2022-03

Morphological and Temporal Dynamics of Gully Erosion at Abelasta Watershed, Sekela Woreda, Ethiopia

Aimere Yenew

BAHIR DAR UNIVERSITY

COLLEGE OF AGRICUTLURE AND ENVIRONMENTAL SCIENCES

GRADUATE PROGRAM

MORPHOLOGICAL AND TEMPORAL DYNAMICS OF GULLY EROSION AT ABELASTA WATERSHED, SEKELA WOREDA, ETHIOPIA

M.Sc. Thesis

By:

Aimere Yenew

March, 2022

Bahir Dar, Ethiopia

BAHIR DAR UNIVERSITY

COLLEGE OF AGRICUTLURE AND ENVIRONMENTAL SCIENCES

GRADUATE PROGRAM

MORPHOLOGICAL AND TEMPORAL DYNAMICS OF GULLY EROSION AT ABELASTA WATERSHED, SEKELA WOREDA, NORTHWESTERN ETHIOPIA

M.Sc. Thesis

By:

Aimere Yenew

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (MSC.) IN WATERSHED MANAGEMENT AND SOIL WATER CONSERVATION

Main Advisor: Dereje Tsegaye (PhD)

Co-advisor: Anwar Assefa (PhD)

March, 2022

Bahir Dar, Ethiopia

THESIS APPROVAL SHEET

As members of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by **Mr. Aimere Yenew** entitled "**Morphological and Temporal Dynamics of Gully Erosion, The Case of Abelasta Watershed, Northwestern Ethiopia**". We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences in **Watershed Management and Soil Water Conservation.**

Board of Examiners

Tilashwork Chanie (PhD) ______________ 4/4/2022

Name of External Examiner Signature Date

Muleta Mekonnen (PhD) ______________ 4/4/2022

Name of Internal Examiner Signature Date

Dr Abebe ______________ 4/4/2022

Name of Chair Person Signature Date

DECLARATION

This is to certify that, this thesis entitled "**Morphological and Temporal Dynamics of Gully Erosion, The Case of Abelasta Watershed, Northwestern Ethiopia**" submitted in partial fulfilment of the requirement of the award of the degree of science in "**Watershed Management and Soil Water Conservation**" to the Graduate Program of College of Agriculture and Environmental Sciences, Bahir Dar University by **Mr. Aimere Yenew Nebeyu** (Id No. BDU 0906366 PS) is an authentic work carried out by him under our guidance the matter embodied in this project work has not been submitted earlier for an award of any degree or diploma to the best of our knowledge and belief.

Name of the Student

Aimere Yenew		4/4/2022
(Name)	Signature	Date

Name of Advisor

1) Dereje Tsegaye (PhD)		4/4/2022
(Main Advisor)	Signature	Date
2) Anwar Assefa (PhD)		04 April 2022
(Co Advisor)	Signature	Date

ACKNOWLEDGEMENT

The writing of this thesis is not possible without the personal and practical support of numerous people. Primarly, I thank the LORD GOD for giving me the strength to start and go through with my studies and his mercy and grace upon me during all these days here in all my life.

This thesis would not have been possible without the expert guidance of my esteemed Advisors major advisor Dr. Dereje Tsegaye and co-advisor Dr. Anwar Assefa. I would like to express my deepest gratitude to them for thier follow up and encouragement throughout my study. Their comments are always extremely perceptive, helpful and appropriate.

I would like to acknowledge Amhara Design and Supervision Works Enterprise for financial and material support for my research work. I would like to acknowledge my family whom support me during data collection and encourage me to do actively.

I would like to acknowledge Sekela wereda agricultural office experts and Bahirzafa Guderkani kebele Adminstrator. Also I would like to acknowledge peasants live around the gully area whom supported me and gave relivant information .

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

A.s.l:	above sea level
Eg:	Example
ELD	Economic of Land Degradation
FAO:	Food and agriculture organization
GIS/RS:	Geographic information system/ remote sensing
Ha:	hectare
Km:	kilometer
RUSLE:	Revised universal soil loss equation
M/yr:	meter/year
SLg:	Soil losses by gullying
T/ha/yr:	ton/hectare/year
UNCCD	United Nations Convention to Combat Desertification
USAID:	The United States Agency for International Development

Morphological and Temporal dynamics of Gully Erosion, The Case of Abelasta Watershed, Northwestern Ethiopia.

ABSTRACT

In Ethiopian highlands, gully erosion has many negative impacts on both cultivated and grazing lands. It also damages infrastructures, social and economic situations of society. Besides, sediment due to gully erosion fills reservoirs and reduce thier life time. But the contribution of gully erosion to soil loss has not been quantified yet. Therefore quantifying soil loss due to gully erosion is important. There is a scarcity of data on soil loss due to gully erosion in our country as well as in the woreda. Previous studies around the district were focused on land degradation, thus, this study attempted to address soil loss due to gully erosion through field measurement and application of GIS and remote sensing. The study is important for soil and water conservation experts, land evaluators and project coordinators to take conservation measures. This study was conducted in Abelasta watershed, Ethiopia. The aim of the study was to investigate morphological and temporal dynamics of gully erosion by using ground measurements and remote sensing. The area of Abelasta watershed is 238.04 ha that quantified gully expansion (by area and width) in 2005, 2013, 2016 and 2020. In addition, I measured gully dimensions in 2021 to determine soil loss because of gully erosion. The results showed that gullies were expanding by depth, width and length. Depending on morphology, gullies described by area, depth and length. Between 2005 and 2020 in the watershed, area covered by gullies increased from 6.24 ha to 15.01 ha, indicating that the proportion of the watershed covered by gullies was over doubled in the investigated period. based on width gullies increased from 129.71 meters to 265.13 meters, they increased from 3335.43 meters to 4247 meters by length between 2005 and 2020. From the watershed, 119.36, 141.43, 14.84, 130.09, 135.82 and 216.83 t ha^{-1} $year^{-1}$ soil was lost at gully 1, gully 2, gully 3, gully 4, gully 5 and gully 6 respectively. The estimated total soil loss due to gully erosion in the watershed was 758.37 t ha^{-1} $year^{-1}$. The results showed that in Abelasta watershed gullies contributed sediment to Abay river which would further fill the Grand Rennaissance Dam of Ethiopia. So, integrated soil and water conservation and gully rehabilitation measures are required to reduce gully erosion.

Keywords: Gully expansion, gully measurement, Soil loss

CHAPTER 1. INTRODUCTION

1.1 Background

Worldwide, soil erosion has been recognized as one of the major problems restricting agriculture (Addisie *et al.*, 2016; Zegeye, 2016; Hayas *et al.*, 2017; Molla and Sisheber, 2017a). It has on-site effects of Erosion like reduction of crop production (reduction of soil fertility) and off-site effects like sedimentation of reservoirs, water quality problem, damage of infrastructures and damage of living organism in water bodies (Desta and Adugna, 2012b).

One of the major devastating catastrophe that speed up soil erosion is gully erosion (Shit *et al.*, 2012) which is greater than 30 cm in depth (Peasley and Taylor, 2009; Luffman *et al.*, 2015). It ranged from simple longitudinal linear incisions to deeply incised dendritic networks and even overhanging cross-profiles to complex badlands might be V-shaped, U-shaped (D'oleire-Oltmanns *et al.*, 2014).

There are many studies that investigated the rate of gully erosion globally. In Turkey, the amount of soil loss because of gully was on an expectable range which was approximately 10 t ha^{-1} yr^{-1} (Ustun and Sciences, 2008). In Australia, Hughes *et al.* (2001) showed that 10,000 cubic meter amount of soil was lost in 1 kilometer gully which was five meters wide and two meters deep. Sediment yields due to gully erosion are very variable in the world, but may be as high as 32 t ha^{-1} yr^{-1} in Niger, 3.4 t ha^{-1} yr^{-1} in Kenya, 64.9 t ha^{-1} yr^{-1} in Spain , 16.1 t ha^{-1} yr^{-1} in Portugal and 36.8 t ha^{-1} yr^{-1} in the USA (Poesen *et al.*, 2003).

In the highland of Ethiopia, about 43% (537,000 km^2) areas are highly affected by soil erosion with an estimated average from 15 to 20 t ha^{-1} yr^{-1} and the amount can be more than 300 t ha^{-1} yr^{-1} on specific plots (Team, 2000; Dubale, 2001). The Abay basin lost fertile soils with a rate of 131 million t ha^{-1} (Betrie *et al.*, 2011). As Moges (2014) stated, about 29 million ha of land is affected with gully in Africa and gullies are sever and widespread on 7.6 million ha of land in Ethiopian highlands. The rate of sheet and rill erosion ranged from 35 to 130 t ha^{-1} yr^{-1} in the Ethiopian highlands in watershed-scale studies (Bewket *et al.*, 2009) but gully erosion is as high as 540 t ha^{-1} yr^{-1} (Tebebu *et al.*, 2010a). For example, it has been reported that gullies are increasingly affecting agricultural lands and account for an estimated soil loss range of 1248–23 400 million tons per year from 78 million ha of pasture, rangelands and cultivated fields across Ethiopia (Daba *et al.*, 2003a). From soil loss, an estimated 90% is deposited at down slope and the remaining sediment was leaving from Ethiopia and transported to Egypt (Meshesha and Tripathi, 2015).

In 608 ha area of Debre Mawi watershed, which is located south to Lake Tana, the amount of soil loss due to gully erosion reached up to 127 t ha^{-1} yr^{-1} soil (Zegeye *et al.*, 2016). A comparison of the gully and upland erosion rates indicates that the soil loss rate of the gully system is approximately 20 times higher than the erosion rates for the rill and inter-rill systems in Debre Mawi watershed (Steenhuis *et al.*, 2013). Rill erosion is significantly lower than gully erosion but it is still nearly four times greater than the generally accepted soil loss rate for the region and thus cannot be ignored in terms of agricultural productivity and soil fertility (Tebebu *et al.*, 2010b). The main aim of this study was to investigate morphological and temporal dynamics of gully erosion by using ground measurements and remote sensing technique at Abelasta watershed.

1.2 Statement of the problem

Gully erosions are soil erosion types that are severe and widespread covering large tracts of areas in the Ethiopian highlands (Desta and Adugna, 2012a). Gullies can be formed either by surface runoff (Valentin *et al.*, 2005) or by soil type and texture, topography, and land management (Capra *et al.*, 2009; Wells *et al.*, 2009).

High population growth, poor rangeland, lack of vegetation cover, overgrazing, intensive and short-period rainfall, improper land use (cultivation on steep slopes), wrong discharge of water in the channels, improper irrigation design, and soil characteristics are the major driving forces for gully erosions (Tamene and Vlek, 2008; Jahantigh and Pessarakli, 2011). Gullies are one of the most destructive forms of erosion, damaging farmland and difficult to reverse (Billi and Dramis, 2003; Moges *et al.*, 2009).

The spread of gully is seen as a cancer affecting many communal grazing spots and crop lands (Desta and Adugna, 2012c). Extensive socioeconomic and environmental impacts are caused by gully form of soil erosion, and most of them are negative (Valentin *et al.*, 2005). According to Zgłobicki *et al.* (2015) the agricultural land, farm productivity/crop yields and grazing land decreased by gully erosion. It lowers groundwater tables (Daba *et al.*, 2003b), contributes to the siltation of lakes, reservoirs and other water ways (Haregeweyn *et al.*, 2012), and can lead to increase flooding risks (Costa and Bacellar, 2007).

Soil erosion studies have generally focused on sheet and rill erosion, while gully erosion has received less attention in different parts of the world including Ethiopia (Valentin *et al.*, 2005; Harden, 2016; Jean, 2018). Also, assessments of gully erosion volumes and its spatial and temporal extent were scarcely studied (Nyssen *et al.*, 2004b). The problem is very severe that can influence the social, economic, cultural and religious activities of the community in the study area. Previous studies around the district were focused on land degradation (Getachew and Wagayehu, 2007). Thus, this study attempted to address soil loss due to gully erosion on field measurement and GIS and remote sensing. It is known that gully erosion is part of land degradation (Yibeltal *et al.*, 2019).

Therefore, this research was conducted to determine on morphological and temporal dynamics of gully erosion at Abelasta watershed, in Abay basin. Data were collected by ground measurement and by using GIS and remote sensing techniques in 2005, 2013, 2016 and 2020. The gully affected area was found in Abbay basin, west Gojjam administrative zone, Sekela woreda, Bahirzafa Guderkani kebele.

1.3 Objectives

1.3.1 General Objective

The main objective of this study was to investigate morphological and temporal dynamics of gully erosion and to quantify its soil loss by using ground measurements and remote sensing technique at Abelasta watershed.

1.3.2 Specific Objectives

The study more specifically attempted:

- To quantify morphological and temporal change of gully erosion at the Abelasta watershed.
- To assess gully morphology classification of the study area.
- To quantify soil loss due to gully erosion.

1.4 Research Questions

1. In what extent can gully expand?

2. How is the morphological situation of gullies areas?

3. How much amount of soil can be eroded due to gully erosion?

1.5 Significance of the study

First of all, this study is important for the local community in which they can understand the impact and to take rehabilitating measures for their service or use. It is also important for researchers as initial reference for further study. And also, it will be essential for under graduate and post graduate students whom are visiting field to know the impact of Gully erosion. Further, it is helpful for soil and water conservation specialists to consider the impact of this erosion on the study area. On the other hand, decision makers, land use planners and land evaluators, administrators in different level, environmental impact assessment specialists, natural resource specialists and other concerned bodies may use the study according to their disciplines and their specialization. Besides, it will show for governmental and nongovernmental organizations where and how influence cultivated and grazing land and they will take measure for rehabilitate.

CHAPTER 2. LITERATURE REVIEW

2.1 Land degradation and restoration: Global context

Land degradation is a major global problem, which includes the degradation of all terrestrial ecosystems and refers to many processes that drive the decline or loss in biodiversity, ecosystem functions or services (Scholes *et al.*, 2018). It affects forests, soils, water, biodiversity, economics and social services derived from the ecosystem and takes many forms (Nachtergaele and Petri, 2017). Land degradation impact is severe on the livelihoods of the poor who heavily depend on natural resources (Obalum *et al.*, 2012; Macdicken *et al.*, 2016; Unccd, 2016).

Sub-Saharan Africa, south-east Asia and southern China, north-central Australia, the Pampas in Latin America, and swathes of boreal forest in Siberia and the northern part of the Americas are most degraded areas (Bai *et al.*, 2008). About 3.2 billion people are affected by land degradation and its hotpots cover about 29% of global land area (Le *et al.*, 2016). According to Unccd (2016) every year, some 25% of the global arable land surface is considered to be degraded; approximately 12 million hectares are added to the total area of degraded land. Since mid-twentieth century nearly 2 billion ha (22.5%) of agricultural land, pasture, forest and woodland have been degraded Globally (Gibbs and Salmon, 2015; Stewart *et al.*, 2015).

2.1.1 Mechanisms to prevent land degradation and restore degraded lands

Restoring degraded lands is urgently needed to protect biodiversity and ecosystem services, and to halt and reverse land degradation (Scholes *et al.*, 2018) and is high on the international agenda, e.g. Aichi Biodiversity Target 15 (Coppus *et al.*, 2019) , Bonn Challenge (Iucn, 2014), the New York Declaration on Forests (Summit, 2014) and Sustainable Development Goal 15 (Coppus *et al.*, 2019). Depending up on the nature and form of degradation, land degradation can be prevented through different mechanisms. However, some aspects of land degradation are less easily reversed than others. Abebaw (2019) revealed that forests and tree cover combat land degradation and desertification by stabilizing soils, reducing water and wind erosion and maintaining nutrient cycling in soils. If the land is used wisely, broadly speaking, land degradation can be controlled, reduced or even reverted if all functions of the land are taken into account, and if long-term interests of all segments of human kinds replace short-term vested interests of privileged group globally, naturally and locally (Adugna and Bekele, 2005). According to Gilbey *et al.* (2019) the following land restoration mechanisms are important.

Table 2. 1. Land restoration mechanisms

Restoration mechanisms	Description
Agronomic measures	Mixed cropping, intercropping, relay cropping, cover cropping; conservation agriculture, production and application of compost / manure, mulching, trash lines, green manure, crop rotations; zero tillage (no-till), minimum tillage, contour tillage;
Vegetative measures	Agroforestry, windbreaks, afforestation, hedges, live fences; grass strips along the contour, vegetation strips along riverbanks; fire breaks; tree nurseries; upper catchment reforestation; protection of natural tree vegetation / farmer-managed natural regeneration;
Structural measures	Terraces; earth bunds, stone bunds; retention / infiltration ditches, planting holes, micro-catchments; water spreading weirs; dams; pans to store water; stone and earth walls with planted vegetation; barriers; palisades, gabions;
Management measures	Area closure / resting, protection, afforestation; Change from grazing to cutting (for stall feeding), farm enterprise selection (degree of mechanization, inputs, commercialization), irrigation; from mono-cropping to rotational cropping; from continuous cropping to managed fallow; from open access to controlled access (grazing land, forests); from herding to fencing, adjusting stocking rates, rotational grazing; fodder and seed banks; pasture management; control of invasive species; crop residue management; soil analysis for optimizing plant fertilization; integrating livestock for organic fertilization; improving pastures.

2.2 Land degradation and restoration: Ethiopian context

In developing countries, land degradation is a worldwide problem with its acuteness (Mesene and Science, 2017). In Africa land degradation is a serious problem, but it is most severe in the densely populated highlands of East Africa (Pender *et al.*, 2006). A combination of growing populations and land degradation are increasing the vulnerability of people to both economic and environmental change in sub-Saharan Africa (Assessment, 2005). The most densely populated agricultural areas in Africa are the Ethiopian highlands (Mcginley, 2008). In Ethiopia, like other Sub Saharan Africa countries land resources are facing intense degradation due to proximate drivers such as deforestation, soil erosion, agricultural land expansion and overgrazing (Dubale, 2001; Nyssen *et al.*, 2004a), as well as other underlying drivers, such as weak regulatory context and institutions, demographic growth, unclear user rights to land, low empowerment of local communities, and poverty generally (Kirui and Mirzabaev, 2014).

Based on Ahmed (2009) land degradation, declining agricultural productivity, and poverty are severe and interrelated problems that appear to feed off each other in Ethiopia. Studies revealed that the Ethiopian highlands, which cover 44% of the country's total land area are seriously threatened by soil and biological degradation (Mesene and Science, 2017). Therefore in the Ethiopian highlands, land degradation has been identified as the most serious environmental problems (Aune *et al.*, 2001). Some of the seriously eroded/degraded land surfaces in Ethiopia are the Hararghae highlands in Eastern Ethiopia, Tigrai, Wollo, and Semen Shoa highlands in the north and the Gamo-Gofa highlands and the Bilate River basin, which starts in eastern slopes of Gurage highlands and stretches through eastern Hadiya and Kembatta highlands (Tsegaye and Dadi, 2006; Abiy, 2008).

Throughout history, efforts to combat land degradation in Ethiopia is focused on physical conservation structures (Bewket, 2003). Similarly, Temesgen *et al.* (2014a) reported that farmers in Dera Woreda, Ethiopia heavily depend on physical soil conservation structures. To restore degraded lands improving vegetation composition, sequestering carbon in vegetation and soil, and improving hydrological cycles and micro-climate can be an effective solution (Mekuria *et al.*, 2011a; Chirwa, 2014; Bortoleto *et al.*, 2016; Dagnew *et al.*, 2017). In 2010 the government of Ethiopia launched nationwide ecological restoration programs toward improving the ecosystem services they provide, reversing biodiversity losses and increasing agricultural productivity to restore degraded ecosystems and mitigate human pressures on natural ecosystems (Mofed, 2010).

On the other hand, in the Ethiopian highlands restoring degraded ecosystems through the establishment of exclosures has become a common practice (Mekuria *et al.*, 2017). Exclosures are common land areas, which are traditionally 'open access,' where wood cutting, grazing, and other agricultural activities are forbidden or strictly limited as a means of degraded lands to promote the restoration and natural regeneration (Tesfaye *et al.*, 2015). The many benefits of exclosure include increasing vegetation cover and biodiversity (Asefa *et al.*, 2003; Mengistu *et al.*, 2005; Mekuria and Veldkamp, 2012), enhancing ecosystem carbon stocks (Mekuria *et al.*, 2011b; Mekuria *et al.*, 2015; Aynekulu *et al.*, 2017), reducing soil erosion (Mekuria *et al.*, 2009), restoring soil fertility (Descheemaeker *et al.*, 2009; Damene *et al.*, 2013), increasing in dry season flow (or water availability in the dry season) (Aynalem *et al.*, 2016), decreasing runoff and sediment load (Descheemaeker *et al.*, 2006), increasing in groundwater recharge (Anwar *et al.*, 2016), and increasing in incomes and improving livelihood of smallholder farmers by providing opportunities to diversify livelihood (Tilahun *et al.*, 2007; Babulo *et al.*, 2009).

