolvulaceae
72	Seddera sp.			
73	Crassula schimperi Fisch. & Mey.			Crassulaceae
74	Kalanchoe lanceolata (Forssk.) Pel's.			
75	Cucumis dipsaceus Ehrenb. ex Spach			Cucurbitaceae
76	Cyperus sp.			Cyperaceae
77	*Sansevieria ehrenbergii* Schweinfurth ex Baker			Dracanaceae
78	*Euclea divinorum* Hiern			Ebenaceae
79	Acalypha fruticosa Forssk.			Euphorbiaceae
80	Croton dichogamus Pax			
81	Euphorbia hirta L.			
82	Euphorbia inaequilatera Sond.			
83	Euphorbia tirucalli L.			
84	Euphorbia polyacantha Boiss.			
85	Jatropha curcas L.			
86	Jatropha glauca Vahl			
87	Ricinus communis L.			
88	Acacia bussei Harms ex Sjostedt			Fabaceae
89	Acacia etbaica Schweinf			
90	Acacia mellifera (Vahl) Benth			
91	Acacia nilotica (L.) Willd. ex Del.			
92	Acacia oerfota (Forssk.) Schweinf			

93	Acacia robusta Burch.			
94	Acacia senegal (L.) Wild.			
95	Acacia seyal Del.			
96	Acacia tortilis (Forssk.) Hayne			
97	Crotalaria pycnostachya Benth.			
98	Crotalaria emarginella Vatke			
99	Crotalaria dumosa Franch.			
100	Crotalaria albicaulis Franch.			
101	Crotalaria laburnifolia L.			
102	Indigofera amorphoides Jaub. & Spach			
103	Indigofera articulata Gouan			
104	Indigofera spinosa Forssk			
105	Parkinsonia aculeata L.			
106	Prosopis juliflora (Sw.) DC. **			
107	Senna alexandrina Mill.			
108	Senna didymobotrya (Fresen.) Irwin & Barneby			
109	Senna italica Mill.			
110	Senna obtusifolia (L.) Irwin & Barneby			
111	Senna occidental is (L.) Link			
112	Tamarindus indica L.			
113	Tephrosia pumila (Lam.) Pers.			
114	Vigna sp.			
115	Enicostema axillare (Lam.) Raynal			Getianaceae
116	Endostemon sp.			Lamiaceae
117	Leucas inflata Benth.			
118	Leucas jamesii Bak.			
119	Leucas nubica Benth.			
120	Plectranthus sp.			
121	Premna oligotricha Baker			
122	Abutilon fruticosum Guill. & Perr.			Malvaceae
123	Hibiscus aponeurus Sprague & Hutch.			
124	Hibiscus dongolensis Del.			
125	Hibiscus micranthus L. f.			
126	Malva sp.			

127	Sida urens L.			
128	Azadirachta indica A. Juss.			Meliaceae
129	Cocculus pendulus (J. R. & G. Forst) Diels			Menispermaceae
130	Mollugo nudicaulis Lam.			Molluginaceae
131	Ficus sp.			Moraceae
132	Moringa stenopetala (Bak. f) Cufod.			Moringaceae
133	Boerhavia coccinea Mill.			Nyctaginaceae
134	Commicarpus pedunculosus (A. Rich.) Cufod.			
135	Ochna inermis (Forssk.) Schweinf ex Penzig			Ochnaceae
136	Jasminum abyssinicum Hochst. ex DC.			Oleaceae
137	Jasminum grandiflorum L.subsp. floribundum (R.Br.ex Fresen.) P.S. Green			
138	*Ludwigia stolonifera* (Guill. & Perl'.) Raven			Onagraceae
139	Argemone mexicana L. **			Papaveraceae
140	Adenia venenata Forssk.			Passifloraceae
141	Sesamum orientale L.			Pedaliaceae
142	Aristida sp.			Poaceae
143	Brachiaria sp.			
144	Cenchrus ciliaris L.			
145	Chloris sp.			
146	Cymbopogon sp.			
147	Cynodon sp.			
148	Dactyloctenium aegyptium (L.) Willd.			
149	Digitaria sp.			
150	Echinochloa sp.			
151	Eragrostis sp.			
152	Loudetia cf. flavida (Stapf) CE. Hubb.			
153	Panicum sp.			
154	Sorghum bicolor (L.) Moench			
155	Sporobolus sp.			
156	Portulaca oleracea L.			Portulacaceae

157	Berchemia discolor (Klotzsch) Hemsl			Rhamnaceae
158	Ziziphus mucronata Willd.			
159	Ziziphus spina-christi (L.) Desf.			
160	Kohautia sp.			Rubiaceae
161	Citrus aurantium L.			Rutaceae
162	Dobera glabra (Forssk.) Poir.			Salvadoraceae
163	Dodonea angustifolia L.f.			Sapindaceae
164	*Mimusops kummel* A. DC.	*LC*	*Stable*	Sapotaceae
165	Verbascum sinaiticum Benth.			Scrophulariaceae
166	Veronica anagallis-aquatica L.			
167	Datura metel L.			Solanaceae
168	Datura stramonium L.			
169	Lycium shawii Roem. & Schult.			
170	Physalis ixocarpa Brot. ex Hornem.			
171	Solanum coagulans Forssk.			
172	Solanum dennekense Dammer			
173	Solanum jubae Bitter			
174	Solanum incanum L.			
175	Solanum somalense Franchet.			
176	Withania somnifera (L.) Dunal			
177	*Sterculia rhynchocarpa* K. Schum.			Sterculiaceae
178	Tamarix nilotica (Ehrenb.) Bunge			Tamaricaceae
179	Corchorus sp.			Tiliaceae
180	Grewia arborea (Forssk.) Lam.			
181	Grewia bicolor Juss.			
182	Grewia erythraea Schweinfurth			
183	Grewia flavescens Juss.			
184	Grewia mollis A. Juss.			
185	Grewia schweinfurthii Burret			
186	Grewia tembensis Fresen.			
187	Grewia villosa Willd.			

188	Typha latifolia L.			Typhaceae
189	Lantana camara L. **			Verbenaceae
190	Phyla nodiflora (L.) Greene			
191	Cissus quadrangularis L.			Vitaceae
192	Cissus rotundifolia (Forssk.) Vahl			
193	Fagonia schweinfurthii Hadidi			Zygophyllaceae
194	Tribulus cistoides L.			