2.3 Gully erosion distribution and its impact

2.3.1 Gully erosion in the world

The major cause of land degradation in worldwide has been recognized as Gully erosion (Musa *et al.*, 2016). In different parts of the world, studies have been carried out by researchers such as and Nwilo *et al.* (2011), used GIS/RS to assess gully erosion. In Europe so far, the scientific literature and internal reports have documented over 5,000 cumulative plot-year data on soil loss by sheet and rill erosion (Boardman and Poesen, 2007), while gully erosion has received much less attention with assumedly less than 100 years of cumulative gully monitoring data (Verstraeten *et al.*, 2006). Among the reasons for this scarcity of data are the methodological difficulties associated with the temporal and spatial scales and variability at which gully erosion occurs (Marzolff *et al.*, 2011).

An average annual global erosion rate for pastures and cropland of 1.7 and 10.5 tons ha^{-1}, respectively, which results in a global annual average of 4.2 tons ha^{-1} for total agricultural area (Doetterl *et al.*, 2012). In India, estimated that soil erosion took place at a rate of exceeding 40 tones $ha^{-1}yr^{-1}$ in the ravines and badlands. Damodar River catchment (eastern part of India), severe soil loss increases sediment yield from 1729 to 2387 $m^3km^{-2}yr^{-1}$ and it escalates the siltation of

Panchet reservoir at a rate of 0.033 to 0.047 cm per year (Majumder *et al.*, 2012). Approximately 500 thousand ha yr^{-1} land area is degraded in Russia (Nemes and Constantinescu, 2011). On a global scale, soil is currently lost 13 to 18 times faster than it is being formed (Elsen and Zerbe, 2018).

2.3.2 Gully erosion in Africa

In Africa, it is estimated that about 320 million ha, or about one quarter of its dry lands, are affected by different types of soil erosion (Degefa, 2009). Gully erosion causes severe land degradation in Sub-Saharan Africa, which in turn, disrupts the often-poor local communities (Poesen *et al.*, 2003). Oostwoud Wijdenes *et al.* (2001) studied eleven gully heads over a period of three years and found linear head cut retreat rates that varied between 0.8 and 15 m yr^{-1} in Kenya.linear gully head erosion rates varied between 3.16 and 9.85 m yr^{-1} for two gully heads in Burkinafaso, during the same period, (Marzolff and Ries, 2007). In the south eastern part of Nigeria and Abia state in the past three decades, gully erosion has been an issue of concern in particular which was 450 kg $ha^{-1}yr^{-1}$ of soil lost (Nwilo *et al.*, 2011). Therefore in the southeastern part of Nigeria, gully erosion is the type of erosion that inspires fear in the lives of people (Amangabara and Journal, 2014).

Reported cases of gully erosion indicate in many African countries that both urban and rural areas are affected, e.g., Burkina Faso (Marzolff and Ries, 2007), the Democratic Republic of Congo (Ndona *et al.*, 2011), Ethiopia (Frankl *et al.*, 2011), Kenya (Oostwoud Wijdenes *et al.*, 2001; Katsurada and Technology, 2007), Namibia (Eitel *et al.*, 2002), Niger (Leblanc *et al.*, 2008), Senegal (Poesen *et al.*, 2003) and South Africa (Boardman *et al.*, 2003).

2.3.3 Gully erosion in Ethiopia

The most serious problem of Ethiopia's land resources is soil erosion (Temesgen *et al.*, 2014b). There are a number of research reports pertaining to the peril of soil erosion at various spatial and temporal scales on the highlands of Ethiopian (Amsalu *et al.*, 2007; Bantider, 2007; Haregeweyn *et al.*, 2013; Gelagay *et al.*, 2016). In the Ethiopian highlands, over the past three decades gullying has been widespread and has become more severe contributing as much as 94% of total sediment yield (Nyssen *et al.*, 2004a).

Previous studies in the Ethiopian highlands that focused on upland erosion estimated that transboundary rivers originating carry about 1.3 billion t yr^{-1} of soil to neighboring countries

(Kidane *et al.*, 2015). Team (2000), on the other hand estimated the average annual rate of soil loss in Ethiopia to be 12 tons $ha^{-1}yr^{-1}$, and rising to as high as 300 tons $ha^{-1}yr^{-1}$ on steep slope where vegetation covers is scant. In the Tigray highlands, based on field measurements on 202 plots in 12 sites Gebrernichael *et al.* (2005) have found a mean annual soil loss from crop land in the absence of soil and water conservation measure was 57 tons $ha^{-1}yr^{-1}$. The annual soil loss from Northeast Wolega 65.9 ton ha^{-1} (Adugna *et al.*, 2015); from Bench Maji Zone 118 ton ha^{-1} (Chimdesa, 2016); from Lake Tana basin 30 ton ha^{-1} (Setegn *et al.*, 2009), from Chaleleka Wetland catchment 45 ton ha^{-1} (Wolancho, 2015); and from Borena district of south Wollo 26 ton ha^{-1} (Shiferaw *et al.*, 2011). In Gilgel Gibe-I hydropower dam according to Wolancho and Technology (2012), the siltation deposited is 1.2 to 1.3 tons $m^{-3}year^{-1}$ and it could be reduced the expected life span of the dam from 50 to 20 year. About 43% (537,000 km^2) of the total highland areas are highly affected by soil erosion with an estimated average 15 to 20 tons $ha^{-1}yr^{-1}$ and measured amounts of more than 300 tons $ha^{-1}yr^{-1}$ on specific plots in Ethiopia (Dubale, 2001). Whereas the Abay basin lost fertile soils with a rate of 131 million tons yr^{-1} soil (Betrie *et al.*, 2011; Kidane *et al.*, 2015). Annually, Ethiopia losses over 1493 million tons of topsoil from the highlands due to erosion which can add about 1.5 million tons of grain to the country's harvest (Lulseged and Vlek, 2008; Yitbarek *et al.*, 2012; Erkossa *et al.*, 2015). From watersheds of Andit Tid, Anjeni and Maybar, based on sediment concentration and discharge data measurements, annual sediment yields during run-off events were 5.4, 22.5 and 8.8 t $ha^{-1}yr^{-1}$ respectively (Ahmed *et al.*, 2012).

Additionally, in northern Ethiopia, soil losses by gullying (SLg) are considerable according to Frankl *et al.* (2013) and conclude the following. During 1963/1965–2008/2010, average SLg was 8.3 t $ha^{-1}yr^{-1}$. However, these rates have varied considerably in space and time. Average SLg values for shales and volcanic differ considerably. The gully cut-phase from 1963/1965 to 1994 gave a much higher average SLg of 17.6 t $ha^{-1}yr^{-1}$ and from 1994 to 2008/2010 a net filling of 8.3 t $ha^{-1}yr^{-1}$ occurred. Although gully erosion is a common feature throughout the Ethiopian highlands, most gully erosion studies have been carried out in the semi-arid Tigray region, in northern Ethiopia (Billi and Dramis, 2003; Tamene *et al.*, 2006; Frankl *et al.*, 2012; Frankl *et al.*, 2013). In Tigray in the semiarid northern Ethiopia estimated that gully erosion accounted about 28% of the total soil loss (Nyssen *et al.*, 2008), whereas in the humid highlands of Ethiopia, the contribution of gully erosion to the total soil loss reaches about 96% (Zegeye *et al.*, 2014). In central Tigray, soil loss rates by gully erosion estimated 5 tons $ha^{-1}yr^{-1}$ (Nyssen, 2001) and 6.2 tons

$ha^{-1}yr^{-1}$ over a 65 year period in an 18 km^2 catchment (De Wit, 2003). As Shibru *et al.* (2003) estimated that using photogrammetric techniques, between 1966 and 1996, 700000 ton of soil were lost by gully erosion from a 9 km^2 catchment in the eastern highlands (26 tons $ha^{-1}yr^{-1}$).

2.3.4 Gully erosion in northwestern Ethiopian highlands

Gully systems in northern Ethiopia, were re-activated expanded from the 1960s onwards as a result of intensified land use and a series of droughts in the 1970s and 1980s (Gebrernichael *et al.*, 2005). From Jabi Tehinan district (in Abay Basin) annual soil loss was estimated about 504.6 ton ha^{-1} using RUSLE model (Amsalu and Mengaw, 2014). In Koga watershed average soil loss was about 30.2 tons $ha^{-1}yr^{-1}$ and total soil loss was estimated as 10.8 million tons $ha^{-1}yr^{-1}$ by using RUSLE software which is very high (Molla and Sisheber, 2017b).

In the highlands of Ethiopia wide and deep gullies are common features, significantly affecting land used for agriculture (Yitbarek *et al.*, 2012). As Addisie *et al.* (2016) stated, quoted by Hadera and Asfaw (2016), in the Amhara National Regional State, 2.6 million hectares of land is considered as degraded and about 200,000 – 300,000 hectares of land is covered with gullies. In Debre-Mawi, south of Lake Tana in a 17.4 ha watershed, 530 ton $ha^{-1}yr^{-1}$ was lost due to gully erosion (Tilahun *et al.*, 2015). In Debre mawi watershed which is about 608 ha area, the total soil loss from the gully during 2013-2014 was 5445 ton or 160 tons $ha^{-1}yr^{-1}$ (Zegeye *et al.*, 2017).

2.4 Gully morphological classfications

2.4.1 Gully classification Based on shape

Based on cross-section shape the gullies may be classified as following (Rivas, 2006):

- V- Shape Gullies are developed where the topsoil has less resistance than subsoil against erosion. The most common gully form is this.
- U- Shape Gullies are formed where both subsoil and topsoil against erosion have the same resistance. Nearly vertical walls are developed on each side of the gully, since the subsoil is eroded as easily as the topsoil, .
- Trapezoidal gullies are formed where bottom and subsoil is made of more resistant material than the topsoil because the erosion rate along the gully bank is greater than along the bottom.

2.4.2 Gully classification Based on size

Based on their size Gullies can be classified as small, medium and large (Fao, 1986).

Table 2. 2. Gully classification systems based on depth and drainage area

Relative size	small	medium	large
Gully depth (m)	<1	1 to 5	>5
Drainage area (ha)	<2	2 to 20	>20

2.5 Application of GIS and RS for gully erosion study

Remote sensing is a robust tool that offers meaningful spatial data for the assessment and monitoring of spatio-temporal variations of soil erosion over large areas (Liberti *et al.*, 2009; Le Roux *et al.*, 2012). GIS and RS are technical tools, which is playing a great role for assessing, analyzing and screening a direction for how the gully erosion problems solved. For example, it used to examine watershed characteristics and delineate (Gebre *et al.*, 2015; Chernet and Science, 2018), identify eroded area, estimate amount of soil loss and prioritize soil severity area (Demeke and Andualem, 2018; Tesfaye *et al.*, 2018) .

The findings showed that the application of remote sensing for soil erosion studies has significantly increased by 45% since the 1960s (Makaya, 2018).

With the headway of innovation and advancement of GIS and Remote Sensing researchers and scientists can assess soil erosion using various developed model (Prasad *et al.*, 2019). In gully identification and characterization with high and desirable levels of accuracy remote sensing techniques (satellite imagery) are applicable (Onuoha *et al.*, 2020). Application of GIS techniques in the study of erosion in watershed has high potential for decreasing computer time used and increasing accuracy of the sediment and erosion estimation (Nasri *et al.*, 2012).

CHAPTER 3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Geographical location

The research was conducted in Amhara Region, West Gojjam administration, Sekela woreda, in Abay basin, at Abelasta watershed (in Bahirzafa kebele) which is nearly 200 km far from Bahir Dar or 435 km far from Addis Ababa (figure 3.1). It was located between 10^{o}55’03’’ to 10^{o}56’29’’ latitude and 37^{o}11’10’’ to 37^{o}12’03’’ longitude. The study area covered about 238.04 hectares with elevation ranges between 2,343 and 2725 m a.s.l.

In this study, six gullies were selected purposly in Abelasta watershed. The Watershed was faced north (upper part) to south east (lower part). The gullies found at lower part of the watershed which was communal grazing land. Based on the farmers information the gully was emerged since 1990 GC which was passed 31 years. Gully 1 was at left side of all gullies; gully 3 was right to gully 1 which was connected to gully 1. Gully 2 was right from gully 3; gully 4 was left to gully 2 which connected to gully 2. In addition gully 5 was right to gully 2 and gully 6 was right to gully 5.

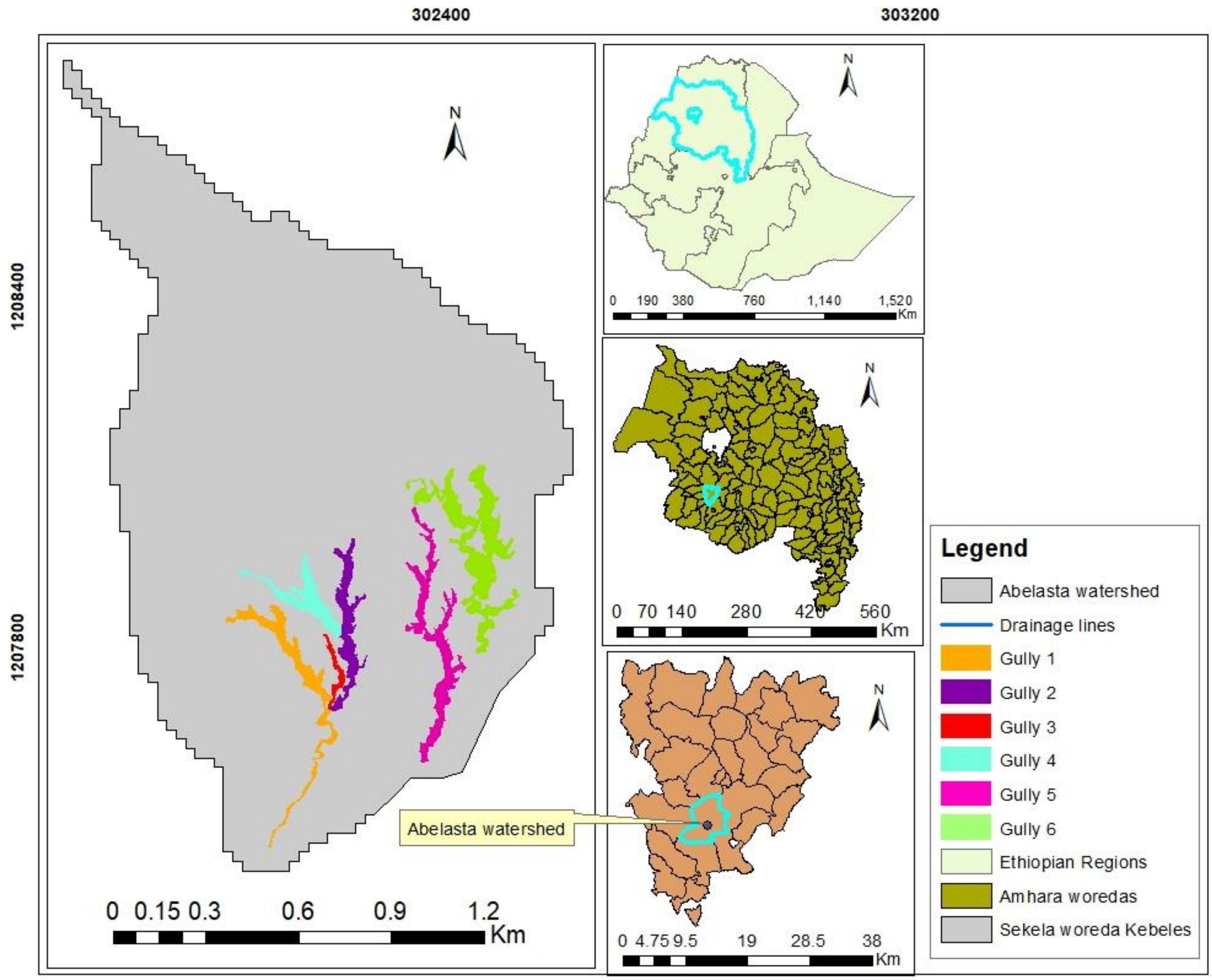

Figure 3. 1. Location map of the study area.

The study watershed was highly damaged due to gully erosion. The gullies damaged streets, grazing land and in some extent farm lands. On the damaged area, societies used for different cultural and spritual activities like horse riding, xmass day playing and others before.

Figure 3. 2. The degradation of study watershed

3.1.2 Soil Types

According to Shawul (2005), the study area had two major soil types. These were Eutric Vertisol that covered 229.36 ha (96.35%) area and Alisol that covered 8.68 ha (3.65%); the soil texture was clay and clay loam to sandy clay. The internal drainage was imperfect and well drained.

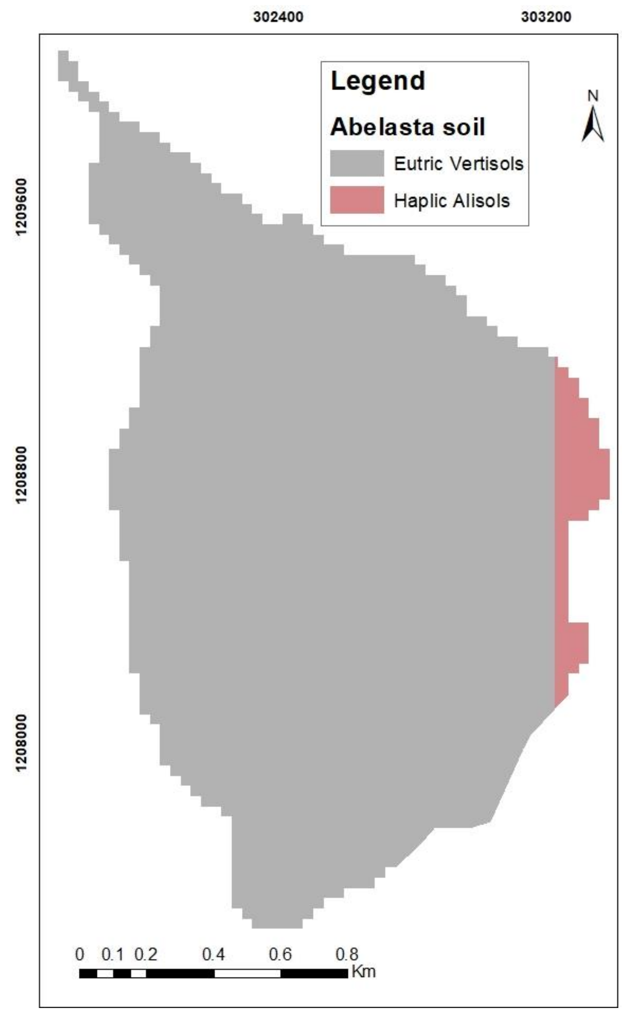

Figure 3. 3. Major soil types in the study watershed

3.1.3 Climate

The study area has Sub humid Tropical climatic condition which is Weyna Dega and Dega. The mean annual minimum temperature is 11 ^{o}c and mean annual maximum temperature is 21 ^{o}c. The average annual temperature is 18 ^{o}c and the mean annual rainfall is 1700 mm (Resource, 2018).

3.1.4 Topography

The study area was found between 2343 to 2725 meters above sea level. It had marked topographic variation. There were six slope gradient classes which were 0-2%, 2-5%, 5-8%, 8-15%, 15-30% and 30-60%.

Table 3. 1. Slope class and its area coverage

Slope Name	Slope class (%)	Area (ha)	Area (%)

Flat	0-2	5.63	2.36
Gently undulating	2-5	26.13	10.98
Undulating	5-8	29.22	12.27
Rolling	8-15	71.43	30.01
Moderately steep	15-30	93.18	39.15
Steep	30-60	12.46	5.24
Total		238.04	100
Source: (FAO, 2006)			

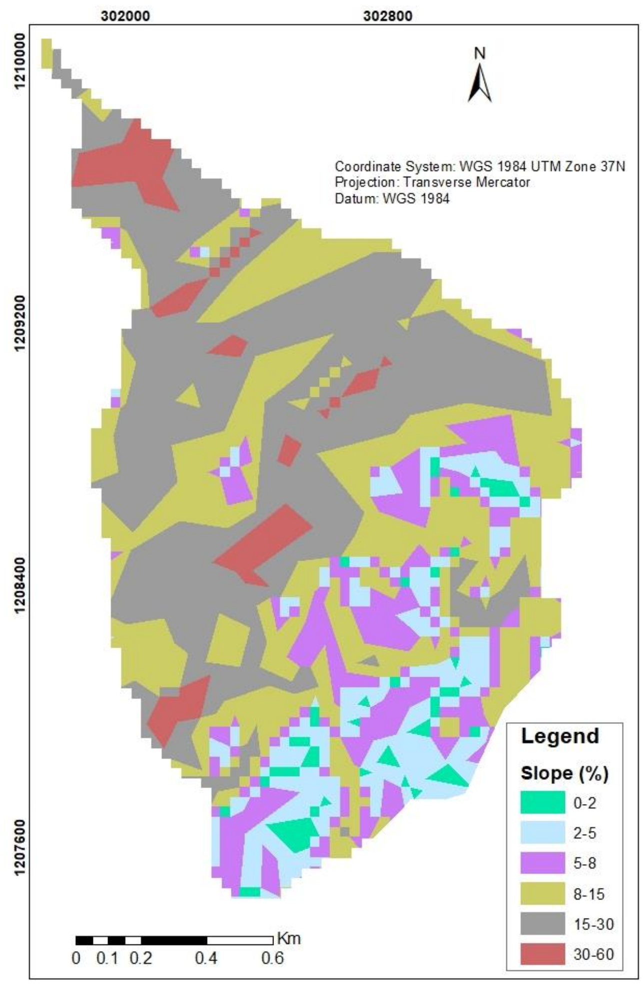

Figure 3. 4. Slope map of the study area

3.1.5 Demography and farming system

Human population of Abelasta watershed was homogeneous linguistically and consists of the ethnic families of Amhara that had 200 house holds. Farming system of the study area was mixed agriculture (field crop and livestock production). Agricultural field crop production was predominantly prevailing. With this respect, agricultural production was the mainstay for the livelihood of people in the study area. The major crops grew around the study area were teff, maize, beans, barley, and wheat. On the other hand, livestock production was a major part of the farming system next to crop production, providing draft power, producing milk and conferring a certain degree of security against crop failures.

3.2 Data type and method of data collection

3.2.1 Primary data

The most important sources of data in this study was the primary sources to obtain firsthand information, issues related to spatial and temporal variability of gully erosion. The sources of the information were focused on field measurements.

3.2.2 Secondary Sources

The secondary source of information includes Google earth images and SAS planet images. These grasp the spatial and temporal variability of gullies that helped to look and understand the issues under inquiry.

3.2.3 Primary Data Collection methods

3.2.3.1 Field gully measurement

Gully width length and depth were measured intensively in the study area to estimate the average volume of soil removed from gullies.

To measure loss from gullies in the study area:

A. First ropes were stretching by peg (stake) along the gully length and at gully edge on both sides. The other rope was stretched at the gully width and connected with the two ropes.
B. At the center of the rope across the gully bob put and drop down until it reached at the base which was the height of the gully. This activity was conducted every 15 meter length along the gully and changed when the shape of the gully was changed. When the shape of gully bended before 15 meter, the measurement was done below 15 meter length. When the gullies was bend until 20 meter length measurement was performed at that length.
C. To estimate soil loss due to gully erosion, I selected six gullies (Gully 1, Gully 2, Gully 3, Gully 4, Gully 5 and Gully 6) within the Abelasta watershed. Before measuring the dimensions of selected gullies, we were subdivided the cross-sections of them in 15 m interval, depending on their morphology. Then the width and depth of each point cross-

section of a gully was measured at aminimum of three points (i.e., left, middle and right) in 2021 using a measuring tape. But when the width of the gullies were very wide over three points measurement was done.

In addition to the gully measurement, three soil core samples were collected from bottom, mid and up slope parts of each gully of adepth 0 to 30 cm and 30 to 60 cm with a tube having diameter of 2.5 cm and 5 cm long for determining the bulk density.

3.2.3.2 Temporal variability of gullies

The expansion rates of gullies (Gully 1, Gully 2, Gully 3, Gully 4, Gully 5 and Gully 6) with time were assessed using cloud free google earth images. The required images were digitized from google earth which is freely available for everybody. In order to see the spatio-temporal variability of gullies, google earth images in 2005, 2013, 2016 and 2020 GC were used. Each gully in each year was digitized from google earth pro, named in file saving folder (kml form) then converted to polygon on ArcGIS map. After conversion the data were exported and projected to be manageable on area calculating.

3.3 Method of data analysis

3.3.1 Changes in gully volume and soil loss

We estimated the volume of a cross-section of a gully by multiplying cross-sectional area by length of the cross-section. The soil loss due to gully erosion (t $ha^{-1}yr^{-1}$) were estimated by multiplying the change in gully volume (m^3) by bulk density and dividing it by the area of the watershed.

The assessment of gully erosion rates through measurements allowed the assessment of the temporal change of gully dimensions. In precise measurements of long-term changes, the gully erosion rates calculated below (Nyssen *et al.*, 2006).

$$\mathrm{RL} = \frac{\mathrm{VB_d}}{\mathrm{TC}}$$

Where RL is area specific long term gully erosion rate in t ha^{-1} yr^{-1}, V is total gully volume in m^3, T is time span considered in years, B_d is soil bulk density in gcm^{-3} and C is catchment area in ha.

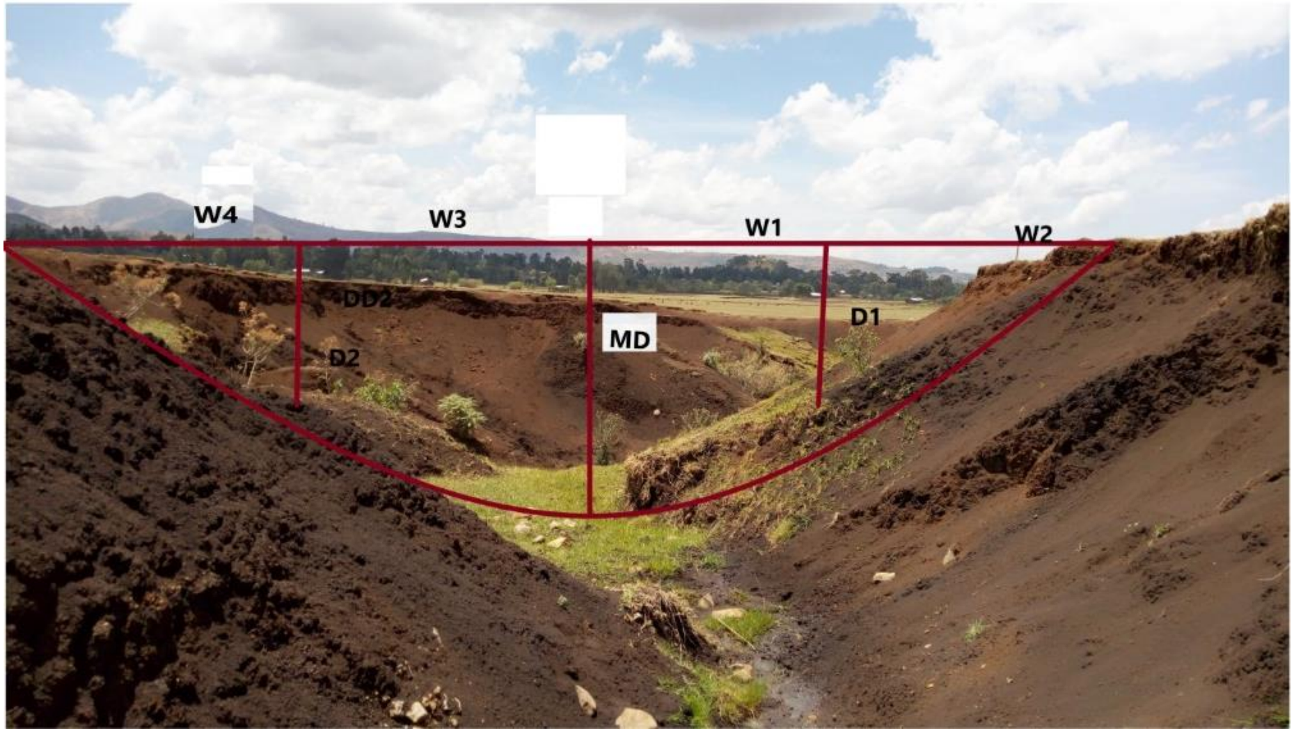

Figure 3. 5. Gully morphology of the study area

Where, W1, W2, W3, W4 were gully widths; D1 and D2 were gully depths and MD was middle depth.

Gully area and volume could be calculated as follow (Zegeye, 2016):

$$A = \sum_{j=1}^{n} Dj(Wj + Wj + 1)/_2$$

Where, A was cross sectional area, Dj was depth at j, W_j and W_{j+1} was widths between D_j.

$$V = \sum_{j=1}^{n} \text{Lj (Aj)}$$

Where, V was volume of soil loss, L_j length of gully at j and Aj was cross sectional area at j.

3.3.2 Analysis of gully erosion expansion

The surface area of Gully 1, Gully 2, Gully 3, Gully 4, Gully 5 and Gully 6 were digitized from google earth images which were available in 2005, 2013, 2016 and 2020. Gullies of different years were performed by using ArcGIS10.4. The digitized shape files were exported and projected to know the horizontal expansion rate of gullies.The Gullies areas were authomatically calculated by ArcGIS 10.4 software.

3.3.3 Bulk density

Total bulk density (D_{bt}, Mg m^{-3}) was calculated by dividing the oven-dry mass by the sample volume (Han *et al.*, 2016).

$$\mathrm{Dbt} = \frac{\mathrm{Ws}}{\mathrm{Vt}}$$

Where, Ws was the oven-dry mass of the sample (g) and Vt was the total volume of the sample including pore volume and solid volume (cm^3). The hight of the core sampler was 5 centi meter, radius was 2.5 centi meter; therefore the volume of the core sampler was 98.12 cubic centi meter.

3.3.4 Land cover/land use types

Land use and land cover was prepared in SAS planet and ArcGIS softwares. First the watershed was buffered in 50 meters and converted to kml file in ArcGIS, then add to SAS planet. In SAS planet, we waited until the image was clear to identify each land cover type. After the image was cleared by right click on image, we clicked selection manager. Then by increasing its quality above 95% and at stitch out put format was JPEG and zoom was between 18 to 20 and by giving saving folder we clicked start. Finally, in ArcGIS we classified the image by supervised classification and edit each classified polygon by comparing with the image.

CHAPTER 4. RESULT AND DISCUSSION

4.1 Gully erosion morphological and temporal changes

Gullies at Abelasta watershad had different horizontal expansion rate based on google earth images (Table 4.1 and Figure 4.1). Based on length from 2005 to 2013, gully 3 was mostly increased; from 2013 to 2016, gully 4 was increased highly; from 2016 to 2020 gully 6 was highly increased.

Based on width from 2005 to 2013, gully 6 was increased by double; from 2013 to 2016 gully 1 was increased by 10m; from 2016 to 2020 gully 5 was increased by 10. Depending on surface area, from 2005 to 2013, gully 1, gully 2 and gully 5 all was doubled; from 2013 to 2016, gully 6 was increased by 0.62m; from 2016 to 2020, gully 6 was increased by 0.77m. In Birr watershed which is found South west Amhara, the one gully expanded in length by 23 m, the depth increased by 1.9 m and the width expanded by 13 m; Soil loss was estimated at 1,900 tons (Nicholson *et al.*, 2015).

Table 4. 1. morpholigical and spatial variability of gullies

	2005			2013			2016			2020		
	L	W	A	L	W	A	L	W	A	L	W	A
Gully 1	822.98	18.74	1.09	935	23.99	2.01	940.87	34.877	2.26	975	37.13	2.43
Gully 2	550	24.79	1.05	613.82	45.79	1.92	630	53	1.96	670	55.65	2.15
Gully 3	132.24	17.94	0.2	200.77	22.78	0.35	243.11	23.13	0.37	259	23.22	0.38
Gully 4	273.19	26.31	0.7	298.53	35.59	1.33	434.87	39.78	1.58	440	48.72	1.65
Gully 5	773.31	13.58	1.1	835.09	34.23	2.48	958.45	40.31	2.9	960	40.63	3.12
Gully 6	783.71	28.35	2.1	830.58	56.02	3.89	891.32	57.65	4.51	943	59.78	5.28

Where L is length (meter), W is width (meter), A is area (ha).

Based on gully length, gully 3 was increased by 51.82% from 2005 to 2013; gully 4 was increased by 45.67% from 2013 to 2016; gully 3 was increased by 6.38% from 2016 to 2020. Depending on gully width, gully 5, gully 6 and gully 2 increased by 152.03%, 97.61% and 84.67% respectively from 2005 to 2013. From 2013 to 2016, gully 1 increased by 45.38%; from 2016 to 2020, gully 4 increased by 22.47%. Based on area, gully 5, gully 4 and gully 6 increased by125.46%, 90% and 85.24% respectively from 2005 to 2013. From 2013 to 2016, gully 4 increased by 18.8%; from 2016 to 2020, gully 6 increased by 17.07%.

The gullies temporal changes over the period 2001 to 2018 in Gumara watershed, the total gully length was 10.04 km, the estimated total surface area damage was 11.42 ha, (Belayneh *et al.*, 2020).

Generally, the gullies expanded from 2005 to latest (2020) in length, width and area. But the expansion rate was increased from 2005 to 2013 and increasment reduced to next years. According to Dar and Nile (2009) from 2005 to 2007, the gully system increased from 0.65 ha to 1.0 ha, respectively, a 43% increase in area. The following year, it increased by 60% to cover 1.43 ha in 2008. The following table summarized spatial and temporal variability of gullies in Abelasta watershed.

Table 4. 2. Gullies morpholigical and spatial changes in dimension (%)

	2005 to 2013			2013 to 2016			2016 to 2020		
Gullies	L	W	A	L	W	A	L	W	A
Gully 1	13.61	28.02	84.04	0.63	45.38	12.44	3.63	6.47	7.52
Gully 2	11.6	84.67	82.86	2.64	15.75	2.08	3.63	5	9.69
Gully 3	51.82	27	75	21.09	1.52	5.71	6.38	0.39	2.7
Gully 4	9.28	35.29	90	45.67	11.77	18.8	1.18	22.47	4.43
Gully 5	7.99	152.03	125.46	14.77	17.75	16.94	0.18	0.79	7.59
Gully 6	5.98	97.61	85.24	7.31	2.9	15.94	5.8	3.7	17.07

Where, L was gully length (m); W was gully width (m) and A (ha) was surface area.

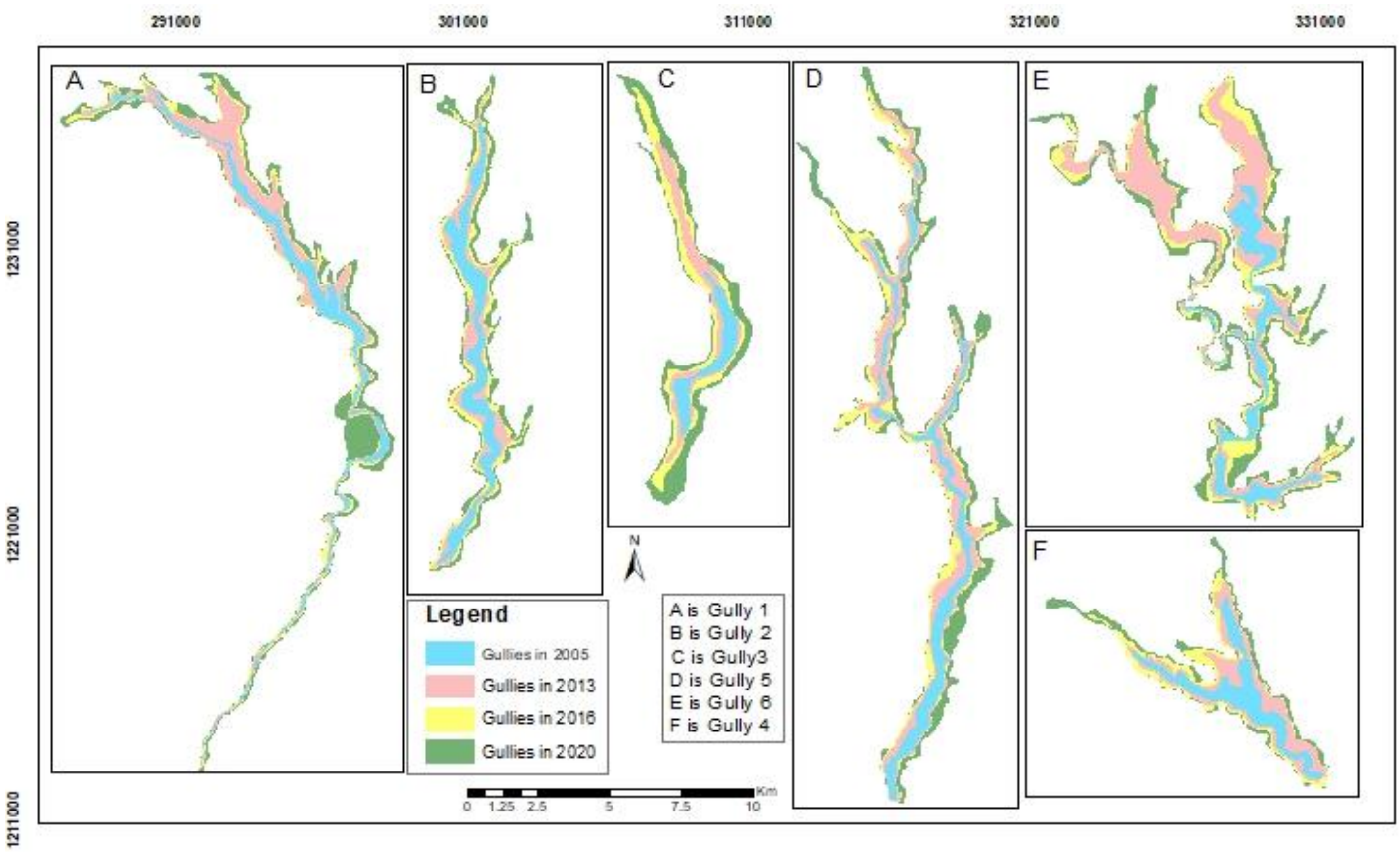

Figure 4. 1. Morpholigical and temporal variability of gullies

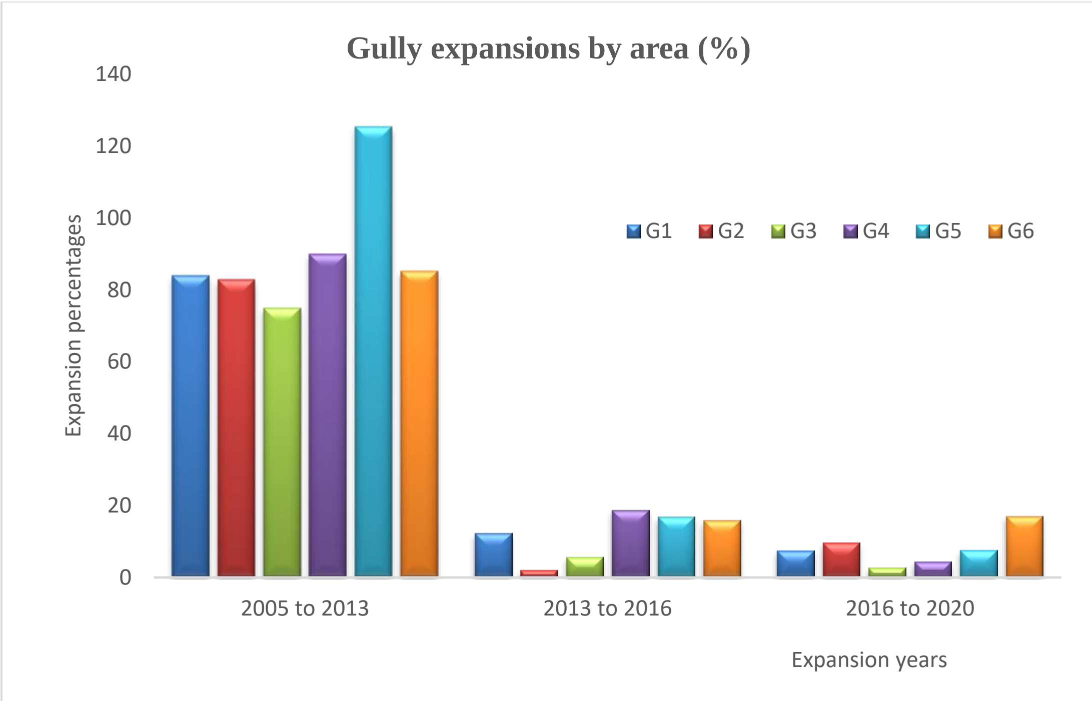

Figure 4. 2. Gully expansion percentage by area

4.2 Gully morphology

Assessing gully morphology is important. Therefore, a systematic compilation of the different morphological characteristics of gully types (e.g., length, depth, and width) in a wide range of environments is necessary (Poesen *et al.*, 2002). This activity was based on field measurement results.

Gully morphology description was started from gully length (Table 4.3). The length of gully l, gully 2, gully 3, gully 4, gully 5 and gully 6 was 958, 673.2, 270, 375, 1037 and 956 meters repectively. Here, gully 5 was the longest, gully 1 was the second longest and Gully 3 was the shortest. On Dembia district, the highest gully length (2,400 m) and highest lower width (6m) were observed (Addis *et al.*, 2015). Based on depth the size of gully 1, gully 2 and gully 4 were large at most lengths. Gully 3 was medium in all parts. Gully 5 and gully 6 were medium at most parts.

On the other hand based on area of the gully, all gullies were grouped under medium size on their morphology. Further, based on width gully 6, gully 2 and gully 4 were very wide which reached to 56, 55 and 54 meters respectively. The areas of the gullies ranged from 11,675 (m^2) to 127,600 (m^2), depth ranged from 7.77m to 26.58m, and width from 22.50m to 62.79m (Ehiorobo *et al.*, 2013). Gully morphology is presented below (Table 4.3).

Table 4. 3. Gully morphology of the study area

Gully types	width (m) minimum	maximum	Average	Depth (m) minimum	maximum	Average	Area (ha)	Length (m)
Gully 1	2	35	15	0.3	6.9	2.13	7.52	958
Gully 2	3	55	21.5	0.3	5.6	2.29	9.69	673
Gully 3	5.4	22	14.4	0.8	2	1.25	2.7	270
Gully 4	5.5	54	26.6	1.2	5.9	4.14	4.43	375
Gully 5	5	36	21.9	0.3	2.8	1.82	7.59	1037
Gully 6	6	56	28	0.3	3.7	2.39	17.07	956

Figure 4. 3. Different gullies photos of the study area

4.3 Comparision of soil loss among gullies based on field measurement

Gullies at the watershed had different soil loss quantity due to the difference on the morphologies of widths and depths (Table 4.4).

At the lengths from 0 to 150 meters gully 1, gully 2, gully 3, gully 4, gully 5 and gully 6 had soil loss of 441.53; 5010.56; 2412; 14473.5; 3357.45 and 4091.55 m^3 respectively. At the lengths from

150 to 300 meters, soil loss was 617; 8232; 222; 6206; 3340 and 4192 m^3 for gully 1, gully 2, gully 3, gully 4, gully 5 and gully 6 respectively.

Further, from 300 to 450 meter lengths, gully 1, gully 2, gully 4, gully 5 and gully 6 had soil loss amounts of 2500.72; 4720.5; 4461.3; 4504.25 and 8654.3 m^3 respectively. Additionally, gully lengths from 450 to 600 meters, 4627; 6989; 2962 and 7161 m^3 amount of soil was lost at gully 1, gully 2, gully 5 and gully 6 respectively.

Finally, gully 1, gully 2, gully 3, gully 4, gully 5 and gully 6 had 23331, 12487, 2634.2, 25140, 22077 and 33267 m^3 total amount of soil was lost (Table 4.4). Gully rosion area and volume of two gullies were 2141.6250m^2, 5074.1790m^3 and 1316.1250m^2, 1591.5784m^3 respectively in Beiyanzikou watershed (Wang *et al.*, 2014).

Table 4. 4. Comparing soil loss in each gully with their length

Gully types		Lengths (m)							
		0-150	150-300	300-450	450-600	600-750	750-900	900-1050	Total
Gully 1	A (m^2)	538.2	754.5	1357.5	4212.26	4065.47	7344.43	2905.06	21177.4
	V (m^3)	42.14	616.95	42.14	616.95	42.14	616.95	42.14	23331.5
Gully 2	A (m^2)	3360	6419.22	6346.5	5136.48	1922.5	-	-	23184.7
	V (m^3)	552.49	8232.23	552.49	8232.23	552.49	-	-	25729.8
Gully 3	A (m^2)	2680.5	1671	-	-	-	-	-	4351.5
	V (m^3)	552.49	8232.23	552.49	8232.23	552.49	-	-	25729.8
Gully 4	A (m^2)	5788.5	4041	5458.5	-	-	-	-	15288
	V (m^3)	14473.5	6205.5	-	-	-	-	-	25140.3
Gully 5	A (m^2)	4206.75	4241.25	5195.75	6035.25	3669	4902	2080.5	30330.5
	V (m^3)	3357.45	3339.6	4504.25	2962.05	4376.4	3036.3	501.15	22077.2
Gully 6	A (m^2)	3151.5	6201.7	6785	4810.5	12748.7	2796	718.5	37211.9
	V (m^3)	4091.55	4191.63	8654.3	7160.85	10137.2	3123.45	-	37358.9

Dash (-) showed absence of length, A was surface area and V was volume.

4.4 Gully erosion soil loss assessment in Abelasta watershed

In Abelasta watershed at the lower part (grazing area) was themost degraded and eroded area. The degradation was due to gully erosion. Each gully impact was quantified and calculated based on field measurement (Table 4.5 and Figure 4.4). At G1, 23331.48 m^3 soil was lost which was 119.39 ton $ha^{-1}yr^{-1}$; at G2, 25729.78 m^3 which was 141.43 ton $ha^{-1}yr^{-1}$ soil was lost. Additionally, at G3, 2634.15 m^3 in which 14.84 ton $ha^{-1}yr^{-1}$ soil was lost; at G4, 25140.3 m^3 (130.09 ton $ha^{-1}yr^{-1}$) soil was lost. Further at G5, 22077.2 m^3 in which 135.82 ton $ha^{-1}yr^{-1}$ and at G6, 37358.93 m^3(216.83 ton $ha^{-1}yr^{-1}$) soil was lost.

There were similar studies in which soil loss due to gully erosion which was quantified.The average volume of soil loss estimates in 2003 ranged between 805.93m^3 (Vimtim) to 4133.02m^3 at (Muvur) while the 2004 soil volume conceded to erosion was 520.80m^3 (Gella) and 5609.12m^3 (Tekwa and Usman, 2006). Soil loss due to gully erosion was 35.33 t ha^{-1} $year^{-1}$ at Chentale watershed (Bogale *et al.*, 2020). In Awasa watershed, the total volume of gully system 1 was 965000 m^3 and the gully erosion rate was 23.4 t $ha^{-1}y^{-1}$, for gully system 2 the total volume was estimated to be 1778000 m^3 and the gully erosion rate 20.7 t $ha^{-1}y^{-1}$ at Tabota Koromo and Koromo Danshe watersheds (Hoogenboom, 2013).

Finally, total soil loss due to gully erosion in the watershed was 133,637.68 m^3 (758.37 ton $ha^{-1}yr^{-1}$) . In the Genbo Wonz Watershed, north-west highlands of Ethiopia, the annual rate of gully erosion was found to be 62 t ha^{-1} (Yazie *et al.*, 2020).

Table 4. 5. Gully erosion measured in 2021

Gully names	A (m2)	V (m3)	soil loss (ton $ha^{-1}yr^{-1}$)	Bd (g/cm3)
Gully 1	1742.34	23331.48	119.36	1.22
Gully 2	6224.32	25729.78	141.43	1.31
Gully 3	192.37	2634.15	14.84	1.34
Gully 4	1785.57	25140.3	130.09	1.23
Gully 5	1545.97	22077.2	135.82	1.46
Gully 6	2584.55	37358.93	216.83	1.38
Total	14,075.12	133,637.68	758.37	-

Where, A was cross sectional area, V was volume, Bd was bulk density

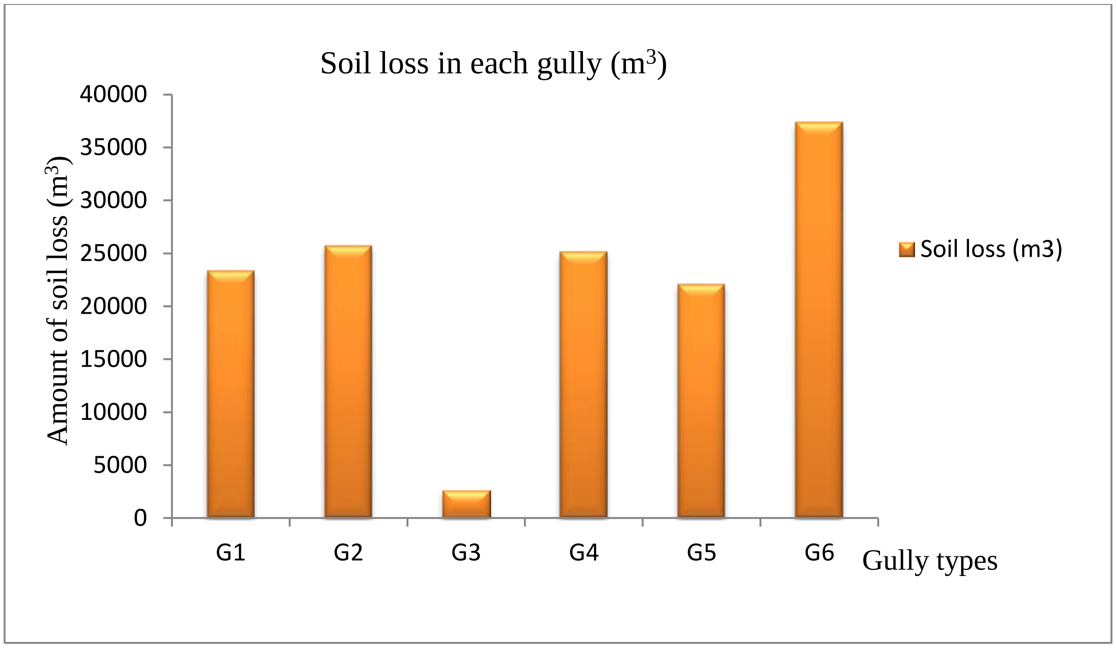

Figure 4. 4. Soil loss in Abelasta watershed

In Abelasta watershed the expansion situation of gullies were different one another. Some gullies were active and the others were stablized. Even in a gully some part was active and on the other part was stablized. Gully 1, gully 4 and gully 6 were active and ready to expand during the study time but gully 2, gully 3 and gully 5 in most parts were stablized and coverd by grasses (Figure 4.5).

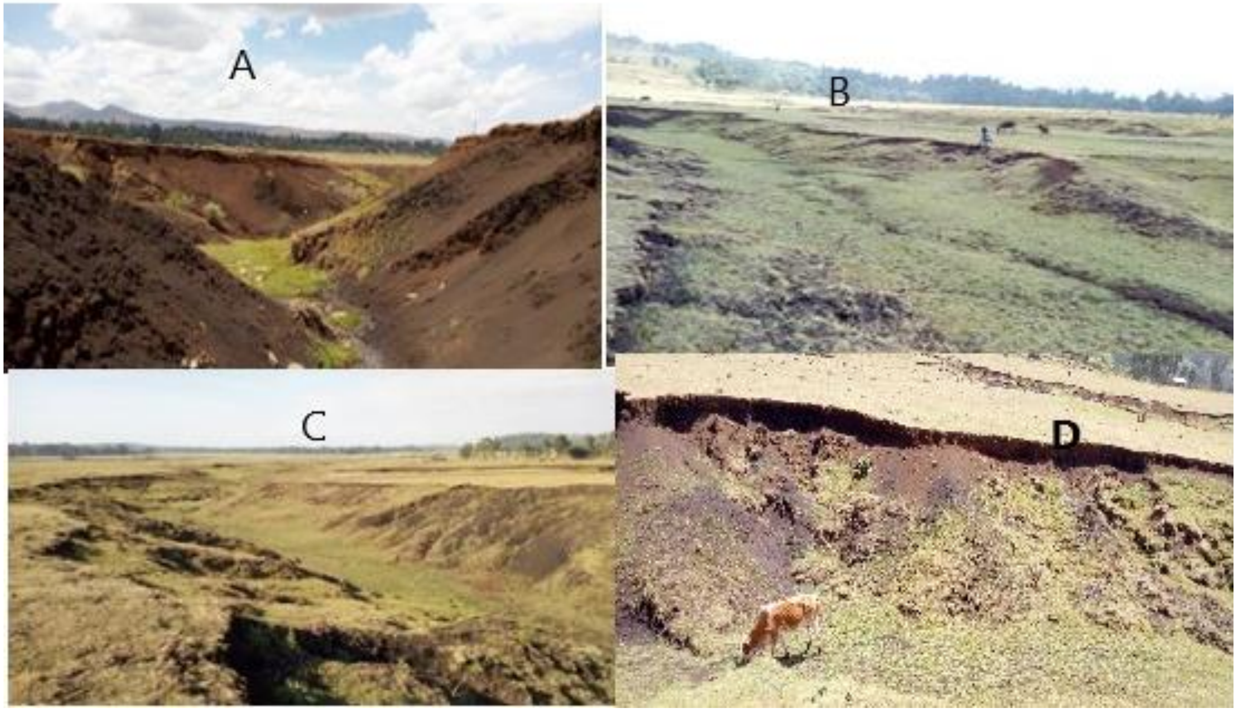

Figure 4. 5. Active and inactive gullies

Where, A was gully 1, B was gully 3, C was gully 2, and D was gully 4.

4.5 Land use/land cover of the watershed

The study watershed was covered by different major land cover types. Based on land use and land cover classification, seven major land covere/land use types were identified. Cultivated land was dominant that covered 99.08 ha (39.08%), grass land was the second dominant which covered 75.61 ha (30.44%) and farm village was the least which covered 0.81 ha (0.32%). The watershed was highly degraded. All gullies were existed at the lower part of the watershed. They existed at the grazing land.

Table 4. 6. Land cover types and their area coverage

Types of land cover	Area (ha)	Area (%)
Cultivated land	99.08	39.88
Grass land	75.61	30.44
Bush and shrub land	23.99	9.66
Eucalyptus plantation	20.76	8.36
Forest land	16.47	6.63
Gully	11.7	4.71
Farm village	0.81	0.32
Total	238.04	100

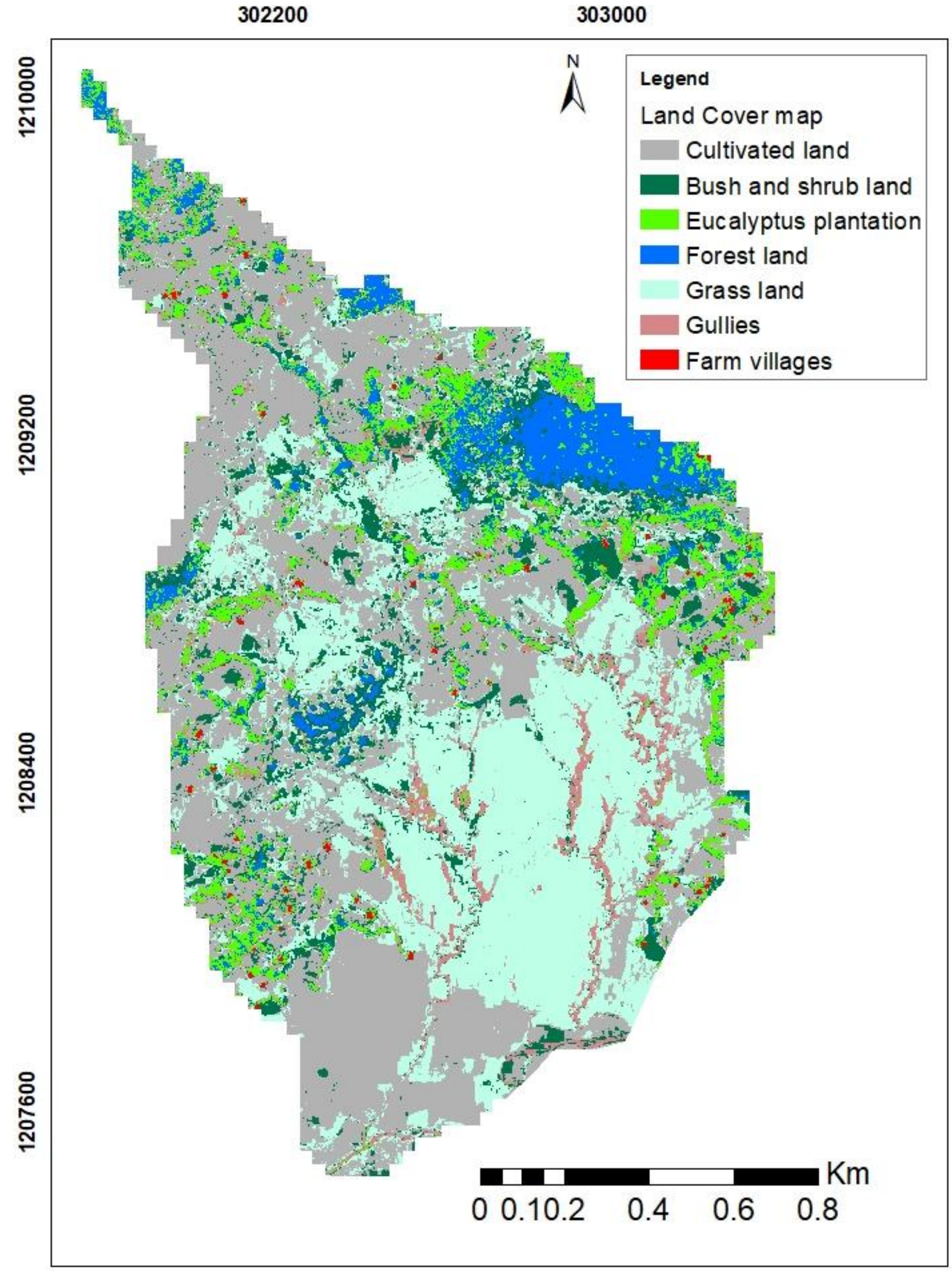

Figure 4. 6. Land use/cover map

CHAPTER 5. CONCLUSION AND RECOMMANDATION

5.1 Conclusion

This study examined morphological and temporal dynamics of gully in Abelasta watershed. Gully erosion was conceived as danger for current land degradation in the watershed. Thus studying soil loss due to gully erosion was important.

Six gullies were selected purposly for field measurement and remote sensing analysis. They were named as gully 1, gully 2, gully 3, gully 4, gully 5 and gully 6. The gully morphologies were described by depth, width and surface area. Among the gully channels, google earth pro images and field observations showed geomorphic differences. And also, the morphological and temporal dynamics of gullies were assessed by google earth pro historical image in 2005, 2013, 2016 and 2020. So that, gully 1 was increased by 13.61%, 28.01%, 84.04% in length, width and area respectively from 2005 to 2013. In addition, it increased from 2013 to 2016 by 0.63%, 45.38% and 12.44% in length, width and area respectively.

In general, morphological and temporal dynamics of gullies in length, width and area were increased highly from 2005 to 2013 but from 2013 to 2020 expansion was reduced. On the other hand, soil loss in the measured gullies at field in 2021 for gully 1, gully 2, gully 3, gully 4, gully 5 and gully 6 were 119.36, 141.43, 14.84, 130.09, 135.82 and 216.83 ton $ha^{-1}yr^{-1}$. Total soil loss due to the gullies was 758.37 ton $ha^{-1}yr^{-1}$.

5.2 Recommendation

Based on the study of Abelasta watershed the following things recommended:

A. Before the gullies would be connected one another, gully rehabilitation measures should be peformed to solve the problem.

B. At the upper part of the watershed biophysical soil conservation structures should be implemented to reduce runoff that aggravate the gullies.

C. Further study is important for all soil loss types due to erosion.

REFERENCES

Abebaw Wudu Abiye. (2019). Review on Impacts of Land Degradation on Agricultural Production in Ethiopia. *57*.

Abiy T (2008). Area closure as a strategy for land management: A Case study at Kelala Dalacha enclosure in the Central rift valley of Ethiopia (M. Sc. Thesis).

Addis Hailu Kendie, Belayneh Adugna, Muuz Gebretsadik, Baye J Ayalew. (2015). Gully morphology and rehabilitation measures in different agroecological environments of northwestern Ethiopia. Environmental and Applied soil science *2015*.

Addisie Meseret B, Getaneh K Ayele, Azalu A Gessesse, Seifu A Tilahun, Mikael M Moges, Assefa D Zegeye, Wolde Mekuria, Petra Schmitter, Eddy J Langendoen and Tammo S Steenhuis. (2016). *Rehabilitating gullies with low cost methods, in the sub humid Ethiopian highlands*. Retrieved from

Adugna A, A Abegaz and A Cerdà. (2015). Soil erosion assessment and control in Northeast Wollega, Ethiopia. Solid Earth Discussions. *7*(4).

Adugna Getachew and Wagayehu Bekele. (2005). *Determinants of Land Degradation in the Lake Tana Basin and Its Implications for Sustainable Land Management: The Case of Angereb and Gishe Abbay Watersheds.* MSc thesis]. Haramaya, Ethiopia: Haramaya University. Also available at …,

Ahmed Abdalla A, Kamaleddin E Bashar, Enyew Adgo, Yihenew G. Selassie and Seifu A. Tilahun. (2012). The Nile River Basin: Water Agriculture, Governance and Livelihoods. 112.

AHMED HANAN OSMAN ALI. (2009). *Land degradation and sorghum productivity assessment using spatial analysis at Gadambalyia schemes, Gadaref State, Sudan.*

Amangabara Gordon Tami. (2014). Understanding Effective Gully Control Measures in Imo State, Nigeria. Canadian Open Soil and Erosion Journal *1*(1), 1-9.

Amsalu Aklilu, Leo Stroosnijder and Jan Journal of environmental management de Graaff. (2007). Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia. *83*(4), 448-459.

Amsalu Tadesse and Abebe Mengaw. (2014). GIS based soil loss estimation using rusle model: the case of jabi tehinan woreda, ANRS, Ethiopia. Natural Resources. *5*(11), 616.

Anwar Arif A, DW Aynalem, Seifu A Tilahun, Wolde Mekuria, M Azeze and Tammo S Steenhuis. (2016). *Effectiveness of land and water management interventions in reducing runoff and soil erosion in the northwestern highlands of Ethiopian*. Retrieved from

Asefa DT, Gufu Oba, RB Weladji, JE Colman. (2003). An assessment of restoration of biodiversity in degraded high mountain grazing lands in northern Ethiopia. Land degradation and development. *14*(1), 25-38.

Assessment Millennium Ecosystem. (2005). *Ecosystems and human well-being: wetlands and water*: World Resources Institute.

Aune Jens B, Matewos Tera Bussa, Fenta Gugsa Asfaw and Abyie Alemu Ayele. (2001). The ox ploughing system in Ethiopia: can it be sustained? Outlook on Agriculture, *30*(4), 275-280.

Aynalem D, AA Adem, Seifu A Tilahun, Wolde Mekuria, Charles F Nicholson and Tammo S Steenhuis. (2016). Enhancing ecosystem services in the upper Blue Nile Basin, Ethiopia through soil and water conservation implementation.

Aynekulu Ermias, Wolde Mekuria, Diress Tsegaye, Kenea Feyissa, Ayana Angassa, Jan de Leeuw and Keith Geoderma Shepherd. (2017). Long-term livestock exclosure did not affect soil carbon in southern Ethiopian rangelands. *307*, 1-7.

Babulo Bedru, Bart Muys, Fredu Nega, Eric Tollens, Jan Nyssen, Jozef Deckers, Erik Mathijs. (2009). The economic contribution of forest resource use to rural livelihoods in Tigray, Northern Ethiopia. Forest policy and Economics. *11*(2), 109-117.

Bai ZG, David L Dent, Lennart Olsson and Michael E Schaepman. (2008). *Global assessment of land degradation and improvement: 1. identification by remote sensing*. Retrieved from

Bantider Amare. (2007). *Landscape Transformation and Opportunities for Sustainable Land Management along the Eastern Escarpment of Wello (EEW), Ethiopia.* Verlag nicht ermittelbar,

Belayneh Mengie, Teshome Yirgu, Dereje Tsegaye. (2020). Current extent, temporal trends, and rates of gully erosion in the Gumara watershed, Northwestern Ethiopia. Global Ecology and Conservation. *24*, e01255.

Betrie Getnet D, Yasir A Mohamed, Ann van Griensven and Raghavan Srinivasan. (2011). Sediment management modelling in the Blue Nile Basin using SWAT model. Import foldr 1 -10-08 Batch 5

Bewket Woldeamlak. (2003). *Towards integrated watershed management in highland Ethiopia: the Chemoga watershed case study*.

Bewket Woldeamlak, Ermiyas Teferi. (2009). Assessment of soil erosion hazard and prioritization for treatment at the watershed level: case study in the Chemoga watershed, Blue Nile basin, Ethiopia. Land Degradation and Development. *20*(6), 609-622.

Billi Paolo and F Catena Dramis. (2003). Geomorphological investigation on gully erosion in the Rift Valley and the northern highlands of Ethiopia. *50*(2-4), 353-368.

Boardman J, AJ Parsons, R Holland, PJ Holmes and R Catena. (2003). Development of badlands and gullies in the Sneeuberg, Great Karoo, South Africa. *50*(2-4), 165-184.

Boardman John and Jean Poesen. (2007). *Soil erosion in Europe*: John Wiley & Sons.

Bogale Alemsha, Dessalew Aynalem, Anwar Adem, Wolde Mekuria and Seifu Tilahun. (2020). Spatial and temporal variability of soil loss in gully erosion in upper Blue Nile basin, Ethiopia. Applied Water Science. *10*(5), 1-8.

Bortoleto Ludmila Araujo, Cassio Jose Montagnani Figueira, John B Dunning Jr, John Rodgers and Alexandre Marco da Silva. (2016). Suitability index for restoration in landscapes: An alternative proposal for restoration projects. Ecological Indicators. *60*, 724-735.

Capra A, P Porto, B. (2009). Relationships between rainfall characteristics and ephemeral gully erosion in a cultivated catchment in Sicily (Italy). Soil Scicolone and Tillage Research. *105*(1), 77-87.

Chernet D. (2018). Micro watershed development using GIS & remote sensing in the case of chille and ocholo watersheds, duguna Fango Woreda, Wolaita Zone, Southern Ethiopia. Journal of Environment and Earth Science. *8*(2), 39-47.

Chimdesa Gadisa. (2016). Historical Perspectives and Present Scenarios of Watershed Management in Ethiopia. Int. J. Nat. Resour. Ecol. Manag. *1*, 115-127.

Chirwa PW. (2014). *Restoration practices in degraded landscapes of Eastern Africa. African Forest Forum*. Retrieved from

Coppus R, JE Romijn, M Méndez-Toribio, C Murcia, E Thomas, MR Guariguata, M Herold and L Verchot. (2019). What is out there? a typology of land restoration projects in Latin America and the Caribbean. Environmental Research Communications. *1*(4), 041004.

Costa Fernanda Martineli and Luis de Almeida Prado Catena Bacellar. (2007). Analysis of the influence of gully erosion in the flow pattern of catchment streams, Southeastern Brazil. *69*(3), 230-238.

d'Oleire-Oltmanns Sebastian, Irene Marzolff, Dirk Tiede and Thomas Blaschke. (2014). Detection of gully-affected areas by applying object-based image analysis (OBIA) in the region of Taroudannt, Morocco. *6*(9), 8287-8309.

Daba Shibru, Wolfgang Rieger and Peter Catena Strauss. (2003). Assessment of gully erosion in eastern Ethiopia using photogrammetric techniques. *50*(2-4), 273-291.

Daba Shibru, Wolfgang Rieger and Peter Catena Strauss. (2003). Assessment of gully erosion in eastern Ethiopia using photogrammetric techniques. *50*(2-4), 273-291.

Dagnew Dessalegn C, Christian D Guzman, Assefa D Zegeye, Adugnaw T Akal, Mamaru A Moges, Tigist Y Tebebu, Wolde Mekuria, Essayas K Ayana, Seifu A Tilahun, Tammo

S Steenhuis. (2017). Sediment loss patterns in the sub-humid Ethiopian highlands. Land Degradation and Development. *28*(6), 1795-1805.

Damene Shimeles, Lulseged Tamene and Paul LG Catena Vlek. (2013). Performance of exclosure in restoring soil fertility: a case of Gubalafto district in North Wello Zone, northern highlands of Ethiopia. *101*, 136-142.

Dar. (2009). Ethiopia Improved Water and Land Management in the Ethiopian Highlands: Its Impact on Downstream Stakeholders Dependent on the Blue Nile, Assessment of Hydrological Controls on Gully Formation and Upland Erosion near Lake Tana, Northern Highlands of Ethiopia. 160.

De Wit J, KU Leuven. (2003). Stuwmeren in Tigray (Noord-Ethiopië): kenmerken, sedimentatie en sedimentbronnen. Unpublished M. Sc. thesis, Department of Geography

Degefa Alemayehu. (2009). *Faculty of Science Department of Earth Science Remote Sensing and GIS Stream.* Addis Ababa University,

Demeke GG and TG Andualem. (2018). Application of remote sensing for evaluation of land use change responses on hydrology of Muga watershed, Abbay River Basin, Ethiopia. *9*(493), 2.

Descheemaeker Katrien, Bart Muys, Jan Nyssen, Wim Sauwens, Mitiku Haile, Jean Poesen, Dirk Raes and Jozef Deckers. (2009). Humus form development during forest restoration in exclosures of the Tigray highlands, Northern Ethiopia. *17*(2), 280-289.

Descheemaeker Katrien, Jan Nyssen, Joni Rossi, Jean Poesen, Mitiku Haile, Dirk Raes, Bart Muys, Jan Moeyersons and Seppe Geoderma Deckers. (2006). Sediment deposition and pedogenesis in exclosures in the Tigray Highlands, Ethiopia. *132*(3-4), 291-314.

Desta Lakew and Belayneh Adugna. (2012a). A field guide on gully prevention and control. *Nile Basin Initiative Eastern Nile Subsidiary Action Program (ENSAP), Addis Ababa, Ethiopia, 67*.

Desta Lakew and Belayneh Adugna. (2012b). Nile Basin Initiative Eastern Nile Subsidiary Action Program (ENSAP).

Desta Lakew and Belayneh Adugna (2012). Nile Basin Initiative Eastern Nile Subsidiary Action Program, Addis Ababa, Ethiopia. A field guide on gully prevention and control. *67*.

Doetterl Sebastian, Kristof Van Oost and Johan Six. (2012). Earth Surface Processes and Landforms Towards constraining the magnitude of global agricultural sediment and soil organic carbon fluxes. *37*(6), 642-655.

Dubale Paulos. (2001). Soil and water resources and degradation factors affecting productivity in Ethiopian highland agro-ecosystems. Northeast African Studies. 27-51.

Ehiorobo Jacob Odeh and Osadolor Christopher Izinyon. (2013). Monitoring of soil loss from erosion using geoinformatics and geotechnical engineering methods. Journal of Civil Engineering and Architecture. *7*(1), 78.

Eitel Bernhard, Joachim Eberle and Ralf Catena Kuhn. (2002). Holocene environmental change in the Otjiwarongo thornbush savanna (Northern Namibia): evidence from soils and sediments. *47*(1), 43-62.

Elsen Susanne and Stefan Zerbe. (2018). Transformation in the Javakheti Highlands Georgia–a community-based participatory approach towards sustainable pasture management in a remote mountain area. *8*(3), 369-394.

Erkossa Teklu, A Wudneh, B Desalegn and G Taye. (2015). Linking soil erosion to on-site financial cost: lessons from watersheds in the Blue Nile basin. *6*(2), 765-774.

FAO. (1986). FAO watershed management field manual, Gully control. 1986.

Frankl Amaury, Jan Nyssen, Morgan De Dapper, Mitiku Haile, Paolo Billi, R Neil Munro, Jozef Deckers and Jean Poesen. (2011). Linking long-term gully and river channel dynamics to environmental change using repeat photography (Northern Ethiopia). *129*(3-4), 238-251.

Frankl Amaury, Jean Poesen, Jozef Deckers, Mitiku Haile and Jan Nyssen. (2012). Gully head retreat rates in the semi-arid highlands of Northern Ethiopia. *173*, 185-195.

Frankl Amaury, Jean Poesen, Mitiku Haile, Jozef Deckers and Jan Nyssen. (2013). Quantifying long-term changes in gully networks and volumes in dryland environments: The case of Northern Ethiopia. *201*, 254-263.

Gebre Tesfaye, Tigist Kibru, Samuale Tesfaye and Gebeyehu Taye. (2015). Analysis of watershed attributes for water resources management using GIS: The case of Chelekot micro-watershed, Tigray, Ethiopia. *7*(02), 177.

Gebrernichael Desta, Jan Nyssen, Jean Poesen, J Deckers, Mitiku Haile, Gerard Govers, Moeyersons. (2005). Effectiveness of stone bunds in controlling soil erosion on cropland in the Tigray Highlands, northern Ethiopia. *21*(3), 287-297.

Gelagay Habtamu Sewnet, Amare Sewnet. (2016). Soil loss estimation using GIS and Remote sensing techniques: A case of Koga watershed, Northwestern Ethiopia. International Soil Minale and Water Conservation Research. *4*(2), 126-136.

Getachew A and B Wagayehu. (2007). Determinants of land degradation in the Lake Tana basin and its implications for sustainable land management: the case of Angereb and Gish-Abbay watersheds. Ethiopian Journal of Agricultural Economics. *6*(2), 69-101.

Gibbs HK and J Megham Salmon. (2015). Mapping the world's degraded lands. Applied geography. *57*, 12-21.

Gilbey Ben, Jonathan Davies, Graciela Metternicht, Chris Magero. (2019). Taking land degradation neutrality from concept to practice: Early reflections on LDN target setting and planning. Environmental Science and Policy. *100*, 230-237.

Hadera D and B J. Asfaw. (2016). Socioeconomic Impact Assessment of Highway Drainage Outlet Erosion, Case Study of Mekelle to Adigrat Highway, Tigray, Ethiopia. Civil. Environ. Eng. *6*, 215.

Han Youzhi, Jianwei Zhang, Kim G Mattson, Weidong Zhang and Thomas A Weber. (2016). Sample sizes to control error estimates in determining soil bulk density in California forest soils. *80*(3), 756-764.

Harden Carol. (2016). Special focus on new studies of gully erosion. In: Taylor & Francis.

Haregeweyn Nigussie, Bekure Melesse, Atsushi Tsunekawa, Mitsuru Tsubo, Derege Meshesha, Bedru Babulo Balana. (2012). Reservoir sedimentation and its mitigating strategies: a case study of Angereb reservoir (NW Ethiopia). *12*(2), 291-305.

Haregeweyn Nigussie, Jean Poesen, Gert Verstraeten, Gerard Govers, Joris de Vente, Jan Nyssen, J Deckers, Jan Moeyersons. (2013). Assessing the performance of a spatially distributed soil erosion and sediment delivery model (WATEM/SEDEM) in Northern Ethiopia. *24*(2), 188-204.

Hayas Antonio, Tom Vanwalleghem, Ana Laguna, Adolfo Peña Acevedo and Juan Vicente Giráldez. (2017). Reconstructing long-term gully dynamics in Mediterranean agricultural areas.

Hoogenboom PE. (2013). Sediment yield by gully erosion in a sub catchment of the Awassa watershed, Ethiopia.

Hughes Andrew O, Ian P Prosser, Janelle Stevenson, Anthony Scott, Hua Lu, John Gallant, Chris J CSIRO Moran and Canberra. (2001). Gully erosion mapping for the national land and water resources audit. *26*, 01-20.

IUCN WRI IUCN, Gland, Switzerland. (2014). A guide to the restoration opportunities assessment methodology (ROAM): assessing forest landscape restoration opportunities at the national or sub-national level.

Jahantigh Mansour and Mohammad Pessarakli. (2011). Causes and effects of gully erosion on agricultural lands and the environment. *42*(18), 2250-2255.

Jean Poesen. (2018). Soil erosion in the Anthropocene: Research needs. *43*(1), 64-84.

Katsurada Yusuke. (2007). Regional scaled mapping of gully erosion sensitivity in Western Kenya. African Journal of Environmental Science and Technology. *1*(3), 49-52.

Kidane Desale and Binyam Alemu. (2015). The effect of upstream land use practices on soil erosion and sedimentation in the Upper Blue Nile Basin, Ethiopia. Research Journal of Agriculture and Environmental Management. *4*(2), 55-68.

Kirui Oliver Kiptoo and Alisher Mirzabaev. (2014). *Economics of land degradation in Eastern Africa*. Retrieved from

Le Quang Bao, Ephraim Nkonya, Alisher Mirzabaev. (2016). Global assessment for sustainable development. Biomass productivity-based mapping of global land degradation hotspots. 55.

Le Roux Jacobus Johannes and PD Sumner. (2012). Factors controlling gully development: comparing continuous and discontinuous gullies. *23*(5), 440-449.

Leblanc Marc J, Guillaume Favreau, Sylvain Massuel, Sarah O Tweed, Maud Loireau, Bernard Cappelaere. (2008). Land clearance and hydrological change in the Sahel: SW Niger. *61*(3-4), 135-150.

Liberti M, T Simoniello, MT Carone, R Coppola, M D'Emilio and M Macchiato. (2009). Mapping badland areas using LANDSAT TM/ETM satellite imagery and morphological data. *106*(3-4), 333-343.

Luffman Ingrid E, Arpita Nandi and Tim Catena Spiegel. (2015). Gully morphology, hillslope erosion, and precipitation characteristics in the Appalachian Valley and Ridge province, southeastern USA. *133*, 221-232.

Lulseged T and PLG Vlek. (2008). Soil erosion studies in northern Ethiopia. Center for Development Research, University of Bonn, Bonn, Germany.

MacDicken K, Ö Jonsson, L Piña, S Maulo, V Contessa, Y Adikari, M Garzuglia, E Lindquist, G Reams and R D'Annunzio. (2016). Global forest resources assessment 2015: how are the world's forests changing?

Majumder Arijit, Sandipan Ghosh, Abhik Dasgupta and Debabrata Panchakotessays Seth. (2012). Analyzing reservoir sedimentation of Panchet Dam, India using remote sensing and GIS. *2*(3), 82-95.

Makaya Nosipho Pearl. (2018). *Remote sensing of gully erosion in the communal lands of Okhombe Valley, Drakensberg, South Africa.*

Marzolff Irene, Jean Poesen and Johannes B Ries. (2011). Short to medium-term gully development: human activity and gully erosion variability in selected Spanish gully catchments. *17*, 111-116.

Marzolff Irene and Johannes B Zeitschrift für Ries. (2007). Gully erosion monitoring in semi-arid landscapes. *51*(4), 405-425.

McGinley Mark. (2008). Ethiopian montane moorlands.

Mekuria Wolde, Simon Langan, Robyn Johnston, Beyene Belay, Dagninet Amare, Tadesse Gashaw, Gizaw Desta, Andrew Noble, Abeyou Wale. (2015). Restoring aboveground carbon and biodiversity: a case study from the Nile basin, Ethiopia. *11*(2), 86-96.

Mekuria Wolde, Simon Langan, Andrew Noble, Robyn Johnston. (2017). Soil restoration after seven years of exclosure management in northwestern Ethiopia. *28*(4), 1287-1297.

Mekuria Wolde, E Veldkamp, Mesfin Tilahun and R Olschewski. (2011). Economic valuation of land restoration: the case of exclosures established on communal grazing lands in Tigray, Ethiopia. *Land Degradation Development, 22*(3), 334-344.

Mekuria Wolde and Edzo Veldkamp. (2012). Restoration of native vegetation following exclosure establishment on communal grazing lands in Tigray, Ethiopia. *15*(1), 71-83.

Mekuria Wolde, Edzo Veldkamp, Marife D Corre and Mitiku Haile. (2011). Restoration of ecosystem carbon stocks following exclosure establishment in communal grazing lands in Tigray, Ethiopia. *75*(1), 246-256.

Mekuria Wolde, Edzo Veldkamp, Mitiku Haile, Kindeya Gebrehiwot, Bart Muys and Jan African Journal of Agricultural Research Nyssen. (2009). Effectiveness of exclosures to control soil erosion and local communities perception on soil erosion. *4*(4), 365-377.

Mengistu Tefera, Demel Teketay, H Hulten and Yonas Yemshaw. (2005). The role of enclosures in the recovery of woody vegetation in degraded dryland hillsides of central and northern Ethiopia. *60*(2), 259-281.

Mesene Merkineh. (2017). Extent and impact of land degradation and rehabilitation strategies: Ethiopian Highlands. *7*(11), 22-32.

Meshesha Tesfa Worku and K Tripathi. (2015). An Evaluation of Watershed Management Practice in Ethiopia: A Preliminary. *4*(1), 24-30.

MOFED. (2010). Growth and transformation plan of Ethiopia (GTP), 2010/2011–2014/15 of the Federal Democratic Republic of Ethiopia (FDRE).

Moges Awdenegest, Nicholas M Holden. (2009). Land cover change and gully development between 1965 and 2000 in Umbulo Catchment, Ethiopia. *29*(3), 265-276.

Moges Hagos Gebreslassie and Gessesse Dessie Awdenegest. (2014). Rate of Gully Expansion on Major Land Uses, the Case of Huluka Watershed, Central Rift Valley, Ethiopia.

Molla Tegegne and Biniam Sisheber. (2017). Estimating soil erosion risk and evaluating erosion control measures for soil conservation planning at Koga watershed in the highlands of Ethiopia. *Solid Earth, 8*(1), 13.

Molla Tegegne and Biniam Sisheber. (2017). Estimating soil erosion risk and evaluating erosion control measures for soil conservation planning at Koga watershed in the highlands of Ethiopia. *8*(1), 13.

Musa D, AI Ahmed, UB Muhammed and H Abdul. (2016). Assessment of the impacts of gully erosion on Auchi settlement, Southern Nigeria Journal of Geography and Regional Planning Vol. 9 (7). 128-138. http://www. academicjournals. org/JGRP.

Nachtergaele Freddy and Monica Petri. (2017). Mapping land use systems at global and regional scales for land degradation assessment analysis.

Nasri M, S Feiznia, M Jafari and H Ahmadi. (2012). Application of Gully and Rill Erosion Indicators for Estimating Soil Loss Using GIS Techniques. *17*(2), 119-128.

Ndona A, P Truong, TVN July. (2011). Community mobilization for the control of ravine erosion with vetiver technology in the Congo. *14*, 2015.

Nemes Iacob and Laura Constantinescu. (2011). *The Gully Erosion Effect On the Environment.* Paper presented at the HAICTA.

Nicholson C, DB Tenessa, EJ Langendoen, Getaneh K Ayele, Seifu A Tilahun and Tammo S Steenhuis. (2015). Sustaining landscapes: Participatory community-based gully rehabilitation on the Ethiopian highlands: The case of Birr watershed. In: International Water Management Institute (IWMI); CGIAR Research Program on ….

Nwilo Peter Chigozie, Dupe Nihinlola Olayinka, Ibeabuchi Uwadiegwu and Ayila Emmanuel Adzandeh. (2011). An assessment and mapping of gully erosion hazards in Abia State: A GIS approach. *4*(5), 196.

Nyssen Jan. (2001). Erosion processes and soil conservation in a tropical mountain catchment under threat of anthropogenic desertification. A case study from Northern Ethiopia.

Nyssen Jan, Jean Poesen, Jan Moeyersons, Jozef Deckers, Mitiku Haile and Andreas Lang. (2004). Human impact on the environment in the Ethiopian and Eritrean highlands—a state of the art. *64*(3-4), 273-320.

Nyssen Jan, Jean Poesen, Jan Moeyersons, Mitiku Haile, Jozef Deckers. (2008). Dynamics of soil erosion rates and controlling factors in the Northern Ethiopian Highlands–towards a sediment budget. *33*(5), 695-711.

Nyssen Jan, Jean Poesen, Maude Veyret-Picot, Jan Moeyersons, Mitiku Haile, Jozef Deckers, Joke Dewit, Jozef Naudts, Kassa Teka and Gerard Govers. (2006). Assessment of gully erosion rates through interviews and measurements: a case study from Northern Ethiopia. *Earth Surface Processes and Landforms, 31*(2), 167-185.

Nyssen Jan, M Veyret-Picot, Jean Poesen, J Moeyersons, Mitiku Haile, J Deckers, Gerard Govers. (2004). The effectiveness of loose rock check dams for gully control in Tigray, northern Ethiopia. *20*(1), 55-64.

Obalum SE, MM Buri, JC Nwite and Watanabe Hermansah. (2012). Y., Igwe, CA & Wakatsuki, T.(2012). Soil degradation-induced decline in productivity of Sub-Saharan African soils: The prospects of looking downwards the lowlands with the sawah ecotechnology.

Onuoha DC, Nwabueze I Igu and Rotimi Oluwole. (2020). GIS-Based Study of Prioritized Gully Erosion and Flood Locations in Ebonyi State.

Oostwoud Wijdenes DJ and R Bryan. (2001). Gully-head erosion processes on a semi-arid valley floor in Kenya: a case study into temporal variation and sediment budgeting. *26*(9), 911-933.

Peasley B and S Taylor. (2009). MER–Soil and Land Resource Condition in NSW: Water Erosion–Monitor and Evaluate Gully Erosion.

Pender John, Frank Place and Simeon Ehui. (2006). *Strategies for sustainable land management in the East African highlands*: Intl Food Policy Res Inst.

Poesen Jean, Jeroen Nachtergaele, Gert Verstraeten and Christian Catena. (2003). Gully erosion and environmental change: importance and research needs. *50*(2-4), 91-133.

Poesen Jean, Liesbeth Vandekerckhove, Jeroen Nachtergaele, Dirk Oostwoud Wijdenes, Gert Verstraeten and Bas van Wesemael. (2002). Gully erosion in dryland environments.

Prasad B and HL Tiwari. (2019). Assessment of soil erosion in the watershed of upper lake, Bhopal using remote sensing and GIS. *8*(6), 456-462.

Sekela woreda office of Natural resource. (2018). Manual of Sekela woreda natural resource management.

Rivas Todd. (2006). *Erosion control treatment selection guide*. Retrieved from

Scholes RJ, L Montanarella, E Brainich, N Barger, B ten Brink, M Cantele, B Erasmus, J Fisher, T Gardner and TG Holland. (2018). IPBES (2018): Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.

Setegn Shimelis G, Ragahavan Srinivasan, Bijan Dargahi and Assefa M Melesse. (2009). Spatial delineation of soil erosion vulnerability in the Lake Tana Basin, Ethiopia. *23*(26), 3738-3750.

Shawul consultancy with Amhara National Regional state of Investment Office. (2005). Potential Survey, Identification of Opportunities and Preparations of Projects Profiles and Feasibility Studies, Soil Survey Draft Report.

Shibru Daba, W Rieger and P Catena Strauss. (2003). Assessment of gully erosion using phtotogrammetric techniques in eastern Ethiopia. *50*, 273-291.

Shiferaw Abate and KL Singh. (2011). Evaluating The Land Use And Land Cover Dynamics In Borena Woreda South Wollo Highlands, Ethiopia. *2*(1).

Shit Pravat Kumar and Ramkrishna Maiti. (2012). Effects of plant root density on the erodibility of lateritic topsoil by simulated flume experiment. *2*(3), 137-142.

Steenhuis Tammo S, Zachary M Easton, Seleshi B Awulachew, Abdalla A Ahmed, Kamaleddin E Bashar, Enyew Adgo, Yihenew G Selassie and Seifu A Tilahun. (2013). The Nile Basin sediment loss and degradation, with emphasis on the Blue Nile. In *The Nile River Basin* (pp. 134-154): Routledge.

Stewart Naomi, Richard J Thomas, Hannes C Etter, Emmanuelle Quillérou, Mark Schauer, Nicola Favretto, Lindsay C Stringer and Pushpam Kumar. (2015). Outcomes and conclusions. In: The Economics of Land Degradation (ELD).

Summit UN Climate United Nations. (2014). New York declaration on forests. New York, NY.

Tamene Luelseged, SJ Park, R Dikau and PLG Vlek. (2006). Analysis of factors determining sediment yield variability in the highlands of northern Ethiopia. *76*(1-2), 76-91.

Tamene Lulseged and Paul LG Vlek. (2008). Soil erosion studies in northern Ethiopia. In *Land use and soil resources* (pp. 73-100): Springer.

Team UC. (2000). Amhara National regional state Food security Research Assessment report.

Tebebu TY, AZ Abiy, AD Zegeye, HE Dahlke, ZM Easton, SA Tilahun, AS Collick, S Kidnau, S Moges and F Dadgari. (2010). Surface and subsurface flow effect on permanent gully formation and upland erosion near Lake Tana in the northern highlands of Ethiopia. *Hydrology and Earth System Sciences, 14*(11), 2207-2217.

Tebebu TY, AZ Abiy, AD Zegeye, HE Dahlke, ZM Easton, SA Tilahun, AS Collick, S Kidnau, S Moges and F Dadgari. (2010). Surface and subsurface flow effect on permanent gully formation and upland erosion near Lake Tana in the northern highlands of Ethiopia. *14*(11), 2207-2217.

Tekwa JI and BH FUTY Usman. (2006). Estimation of soil loss by gully erosion in Mubi, Adamawa State, Nigeria. *1*(1), 35-43.

Temesgen G, B Amare, and M Abraham. (2014). Farming households' knowledge and perception on soil degradation in Dera Woreda. *2*(3), 1-10.

Temesgen Gashaw and Bantider Amare. (2014). Land degradation in Ethiopia: causes, impacts and rehabilitation techniques. *4*(9), 98-104.

Tesfaye Gizaw and Degifie Tibebe. (2018). Soil erosion modeling using GIS based RUSEL model in Gilgel Gibe-1 catchment, South West Ethiopia. *15*(5), 141-148.

Tesfaye Yemiru, Melaku Bekele, Hussien Kebede, Fekadu Tefera and Habtemariam Kassa. (2015). Enhancing the Role of Forestry in Building Climate Resilient Green Economy in Ethiopia.

Tilahun Mesfin, Roland Olschewski, Christoph Kleinn and Kindeya Gebrehiwot. (2007). Economic analysis of closing degraded Boswellia papyrifera dry forest from human interventions—a study from Tigray, Northern Ethiopia. *9*(8), 996-1005.

Tilahun Seifu A, Christian D Guzman, Assefa D Zegeye, Dessalegn C Dagnew, Amy S Collick, Birru Yitaferu and Tammo S Steenhuis. (2015). Distributed discharge and sediment concentration predictions in the sub-humid Ethiopian highlands: the Debre Mawi watershed. *29*(7), 1817-1828.

Tsegaye Genene and Legesse Dadi. (2006). *farmers' perceptions of land degradation and determinants of household food security status at middle catchment of Bilate watershed.* Haramaya University,

UNCCD Land Degradation Neutrality. (2016). The Target Setting Programme. In: Paris.

Ustun Berk. (2008). Soil erosion modelling by using GIS and remote sensing: a case study Ganos Mountain. *37*, 1681-1684.

Valentin Christian, Jean Poesen and Yong Catena Li. (2005). Gully erosion: impacts, factors and control. *63*(2-3), 132-153.

Verstraeten Gert, Paolo Bazzoffi, Adam Lajczak, Mariá Rãdoane, Freddy Rey, Jean Poesen and Joris de Vente. (2006). Reservoir and pond sedimentation in Europe. 757-774.

Wang Tao, Fuhong He, Anding Zhang, Lijuan Gu, Yangmao Wen, Weiguo Jiang and Hongbo Shao. (2014). A quantitative study of gully erosion based on object-oriented analysis techniques: a case study in Beiyanzikou catchment of Qixia, Shandong, China. *2014*.

Wells Robert R, Sean J Bennett and Carlos V Alonso. (2009). Effect of soil texture, tailwater height, and pore-water pressure on the morphodynamics of migrating headcuts in upland concentrated flows. *34*(14), 1867-1877.

Wolancho Kebede Wolka. (2015). Evaluating watershed management activities of campaign work in Southern nations, nationalities and peoples' regional state of Ethiopia. *4*(1), 6.

Wolancho Kebede Wolka. (2012). Watershed management: An option to sustain dam and reservoir function in Ethiopia. *5*(5), 262-273.

Yazie Tsegaye, Mulatie Mekonenn, Assefa Derebe and Tadele Melese. (2020). Investigating long year gully erosion and its impacts on soil loss, land competition and crop yield reduction, north-west Ethoipia.

Yibeltal Mesenbet, Atsushi Tsunekawa, Nigussie Haregeweyn, Enyew Adgo, Derege Tsegaye Meshesha, Dagnachew Aklog, Tsugiyuki Masunaga, Mitsuru Tsubo, Paolo Billi and Matthias Catena Vanmaercke. (2019). Analysis of long-term gully dynamics in different agro-ecology settings. *179*, 160-174.

Yitbarek TW, S Belliethathan and LC Stringer. (2012). The onsite cost of gully erosion and cost-benefit of gully rehabilitation: A case study in Ethiopia. *23*(2), 157-166.

Zegeye AD, S Damtew, AS Tilahun, E Langendoen, D Dagnew, C Guzman, TY Tebeby and TS Steenhuis. (2014). *Gully development processes in the Ethiopian Highlands.* Paper presented at the Proceedings of the second International Conference on the Advancements in Science and Technology (ICAST), Bahir Dar University.

Zegeye Assefa D, Eddy J Langendoen, Cathelijne R Stoof, Seifu A Tilahun, Dessalegn C Dagnew, Fasikaw A Zimale, Christian D Guzman, Birru Yitaferu and Tammo S Steenhuis. (2016). Morphological dynamics of gully systems in the subhumid Ethiopian Highlands: the Debre Mawi watershed. *2*(3), 443-458.

Zegeye Assefa D, Tammo S Steenhuis, Wolde Mekuria, Dessalegn C Dagnaw, Meseret B Addisse, Seifu A Tilahun and Tadele A Kasse. (2017). Effect of gully headcut treatment on sediment load and gully expansion in the sub humid Ethiopian Highlands. *5*(2), 138-144.

Zegeye Assefa Derebe. (2016). *Extent and impact of gully erosion in a watershed in the sub humid Ethiopian highlands*: Cornell University.

Zgłobicki Wojciech, Bogusława Baran-Zgłobicka, Leszek Gawrysiak and Małgorzata Catena Telecka. (2015). The impact of permanent gullies on present-day land use and agriculture in loess areas (E. Poland). *126*, 28-36.

APPENDICES

1 Field measured data for all gullies

Gully 1

											Widths	
								Total	right			
No	Gully Section	X1(right)	Y1 (right)	X2 (left)	Y2 (left)	Elevation	length	width	w1	w2	w3	w4
1		302320	1207314	302314	1207330	2350	0	6.5	1.6	1.8		
2		302328	1207329	302323	1207329	2346	15	4	1	1		
3		302329	1207337	302325	1207338	2348	7	4.6	1.6	0.7		
4		302325	1207344	302324	1207345	2348	7	2	0.5	0.5		
5		302332	1207356	302333	1207356	2348	15	2.4	0.7	0.7		
6		302336	1207370	302335	1207371	2346	15	3.3	1.65	1.65		
7		302348	1207380	302345	1207383	2345	15	4	1	1		
8		302416	1207476	3024123	1207479	2350	15	4.2	0.85	0.85		
9		302426	1207488	302423	1207490	2350	15	4.1	0.8	0.8		
10		302430	1207502	302427	1207502	2348	15	3.6	0.6	0.6		
11		302439	1207517	302434	1207516	2348	15	3	0.75	0.75		
12		302446	1207525	302442	1207528	2346	15	4.2	0.95	0.95		
13		302456	1207537	302452	1207539	2347	15	4.1	1.3	1.3		
14		302462	1207545	302457	1207547	2351	10	5	1.25	1.25		
15		302459	1207561	302453	1207562	2349	15	4	1	1		
16		302462	1207574	302457	1207575	2351	15	3.9	0.85	0.85		
17		302468	1207578	302463	1207582	2347	10	5.8	1.1	1.1		
18		302473	1207593	302464	1207591	2348	15	6	0.75	0.75		

19		302464	1207600	302459	1207603	2350	10	5.7	1.42	1.42
20		302479	1207600	302477	1207604	2555	15	5.9	0.95	0.95
21		302490	1207608	302487	1207611	2351	15	5.5	0.85	0.85
22		302481	1207625	302477	1207620	2355	15	4.7	1.6	1.6
23		302476	1207629	302470	1207627	2353	15	5.2	1.3	1.3
24		302483	1207640	302479	1207641	2355	15	6.3	2.5	2.5
25		302487	1207655	302480	1207656	2352	15	8	2	2
26		302502	1207648	302503	1207656	2352	15	6.9	0.95	0.95
27		302515	1207651	302513	1207658	2348	15	6.9	1.8	1.8
28		302524	1207661	302519	1207666	2351	15	6.7	1.85	1.85
29		302533	1207676	302517	1207675	2353	15	12.8	5	5
30		302530	1207693	302519	1207690	2352	15	11.9	4.4	4.4
31		302523	1207705	302515	1207703	2349	15	10.8	2	2
32		302516	1207718	302507	1207712	2348	15	8.6	3	3
33		302502	1207713	302502	1207712	2351	15	11.6	4.5	4.5
34		302501	1207729	302489	1207730	2353	15	9	2.25	2.25
35		302504	1207740	302498	1207743	2354	15	9	3.8	3.8
36		302511	1207745	302597	1207963	2352	15	15	4.5	4.5
37		302604	1207919	302586	1207976	2356	15	18	6.45	6.45
38		302605	1207993	302584	1207990	2353	15	21	13.4	13.4
39		302610	1208009	302577	1208002	2351	15	30.8	1.8	1.8
40		302593	1208030	302573	1208017	2354	15	20	4.5	4.5
41		302581	1208040	302561	1208022	2355	15	23.6	3.5	3.5
42	1	302578	1208055	302565	1208056	2362	15	13.8	3.7	3.7
43	1	302590	1208068	302564	1208070	2361	15	18.2	3.7	3.7

44	1	302585	1208080	302567	1208085	2356	15	17.5	5.75	5.75	
45	1	302584	1208093	302575	1208096	2358	15	11.6	3	3	
46	1	302585	1208103			2359	7	8.4	1.6	1.6	
47	2	302565	1208060	302555	1208060	2354	15	10.7	3	3	
48	2	302563	1208075	302550	1208072	2359	15	11.9	3.45	3.45	
49	2	302560	1208081	302557	1208085	2356	8.2	6.8	2.2	2.2	
50		302556	1208053	302550	1208030	2353	15	24.6	4	4	4
51		302552	1208058	302539	1208040	2352	15	22.4	4.3	4.3	4.3
52		302547	1208068	302524	1208043	2350	15	31.15	4	4	
53		302547	1208068	302524	1208059	2351	15	23	3.3	3.3	3.3
54		302550	1208079	302517	1208071	2349	15	32.6	4	4	4
55		302539	1208093	302510	1208086	2350	15	32.3	6	6	6
56	3	302548	1208097	302538	1208095	2357	10.4	10	2.7	2.7	
57	3	302542	1208113	302536	1208111	2358	17.6	7.2	2	2	
58		302535	1208108	302506	1208093	2361	15	35	3.7	3.7	3.7
59		302520	1208115	302498	1208103	2360	15	29	6	6	6
60		302516	1208126	302491	1208115	2360	15	26	3.5	3.5	
61		302514	1208141	302488	1208133	2363	15	25	4	4	4
62		302507	1208151			2361	12	27	5	5	
63		302495	1208159	302477	1208140	2359	15	26.3	4	4	
64	4	302505	1208166			2359	15	13.1	3	3	
65	4	302500	1208176	302489	1208173	2362	15	12.4	2.7	2.7	
66	4	302498	1208192	302486	1208186	2361	15	13.9	3.5	3.5	
67	4	302498	1208204	302488	1208200	2359	15	7.1	2	2	
68		302488	1208174	302468	1208151	2362	15	31.3	5	5	5

69		302476	1208183	302451	1208161	2360	15	34.5	5.7	5.7	5.7
70		302464	1208194	302444	1208179	2359	15	29	5.7	5.7	5.7
71		302464	1208210	302433	1208200	2355	15	30	5.3	5.3	5.3
72		302461	1208225	302430	1208214	2364	15	34	5	5	5
73		302456	1208240	302430	1208214	2365	15	35.3	4.65	4.65	
74	5	302455	1208243	302430	1208242	2368	0	23.75	4.6	4.6	4.6
75	5	302463	1208252	302436	1208254	2366	15	27.45	4.5	4.5	4.5
76	5	302462	1208269	302432	1208264	2367	15	31.3	6.4	6.4	6.4
77	5	302454	1208284	302430	1208273	2365	15	29.8	5.93	5.93	5.93
78	5	302443	1208288	302428	1208278	2365	15	17.6	5.8	5.8	
79	5	302436	1208304	302417	1208285	2369	15	26.75	4.25	4.25	4.25
80	5.1	302423	1208289	302417	1208285	2360	0	6.8	1.7	1.7	
81	5.1	302419	1208292	302417	1208287	2371	3.85	5	2.5		
82	5.2	302437	1208305	302417	1208287	2371	0	16.9	3	3	
83	5.2	302425	1208307	302422	1208300	2369	6.7	10.4	2.35	2.35	
84		302426	1208249	302417	1208223	2364	15	28.8	3.6	3.6	3.6
85		302412	1208255	302406	1208233	2364	15	24.6	5.2	5.2	5.2
86		302401	1208264	302386	1208238	2368	15	30.5	5.3	5.3	5.3
87		302396	1208268	302378	1208254	2358	15	24.3	5	5	5
88	6	302396	1208268	302386	1208263	2368	0	9.6	3	3	
89	6	302390	1208271	302306	1208271	2369	5.2	5.8	1	1	
90		302360	1208262	302376	1208255	2369	0	9	2.5	2.5	
91		302376	1208276	302364	1208261	2368	15	20.6	4	4	
92		302368	1208287	302350	1208270	2371	15	24	3	3	
93	7	302349	1208281	302344	1208272	2371	0	9.1	2.65	2.65	

94	7	302359	1208298	302352	1208290	2372	15	13	3	3	
95	7	302347	1208307	302343	1208293	2371	15	14	5	5	
96		302334	1208289	302328	1208263	2375	17	25.2	5	5	5
97		302318	1208291	302318	1208266	2374	15	25.6	4	4	4
98	8	302318	1208291	302311	1208280	2374	0	12.9	2	2	
99	8	302300	1208297	302297	1208292	2374	15	6.9	2	2	
100		302301	1208268	302301	1208257	2374	15	10.6	2.5	2.5	
101		302280	1208261	302285	1208253	2376	15	8.3	2.15	2.15	
102		302272	1208258	302273	1208251	2380	15	9	0.5	0.5	
103	9	302291	1208265	302279	1208260	2374	0	11.3	2.65	2.65	
104	9	302284	1208271	302276	1208262	2384	10	10.2	3.6	3.6	

Gully 1

	Widths			Depths						
	Left			Right			Left			
No	w3	w4	Middle	D1	D2	D3	D1	D2	D3	Remark
1			2.5	2.5	0.8		1.5			
2			1.95	1.9			1.4			
3			1.75	1.6			0.5			
4			1.75	1.6			0.5			
5			1.8	1.3			1.15			
6			1.55	0.8			0.9			
7			1.4	1			0.9			
8			1.15	0.5			0.5			
9			0.9	0.5			0.35			
10			0.95	0.4			0.23			

11	0.8	0.7	0.2
12	0.9	0.45	0.3
13	0.8	0.2	0.3
14	0.65	0.5	0.4
15	0.7	0.4	0.55
16	0.7	0.3	0.3
17	0.6	0.65	0.4
18	0.6	0.2	0.3
19	0.6	0.3	0.5
20	0.9	0.6	0.6
21	0.9	0.6	0.4
22	0.6	0.3	0.55
23	0.55	0.37	0.2
24	0.65	0.4	0.2
25	0.9	0.6	0.6
26	1.1	0.85	0.75
27	1.1	0.8	0.5
28	1.2	0.6	0.3
29	0.9	0.5	0.75
30	1.4	0.9	0.6
31	1.68	1.1	1.1
32	2	1	1.7
33	1.9	1.5	1
34	1.8	0.85	1.2
35	2	1.3	1.8
36	2	1	1.6
37	1.6	1.4	1

38			1.9	1.3		1.2		
39	9		1.8	1.2		1.2	1	
40			2.4	1.4		1.3		
41			2.4	1.3		1.8	1.3	
42			1.7	1.1		0.9		
43			1.5	0.7		1		
44			1.3	0.7		0.4		
45			0.75	0.5		0.5		
46			0.3	0.25		0.1		
47			1.4	1		1		
48			0.8	0.55		0.6		
49			0.2	0.17		0.2		
50	4.2		2.2	1.5	0.8	1.55	1.1	
51	3.1		2.4	1.8	0.9	1.6	0.9	
52	7.7	7.7	2.4	1		1.6	1.35	
53	4.3		2.4	1.65	0.9	1.8	1.2	
54	5.15	5.15	2.4	1.8	0.85	2.2	2.4	1.1
55	3.6		2.9	0.9	0.8	2	1.2	0.85
56			0.8	0.6		0.4		
57			0.45	0.5		0.4		
58	8		2.9	1.5	0.5	2.6	1.3	
59	3.7		3.2	2.6	1.7	3	1.2	
60	6.3		3.35	1.9		3	1.6	
61	4.3		3.8	2.7	2.1	2.7	1.35	
62	5.7		4.1	3.3		3.45	2.7	
63	6.1		3.4	1.7		3.3	2.3	
64			2.3	1.15		1.4		

65		2.3	1.5		1.7	
66		1.2	1.1		0.9	
67		0.5	0.3		0.6	
68	5.43	4.5	3.15	2	2.9	1.35
69	5.6	4.15	2.15	1.5	3.45	2.2
70	4	4.9	4.4	2.05	3.8	2.2
71	4.7	6.2	4	2.2	4.55	2.7
72	6.3	6.1	4.4	2.2	5.2	2.9
73	8.7	6.9	3		5.4	2.95
74	3.3	6.5	4.4	2	3.3	1.4
75	4.7	5.85	3.9	2.05	3.4	1.5
76	4	6.15	3.5	2.2	4.05	2
77	4	5.4	4.25	2	3.3	1
78		4.85	2.3		1.9	
79		1.8	1.35	0.55	3.15	
80		3.15	1.9		1.8	
81		2.3				
82		1.3	0.4		1.8	
83		1.4	1		0.35	
84	6	6.2	3.9	2.1	4.95	3.25
85	3	4.95	3.95	2.2	3	1.8
86	4.83	4.4	3.05	1.9	4.5	2.5
87		3.25	0.9	1.7	2.55	
88		2.1	0.6		1.2	
89		0.55	0.8		0.6	
90		2.85	0.6		2.45	
91	5.3	1.9	0.9		1.2	1

92	6	1.95	1.5		1	2.3
93	2.4	1.8	0.9		0.7	
94		1.3	1.1		1	
95		0.9	0.85		0.8	
96		2.4	0.5	0.2	0.8	
97	4.53	2	1	1	2.2	1.4
98		1	0.6		0.65	
99		0.85	0.6		0.55	
100		1.3	1.2		0.4	
101		1.5	0.8		0.6	
102		1.1	0.7		0.3	
103		1.2	0.7		1.2	
104		1.4	1		0.9	

Gully 02

										Wedths		
				Coordinates				Total		right		
No	Gully Section	X1(right)	Y1 (right)	X2 (left)	Y2 (left)	Elevation	length	wedth	w1	w2	w3	w4
1		302619	1207963	302615	1207987	2355	0	25	4	4		
2		302631	1207973	302623	1207991	2351	15	25.5	4.75	4.75		
3		302646	1207979	302623	1207991	2355	15	26.2	5.4	5.4	5.4	
4		302649	1207992	302626	1208006	2358	15	24.8	4.13	4.13	4.13	
5		302657	1208002	302634	1208018	2356	15	24.5	5.5	5.5	5.5	
6		302666	1208016	302647	1208025	2353	15	18.7	3.57	3.57	3.57	

7		302667	1208031	302648	1208040	2354	15	18.7	3.57	3.57	3.57	
8		302678	1208040	302662	1208050	2351	15	19	3.67	3.67	3.67	
9		302689	1208047	302667	1208061	2351	15	25.8	4.3	4.3	4.3	
10		302687	1208063	302669	1208065	2353	15	18.3	3.65	3.65		
11		302683	1208076	302663	1208077	2356	15	22.5	5.83	5.83	5.83	
12		302699	1208083	302660	1208094	2358	15	39.4	7.13	7.13	7.13	
13		302699	1208098	302668	1208106	2355	15	31.3	7.77	7.77	7.77	
14		302701	1208114	302668	1208112	2358	15	33.45	6.15	6.15	6.15	
15		302701	1208128	302662	1208126	2354	15	38.5	6.83	6.83	6.83	
16	1	302702	1208100	302699	1208107	2355	0	6.6	2.7	2.7		
17	1	302711	1208099	302708	1208107	2355	10.3	8.2	1.7	1.7		
18	1	302718	1208114	302711	1208117	2356	15	6.2	2	2		
19	1	302722	1208130	302714	1208132	2355	15	3	1	1		
20	2	302692	1208140	302690	1208146	2359	0	7	1.5	1.5		
21	2	302698	1208146	302692	1208150	2361	6.7	5.3	2	2		
22		302692	1208140	302664	1208126	2353	15	33.8	6.47	6.47	6.47	
23		302689	1208154	302654	1208130	2357	15	40.5	6.75	6.75	6.75	
24		302685	1208162	302642	1208142	2357	15	47.6	5.95	5.95	5.95	5.95
25		302685	1208162	302637	1208157	2358	15	50	6.25	6.25	6.25	6.25
26		302689	1208170	302635	1208169	2353	15	54.7	6.84	6.84	6.84	6.84
27		302688	1208169	302647	1208174	2355	15	41.5	5.2	5.2	5.2	5.2
28		302688	1208186	302655	1208184	2354	15	34.8	5.8	5.8	5.8	
29		302682	1208199	302652	1208191	2358	15	31.7	5.28	5.28	5.28	
30		302680	1208214	302650	1208229	2356	15	31.4	5.23	5.23	5.23	
31		302683	1208227	302648	1208244	2358	15	39	6.5	6.5	6.5	

32		302680	1208242	302647	1208249	2360	15	32.2	5.37	5.37	5.37	
33		302680	1208252	302646	1208263	2360	15	38	6.3	6.3	6.3	
34		302686	1208267	302659	1208270	2361	15	27	4.5	4.5	4.5	
35		302683	1208282	302650	1208281	2364	15	34	5.67	5.67	5.67	
36		302669	1208305	302643	1208297	2360	15	28	4.67	4.67	4.67	
37	3	302683	1208281	302673	1208304	2359	0	23.6	5.9	5.9		
38	3	302691	1208295	302683	1208311	2360	15	18	4.5	4.5		
39	3	302700	1208380	302689	1208318	2360	15	14.5	3.62	3.62		
40	3	302704	1208319	302689	1208325	2364	15	18	4.5	4.5		
41	4	302706	1208321	302701	1208331	2362	0	11	2.2	2.2		
42	4	302721	1208329	302715	1208336	2363	15	10.3	3.4	3.4		
43	4	302720	1208343	302717	1208345	2364	15	4	1	1		
44	4	302721	1208359	302717	1208360	2365	15	3.7	0.9	0.9		
45	3	302695	1208339	302687	1208339	2362	15	8	2	2		
46	3	302694	1208354	302688	1208355	2361	15	7.3	1.7	1.7		
47	3	302689	1208370	302685	1208370	2361	15	6.2	1.8	1.8		
48	3	302687	1208384	302679	1208384	2369	15	7.2	2.3	2.3		
49		302666	1208322	302663	1208305	2360	15	29.8	4.97	4.97	4.97	
50		302661	1208324	302629	1208316	2363	15	32.6	5.43	5.43	5.43	
51		302662	1208329	302625	1208332	2365	15	35.5	5.92	5.92	5.92	
52		302666	1208340	302626	1208347	2364	15	50	6.25	6.25	6.25	6.25
53	4	302642	1208356	302625	1208349	2365	0	17.3	4.3	4.3		
54	4	302638	1208370	302620	1208362	2365	15	19.6	6.5	6.5		
55	4	302625	1208374	302613	1208371	2369	15	12.7	3.5	3.5		
56	4	302618	1208388	302608	1208385	2367	15	11.6	2.5	2.5		

57	4	302607	1208399	302600	1208392	2369	15	9.5	2.5	2.5	
58	4	302595	1208404	302592	1208401	2367	13	4.5	1.3	1.3	
59		302666	1208354	302643	1208355	2366	13.2	21.4	5.35	5.35	
60		302664	1208368	302637	1208368	2364	15	25.7	4	4	
61		302668	1208373	302645	1208384	2364	15	25.7	5	5	
62		302674	1208387	302654	1208399	2363	15	23.7	5.5	5.5	
63		302674	1208401	302651	1208407	2361	15	25	4.5	4.5	
64		302683	1208432	302655	1208436	2365	15	26	6	6	
65		302683	1208446	302659	1208448	2368	15	22.1	5.5	5.5	
66		302681	1208461	302654	1208457	2369	15	25.5	6	6	
67	5	302653	1208467	302654	1208457	2370	10	10.3	2.5	2.5	
68	5	302648	120873	302642	1208465	2369	15	9.5	2.3	2.3	
69	5	302641	1208485	302629	1208473	2370	15	16.3	4	4	
70	6	302632	1208480	302629	1208473	2368	0	6.4	1.5	1.5	
71	6	302622	1208488	302617	1208481	2371	15	9.7	2	2	
72	5	302640	1208484	302631	1208479	2373	0	10.1	3	3	
73	5	302634	1208493	302628	1208490	2370	15	7.2	2	2	
74		302678	1208461	302656	1208467	2366	0	25.7	5.17	5.17	5.17
75		302673	1208473	302660	1208480	2370	15	14.4	2.5	2.5	
76		302680	1208486	302665	1208492	2370	15	15	3	3	
77		302686	1208500	302673	1208504	2370	15	13	3	3	
78		302688	1208516	302678	1208520	2370	15	10.7	3	3	
79		302694	1208529	302684	1208534	2374		10.4	2.7	2.7	

Depths

		Right			Left		
No	Middle	D1	D2	D3	D1	D2	D3
1	2.6	1.3			1	0.9	
2	2.9	1.6			1.4	0.65	
3	2.65	1.65			1.75	1.6	
4	1.5	1.2	0.85		2.3	1.45	
5	2.7	1.4	1.3		1.7		
6	2.6	1.6	1		1.2		
7	2.9	1.7	1		1.45		
8	2.65	1.9	0.95		1.25		
9	1.8	2.3	1.5		1.8	0.9	
10	2.5	1.2			1.7		
11	2.5	1.7	1.6		1.9		
12	2.3	1.9	1.4		1.8	1.7	
13	2.3	1.7	1.3		1.6		
14	2	1.3	1.3		2.2	1.3	
15	1.65	1.7	1.7		1.6	1.3	
16	1.6	0.6			1.3		
17	1.2	0.4			0.6		
18	0.9	0.4			0.4		
19	0.8	0.4			0.4		
20	1	0.45			0.55		
21	0.7	0.8			0.45		
22	2	2.15	1.2		1.8	1.2	
23	1.8	1.8	0.9		2	1.9	
24	2	2.45	2.1	1.2	2	2.2	1.2
25	1.8	1.8	1.8	1.6	1.9	1.9	1.4

26	2.3	2.3	2.7	1.3	2.5	1.35	0.6
27	2.3	2.3	2.7	1.4	2.4	1.7	0.9
28	3.3	3.1	1.1		2.3	0.85	
29	3.5	2.8	1.7		2.9	1.2	
30	3.65	3	1.1		3.3	1.5	
31	3.65	2.6	1.2		3.1	1.6	
32	4	2.6	0.7		3.3	1.4	
33	3.85	2.5	1.6		2.7	1.6	
34	3.85	3	1.3		2.3	1.3	
35	3.7	3.5	1.2		2.9	1.5	
36	4.2	3.3	1.3		2.9	1.5	
37	3.2	1.8			1.6		
38	2.8	1.7			1.3		
39	3	1.6			1.4		
40	3.1	1.4			1.1		
41	1.8	0.6			0.8		
42	0.9	0.6			0.55		
43	1	0.6			0.45		
44	0.65	0.3			0.35		
45	1.1	0.35			0.35		
46	1.2	0.7			0.45		
47	0.75	0.5			0.4		
48	0.45	0.4			0.4		
49	4.6	3.95	1.65		3.35	1.5	
50	4.9	3.75	1.8		3.8	2.1	
51	5.15	3.7	1.6		4.5	2.1	
52	5.6	5.3	4.3	1.1	5.4	3.9	1.8

53	3.45	3.15			1.9	
54	1.4	0.65			0.85	
55	1.35	0.8			0.65	
56	1	0.65			0.55	
57	0.6	0.35			0.4	
58	0.3	0.25			0.25	
59	5.4	2.2			2.8	
60	3.55	1.5			1.8	
61	3.1	1.9			1.65	
62	3.2	1.7			1.8	
63	3	1.6			2.7	1.4
64	3.15	2			1.9	
65	3.45	1.9			2.1	
66	3.5	2.2			2.6	1.4
67	2.1	1.15			1.4	
68	1.4	0.75			0.8	
69	0.6	1.1			1.1	
70	1.1	0.45			0.45	
71	0.6	0.45			0.5	
72	0.55	1			0.4	
73	0.6	0.4			0.45	
74	2.7	2.3	1.8		1.6	
75	2.2	1.3			1.4	
76	1.35	1.2			0.85	
77	1.35	0.85			0.7	
78	1.3	0.8			0.5	
79	0.5				0.45	

Gully 03

No	Gully Section	Coordinates						Total	Widths right			
		X1(right)	Y1 (right)	X2 (left)	Y2 (left)	Elevation	length	wedth	w1	w2	w3	w4
1		302612	1207985	302605	1207994	2353	0	10.2	3	3		
2		302621	1207998	302610	1207998	2351	15	12.8	3.4	3.4		
3		302627	1208012	302611	1208015	2352	15	15.8	4	4		
4		302636	1208025	302610	1208030	2350	15	22.1	6.5	6.5		
5		302632	1208032	302610	1208044	2354	15	21.7	5	5		
6		302637	1208035	302625	1208050	2354	15	18.6	4.5	4.5		
7		302648	1208045	302637	1208060	2357	15	17	4	4		
8		302656	1208060	302635	1208062	2353	15	19.4	4.5	4.5		
9		302654	1208073	302632	1208077	2356	15	22.1	5.5	5.5		
10		302654	1208090	302638	1208087	2353	15	13.9	4	4		
11		302644	1208101	302631	1208096	2355	15	15.3	4	4		
12		302639	1208115	302621	1208107	2354	15	20.8	5.4	5.4		
13		302633	1208128	302615	1208121	2353	15	19.6	4.65	4.65		
14		302625	1208140	302614	1208136	2358	15	13.5	3.5	3.5		
15		302625	1208157	302609	1208150	2356	15	17	4.25	4.25		
16		302617	1208169	302603	1208164	2357	15	15	4	4		
17	1	302605	1208171	302603	1208164	2356	0	7	1.5	1.5		
18	1	302596	1208177	302594	1208176	2357	15	3.6	0.9	0.9		
19		302614	1208173	302594	1208176	2356	0	10.4	2.6	2.6		
20		302607	1208187	302601	1208183	2354	15	9	2.5	2.5		
21		302601	1208202	302593	1208200	2355	15	7.5	1.75	1.75		

22		302591	1208212	302587	1208210	2351	15	5.4	1.2	1.2

Gully 3

Gully 04

		Coordinates							Widths			
No	Gully Section	X1(right)	Y1 (right)	X2 (left)	Y2 (left)	Elevation	length	Total wedth	w1	w2	w3	right w4
1		302649	1208228	302641	1208199	2356	0	26.7	5.5	5.5		
2		302643	1208230	302628	1208207	2358	15	26.5	7	7		
3		302642	1208235	302614	1208214	2356	15	34.3	5	5	5	
4		302631	1208250	302606	1208226	2359	15	35.4	6	6	6	
5		302620	1208254	302590	1208234	2359	15	34.5	7	7	7	
6		302614	1208261	302580	1208241	2365	15	38	5.3	5.3	5.3	
7		302612	1208268	302578	1208257	2361	15	34.9	5	5	5	
8		302604	1208286	302577	1208263	2360	15	35	5.67	5.67	5.67	
9		302602	1208300	302563	1208264	2367	15	54.3	6.38	6.38	6.38	6.3
10		302586	1208307	302552	1208274	2360	15	46	7.3	7.3	7.3	
11		302576	1208321	302546	1208284	2367	15	47	7	7	7	
12		302646	1208316	302529	1208294	2365	15	28	5	5	5	
13		302517	1208318	302515	1208287	2363	15	32.6	6.3	6.3	6.3	
14		302511	1208321	302500	1208294	2364	15	28.4	5	5	5	
15		302506	1208334	302481	1208315	2367	15	35	6.3	6.3	6.3	
16		302490	1208342	302466	1208313	2370	15	36.6	7.3	7.3	7.3	
17		302476	1208346	302457	1208323	2369	15	28.5	5.67	5.67	5.67	

18		302460	1208348	302446	1208327	2370	15	25.3	6.33	6.33	
19		302448	1208353	302433	1208337	2371	15	24	6	6	
20		302437	1208362	302423	1208349	2371	15	20	5	5	
21		302427	1208370	302418	1208363	2374	15	11	2	2	
22		302416	1208382	302408	1208373	2374	15	12.5	3	3	
23		302405	1208390	302400	1208382	2372	15	9.5	2.5	2.5	
24		302396	1208399	302386	1208389	2374	15	14.5	4	4	
25		302380	1208401	302372	1208394	2374	15	9.4	2.3	2.3	
26		302363	1208410	302360	1208406	2374	15	5.5	1.2	1.2	
27	1	302545	1208316	302532	1208313	2361	0	13	3	3	
28	1	302538	1208332	302519	1208320	2365	15	24	5	5	
29	1	302533	1208349	302514	1208337	2364	15	20.8	5	5	
30	1	302518	1208356	302507	1208340	2366	15	20	5	5	
31	1	302502	1208361	302491	1208344	2370	15	18	6	6	
32	1	302486	1208364	302479	1208350	2367	15	12	2.5	2.5	
33	2	302575	1208325	302547	1208318	2364	0	30.5	7	7	7
34	2	302573	1208339	302539	1208332	2364	15	33.6	6.3	6.3	6.3
35	2	302566	1208355	302532	1208348	2366	15	33.8	5	5	5
36	2	302562	1208369	302525	1208361	2365	15	30	5	5	5
37	2	302555	1208397	302521	1208396	2370	15	33	5	5	5
38	2	302547	1208411	302518	1208411	2370	15	30	4	4	4
39	2	302540	1208429	302516	1208426	2374	15	27.8	5	5	5
40	2	302535	1208444	302516	1208448	2376	15	19.5	4	4	
41	2	302532	1208466	302522	1208465	2375	15	10	2.5	2.5	

	Widths		Depths					
No	Left		Right			Left		
	w4	Middle	D1	D2	D3	D1	D2	D3
1		3.7	2.1			3.2	2.55	1.2
2		3.6	2.15			3.7	2.35	
3		3.5	3.2	2.6	1.35	3.4	3.05	1.7
4		3.7	3.3	2.2		3.1	2.8	
5		4.7	3.75	1.7		3.9	2.65	
6		4.7	3.15	2.2		4.1	2.7	
7		4.6	3.3	1.9		3.65	1.4	
8		4.7	3.6	2.1		3.7	1.7	
9	7.2	4.1	3.6	2.7	1.4	4.4	4.95	2.9
10		5.4	4.55	1.8		5.15	3.1	
11	6.5	5.7	4.9	2.4		5.3	3.2	1.4
12		4	3.4	1.8		5.15	3.1	
13		5.05	4.2	1.45		3.7	2	
14		5.3	4.1	1.9		3.5	1.5	
15		5.4	4.8	1.2		4.4	2	
16		5	3.7	2		4.4	2.45	
17		5	4.45	2		5.2	3.35	
18		4.9	3.3			3.5		
19		4.9	2.6			3.5		
20		4.85	3.25			3.2		
21		4.6	3.6			2.1		
22		4.1	3.1			1.5		
23		3.9	2.4			2		
24		3.2	2.6			2.35		

25	2.7	1.6		1	
26	3.1	2.7		0.6	
27	3.1	1.7		1.4	
28	4.3	3.25		3.2	
29	4	3.2		2.5	
30	3.4	1.6		2	
31	3.35	1.7		1.4	
32	2	1.3		1.6	
33	4.75	3.5	2	2.8	
34	5.5	4.5	2	4.2	2.3
35	5.85	4.8	2.25	4.5	2.2
36	5.8	4.5	1.6	3.9	1.6
37	5.15	3.25	1.5	2.85	1
38	3.4	2.3	1	2.35	1.8
39	2.1	1.3	0.8	1.2	0.6
40	1.2	1.4		0.7	
41	1.5	0.75		0.8	

		Gully 05										
										Widths		
	Gully Section	Coordinates						Total		right		
No		X1(right)	Y1 (right)	X2 (left)	Y2 (left)	Elevation	length	width	w1	w2	w3	w4
1		302922	1207813	302902	1207803	2347	0	22.1	5.75	5.75		
2		302917	1207825	302899	1207821	2345	15	18.6	5.3	5.3		
3		302923	1207837	302894	1207833	2346	15	31.15	5.38	5.38	5.38	
4		302925	1207842	302903	1207850	2349	15	22.8	3.8	3.8	3.8	
5		302938	1207849	302912	1207859	2353	15	29.2	4.87	4.87	4.87	

6		302942	1207863	302916	1207872	2353	15	28.4	4.73	4.73	4.73
7		302952	1207875	302924	1207886	2353	15	30.85	5.14	5.14	5.14
8		302958	1207886	302926	1207896	2353	15	34.25	5.7	5.7	5.7
9		302960	1207903	302934	1207912	2353	15	27.65	4.55	4.55	4.55
10		302969	1207915	302944	1207922	2355	15	27.2	4.53	4.53	4.53
11		302975	1207927	302946	1207934	2355	15	30.35	5.45	5.45	5.45
12		302973	1207944	302955	1207944	2354	15	18.75	2.9	2.9	2.9
13		302974	1207959	302951	1207953	2356	15	25.5	3.5	3.5	3.5
14		302970	1207973	302947	1207966	2356	15	26.3	4.77	4.77	4.77
15		302966	1207985	302942	1207982	2356	15	25	5.3	5.3	5.3
16		302973	1207999	302947	1207996	2355	15	26.5	3.8	3.8	3.8
17		302982	1208008	302948	1208013	2358	15	35.8	5.93	5.93	5.93
18		302984	1208023	302951	1208023	2358	15	34.9	6.63	6.63	6.63
19		302991	1208031	302960	1208045	2360	15	33.4	5.1	5.1	5.1
20		303001	1208039	302973	1208050	2359	15	33.2	5.67	5.67	5.67
21		303002	1208054	302979	1208056	2359	15	23.4	3.8	3.8	3.8
22		303014	1208068	302975	1208070	2360	15	34.4	6.47	6.47	6.47
23		303004	1208082	302983	1208081	2358	15	22	4.33	4.33	4.33
24	1	303005	1208084	308102	1208102	2362	0	18.2	4.55	4.55	
25	1	303022	1208092	303015	1208092	2362	15	16.7	4.5	4.5	
26	1	303028	1208106	303021	1208114	2361	15	10	2.5	2.5	
27	1	303032	1208118	303024	1208119	2358	12.5	8.2	2	2	
28	1	303029	1208132	303024	1208133	2361	15	5	1.25	1.25	
29		303002	1208104	302976	1208092	2359	15	29	5.67	5.67	5.67
30		302990	1208117	302973	1208108	2358	15	25.75	4.58	4.58	4.58
31		303003	1208130	302969	1208123	2360	15	34.75	5.58	5.58	5.58
32		303002	1208146	302977	1208137	2360	15	27	4	4	4

33		302998	1208159	302967	1208142	2360	15	34.75	6.58	6.58	6.58
34		302993	1208173	302959	1208156	2359	15	38.7	5.9	5.9	5.9
35		302986	1208187	302960	1208167	2364	15	32	5.67	5.67	5.67
36		302977	1208201	302953	1208183	2365	15	29.5	5.83	5.83	5.83
37		302969	1208218	302950	1208193	2361	15	28.4	4.47	4.47	4.47
38	2	302969	1208218	302945	1208215	2361	0	24.8	5.27	5.27	5.27
39	2	302970	1208222	302952	1208232	2361	15	22.7	2.9	2.9	2.9
40	2	302982	1208234	302958	1208241	2361	15	24.9	3.1	3.1	3.1
41	2	302988	1208248	302969	1208250	2361	15	18.6	3	3	3
42	2	302989	1208262	302973	1208265	2365	15	18.3	3.1	3.1	3.1
43	2	302999	1208275	302978	1208277	2365	15	21.85	3.28	3.28	3.28
44	2	303002	1208289	302986	1208290	2369	15	17.3	3	3	3
45	2	303000	1208296	302986	1208299	2369	8	16	4	4	
46	2	302991	1208312	302982	1208306	2363	15	13.6	2.8	2.8	
47	2	302989	1208326	302980	1208319	2364	15	11.5	4.25	4.25	
48	2	302981	1208340	302973	1208340	2361	15	9	2.5	2.5	
49	2	302974	1208357	302967	1208351	2363	17	10	3.45	3.45	
50		302946	1208214	302953	1208198	2359	17	19	3.67	3.67	3.67
51		302935	1208210	302939	1208193	2358	15	18	2.9	2.9	2.9
52		302931	1208215	302922	1208197	2358	15	20.4	3.8	3.8	3.8
53		302922	1208219	302911	1208206	2357	15	21	3.13	3.13	3.13
54		302914	1208231	302903	1208213	2358	15	24	4	4	4
55		302897	1208232	302889	1208209	2361	15	27	5	5	5
56		302897	1208232	302877	1208218	2361	15	26.4	4.8	4.8	4.8
57		302897	1208232	302880	1208232	2359	15	18	4.5	4.5	
58		302906	1208237	302880	1208248	2357	15	20	5	5	
59		302913	1208255	302895	1208253	2364	15	20.6	6.3	6.3	

60		302906	1208268	302886	1208267	2359	15	21.8	5.9	5.9	
61		302908	1208285	302888	1208284	2361	15	23.6	3.87	3.87	3.87
62		302911	1208297	302892	1208297	2364	15	22.7	3.9	3.9	3.9
63		302914	1208313	302893	1208311	2365	15	23.4	3.8	3.8	3.8
64		302919	1208320	302892	1208326	2365	15	25.7	4.57	4.57	4.57
65		302924	1208334	302901	1208341	2366	15	27	5	5	5
66		302929	1208348	302904	1208347	2366	15	26.7	4.9	4.9	4.9
67		302928	1208361	302899	1208359	2368	15	28.6	5.53	5.53	5.53
68		302926	1208377	302901	1208367	2371	15	24.5	4.17	4.17	4.17
69	3	302909	1208395	302901	1208367	2371	0	28.8	4.6	4.6	4.6
70	3	302908	1208394	302893	1208379	2372	15	23.6	3.87	3.87	3.87
71	3	302904	1208407	302884	1208393	2376	15	24	4	4	4
72	3	302895	1208421	302879	1208403	2375	15	23.4	3.6	3.6	3.6
73	3	302889	1208433	302872	1208415	2376	15	24	3.8	3.8	3.8
74	3	302874	1208437	302861	1208424	2373	15	18.5	4.75	4.75	
75	3	302862	1208446	302854	1208436	2374	15	11.5	2.45	2.45	
76	3	302851	1208457	302845	1208449	2373	15	12.5	2.45	2.45	
77	3	302845	1208469	302840	1208463	2372	15	7.6	2.1	2.1	
78		302929	1208393	30302910	1208394	2365	0	20.8	5.4	5.4	
79		302933	1208407	302915	1208410	2369	15	19.5	4.75	4.75	
80		302943	1208418	302920	1208422	2372	15	23.5	3.83	3.83	3.83
81		302951	1208431	302926	1208435	2368	15	24.6	4.2	4.2	4.2
82		302930	1208450	302925	1208440	2372	15	19.4	4.7	4.7	
83		302936	1208462	302919	1208452	2370	15	20.9	6.45	6.45	
84		302939	1208467	302920	1208469	2372	15	19	4.5	4.5	
85		302940	1208482	302925	1208475	2374	15	18.5	5.25	5.25	
86		302947	1208494	302927	1208496	2370	15	19.6	3.8	3.8	

87	302942	1208509	302928	1208506	2367	15	16.7	4.35	4.35
88	302936	1208522	302926	1208510	2368	15	17.4	4.2	4.2
89	302934	1208525	302916	1208521	2369	15	19.6	4.8	4.8
90	302940	1208538	302930	1208535	2370	15	11.2	3.6	3.6
91	302931	1208551	302925	1208540	2371	15	13.4	4.2	4.2
92	302923	1208563	302913	1208554	2370	15	12.6	2.8	2.8
93	302909	1208571	302909	1208561	2368	15	10.1	2.25	2.25
94	302896	1208576	302891	1208570	2368	15	8.1	2.55	2.55
95	302890	1208594	302882	1208585	2369	15	12.5	2.25	2.25
96	302885	1208607	302874	1208600	2370	15	13.4	2.7	2.7
97	302885	1208616	302876	1208616	2369	15	9.6	2.3	2.3
98	302887	1208631	302876	1208629	2374	15	10.8	2	2

		Depths						
		Right			Left			
No	Middle	D1	D2	D3	D1	D2	D3	Remark
1	0.65	1			0.65			
2	1.5	1			0.8			
3	1	1.1	0.9		1	0.9		
4	1.3	1.2	0.8		1.2	0.7		
5	1.3	1.2	0.8		1.2	0.8		
6	1.5	1.25	0.8		1.45	0.8		
7	1.4	1.5	0.9		1.3	0.75		
8	1.9	1.7	0.9		1.5	1.55		
9	1.5	1.4	0.7		1.1	0.7		
10	1.4	1.5	1		1.1	0.9		
11	1.6	1.1	0.4		0.9	0.7		

12	2	1.5	0.9		1.1	0.7
13	1.6	1.4	0.8		1.2	0.6
14	1.8	1.2	0.6		1.1	0.7
15	1.7	1.5	1		1.5	0.7
16	1.8	1.85	0.9		1.3	0.7
17	1.4	1.6	0.6		1.1	0.4
18	1.7	1.7	0.75		1.8	0.7
19	1.8	1.7	0.9		1.3	0.7
20	1.6	1.2	0.9		1.6	0.7
21	1.85	1.7	1		1.6	0.6
22	1.75	1.75	1.2		1.3	1
23	1.85	1.6	0.9		1.7	1
24	2	1.3			1.1	
25	1.55	1.1			1.1	
26	1.2	0.8			0.8	
27	1.1	0.6			0.6	
28	0.9	0.45			0.4	
29	2.3	1.7	1.2		1.85	1
30	1.8	1.75	1.1		1.4	0.75
31	2.3	1.8	0.9		1.8	1.3
32	2.1	1.3	1		1.2	1
33	1.75	2.1	1.6		1.7	1.1
34	2.15	2.5	1.4		2	1.2
35	2.2	1.7	1.15		2.1	1.25
36	2.7	1.8	1		2.3	1.15
37	1.95	2.1	1.15		1.7	1
38	2.4	1.7	0.6		1.6	0.8

39	2.7	1.6	1	1.3	0.6
40	2.5	1.7	0.9	1.4	1.3
41	1.6	0.9		1.8	1
42	2.6	2	1.1	1.8	1.15
43	2	1.6	0.6	1.4	0.9
44	2.2	1.5	0.9	1.7	1.2
45	2.1	1.2		1.1	
46	1.6	1		1	
47	1.3	0.9		1	
48	1.1	0.6		0.8	
49	0.7	0.3		0.2	
50	1.8	1.6	0.7	1.15	0.5
51	2	1.3	0.6	1.2	0.5
52	1.9	1.6	0.8	1.3	0.6
53	2.1	1.6	1	1.5	0.8
54	1.8	1.6	1	1.5	0.7
55	1.9	1.7	1.1	1.9	1
56	1.6	1.5	0.9	1.9	1
57	1.6	0.8		1.1	
58	1.65	1.2		1.2	
59	2.1	1.2		1	
60	2.25	1.3		1.3	
61	2.2	1.7	0.9	1.65	1
62	2	1.5	1.1	1.6	0.9
63	2.3	1.5	1	2	1.2
64	2.4	1.6	0.8	2	1.1
65	2.6	2.2	1.3	2.2	1

66	2.3	1.6	1.1		2.1	1.3
67	2.8	1.9	1.1		1.7	0.9
68	2.4	1.9	0.9		1.9	0.9
69	2.5	2.1	0.9		2	1.4
70	2.8	2	1		1.9	1
71	2.2	1.7	0.9		1.5	1
72	2.5	1.9	1.1		1.9	1
73	2.8	1.8	0.9		1.6	1.1
74	2.1	1.3			1.5	
75	1.7	0.6			1	
76	1.2	0.5			0.7	
77	0.9	0.6			0.6	
78	2.6	1.3			1.3	
79	2.4	1.5			1.5	
80	2.3	1.8	1.1		1.4	0.9
81	2.3	1.6	1		1.8	0.9
82	2.5	1.3			1.2	
83	2.4	1.2			1.5	
84	2.4	1.4			1.2	
85	2.5	1.6			1.3	
86	2.6	1.6			1.2	
87	2.1	1.4			1.2	
88	2.1	1.5			1	
89	2	1.4			0.9	
90	1.6	0.9			0.7	
91	1.1	0.7			0.6	
92	1.2	0.7			0.6	

93	1.2	0.8	0.7
94	0.9	0.6	0.7
95	1.1	0.6	0.5
96	0.9	0.5	0.5
97	0.7	0.3	0.6
98	0.3	0.3	0.3

Gully 6

No	Gully Section	X1(right)	Y1 (right)	X2 (left)	Y2 (left)	Elevation	length	Total width	right w1	w2	w3
1		303089	1208141	303078	1208145	2359	0	11	2.2	2.2	
2		303095	1208149	303079	1208156	2359	15	17.5	4.5	4.5	
3		303103	1208155	303087	1208173	2359	15	24.4	3.1	3.1	3.1
4		303113	1208168	303092	1208180	2360	15	24.6	3.2	3.2	3.2
5		303120	1208179	303091	1208181	2363	15	27.9	4.3	4.3	4.3
6		303099	1208191	303091	1208181	2357	15	13.6	2.3	2.3	
7		303098	1208198	303083	1208190	2360	15	19.2	5.1	5.1	
8		303105	1208202	303082	1208208	2360	15	23.2	3.73	3.73	3.73
9		303107	1208213	303095	1208216	2361	15	15.1	3.55	3.55	
10		303113	1208226	303103	1208228	2362	15	11.8	2.6	2.6	
11		303136	1208237	303107	1208248	2364	15	32.8	7.6	7.6	7.6
12		303137	1208252	303107	1208248	2361	15	32.9	7.97	7.97	7.97
13		303119	1208270	303105	1208269	2361	15	14.5	4.25	4.25	
14	1	303117	1208275	303115	1208306	2361	0	31.4	4.47	4.47	4.47
15	1	303135	1208271	303129	1208306	2363	15	35.9	4.97	4.97	4.97
16	1	303150	1208286	303143	1208299	2364	15	16.9	3.65	3.65	
17	1	303164	1208291	303164	1208308	2362	15	16	4.9	4.9	
18	1	303179	1208292	303171	1208314	2361	15	23.3	6.65	6.65	
19	1	303191	1208316	303182	1208326	2364	15	13.4	3	3	
20	1	303201	1208323	303190	1208337	2363	15	17	2.5	2.5	
21	1	303215	1208333	303209	1208342	2366	15	12.3	2.85	2.85	
22	1	303224	1208344	303223	1208351	2364	15	7.4	1.7	1.7	
23		303106	1208295	303100	1208271	2364	15	22.3	5.15	5.15	
24		303093	1208289	303086	1208273	2364	15	19.9	4.25	4.25	
25		303091	1208296	303072	1208282	2357	15	24.4	5.1	5.1	5.1
26		303089	1208318	303065	1208314	2357	19	26.4	4.8	4.8	4.8
27		303075	1208337	303054	1208324	2364	15	26.3	4.77	4.77	4.77
28		303079	1208341	303063	1208349	2359	15	18.7	3.35	3.35	
29		303081	1208340	303064	1208379	2362	15	42.2	8.1	8.1	8.1
30		303113	1208327	303082	1208337	2362	17	32.3	5.77	5.77	5.77
31		303119	1208341	303080	1208383	2365	15	59	7	7	7
32		303119	1208405	303078	1208354	2362	15	65	7	7	7
33		303129	1208376	303079	1208410	2367	15	60	7	7	7
34		303136	1208378	303082	1208417	2364	15	65	6	6	6
35		303148	1208406	303094	1208431	2365	15	55	4.5	4.5	4.5
36		303138	1208419	303103	1208438	2360	15	39	7	7	7
37		303132	1208441	303100	1208435	2360	15	31.6	7	7	7
38		303125	1208452	303105	1208443	2364	15	26	6	6	6
39		303100	1208478	303090	1208464	2363	20	19	4	4	

40		303079	1208482	303057	1208472	2356	15	26.4	4	4	4
41		303068	1208500	303051	1208479	2373	15	26	5	5	
42		303056	1208499	303040	1208486	2372	15	24.9	7	7	
43		303052	1208513	303024	1208508	2364	15	29.4	6	6	6
44		303056	1208520	303029	1208534	2369	15	31.2	6	6	6
45		303070	1208534	303043	1208547	2373	15	32.5	5	5	5
46		303082	1208546	303048	1208554	2369	15	32.8	5	5	5
47		303080	1208587	303047	1208555	2372	15	44.6	6.8	6.8	6.8
48		303071	1208589	303047	1208555	2372	15	39.3	7.1	7.1	7.1
49		303047	1208588	303047	1208555	2372	15	32.7	5.9	5.9	5.9
50		303029	1208585	303025	1208556	2369	15	27.3	4.1	4.1	4.1
51		303029	1208585	303014	1208569	2367	15	22.1	6.5	6.5	
52		303025	1208596	303010	1208580	2368	15	22.7	4.37	4.37	4.37
53		303027	1208607	303005	1208602	2367	15	25.6	5.53	5.53	5.53
54		303022	1208637	302994	1208612	2368	15	37.6	9.53	9.53	9.53
55		303014	1208642	302979	1208619	2370	15	44	9.67	9.67	9.67
56		303009	1208658	302986	1208649	2374	15	26.2	3.4	3.4	3.4
57		302997	1208683	302986	1208649	2376	15	38.21	9.7	9.7	9.7
58	2	303130	1208461	303099	1208483	2368	15	0	6.53	6.53	6.53
59	2	303133	1208475	303105	1208498	2370	15	33.4	5.8	5.8	5.8
60	2	303143	1208506	303112	1208507	2372	15	32.6	5.87	5.87	5.87
61	2	303142	1208520	303104	1208518	2370	15	40	6.3	6.3	6.6
62	2	303145	1208534	303098	1208532	2368	15	46.7	8	8	8
63	2	303137	1208553	303091	1208543	2370	15	55.7	5	5	5
64	2	303150	1208567	303089	1208558	2370	15	52.7	6.68	6.68	6.68
65	2	303142	1208584	303091	1208567	2372	15	51.6	8.57	8.57	8.57
66	2	303128	1208593	303086	1208584	2369	15	45.4	9	9	9
67	2	303130	1208607	303079	1208605	2370	15	51.4	7.23	7.23	7.23
68	2	303137	1208622	303090	1208644	2370	15	51.2	6.23	6.23	6.23
69	2	303140	1208636	303097	1208658	2374	15	43.4	6	6	6
70	3	302997	1208683	302976	1208689	2371	15	22.3	5.15	5.15	
71	3	302998	1208698	302978	1208702	2374	15	19.5	4.75	4.75	
72	3	302997	1208712	302985	1208716	2374	15	14.5	3.25	3.25	
73	3	303003	1208727	302990	1208732	2374	15	13.9	3.25	3.25	
74	3	303006	1208741	302998	1208743	2370	15	11.3	2.35	2.35	
75		302973	1208680	302974	1208656	2369	15	23.9	3.93	3.93	3.93
76		302966	1208663	302974	1208656	2374	15	12	3	3	
77		302967	1208654	302974	1208647	2370	15	12	3	3	
78		302961	1208660	302951	1208650	2371	15	14.2	2.1	2.1	
79		302960	1208677	302947	1208661	2371	15	23.5	3.83	3.83	3.83
80		302937	1208678	302941	1208667	2372	15	11.2	2.9	2.9	
81		302928	1208660	302936	1208653	2375	15	11.6	3.3	3.3	
82		302921	1208655	302927	1208637	2376	15	19.4	5.7	5.7	

83	302921	1208655	302910	1208640	2376	15	19.8	5.4	5.4	
84	302917	1208663	302895	1208645	2381	15	25.7	2.57	2.57	2.57
85	302916	12508678	302882	1208664	2380	15	35	9	9	9
86	302919	1208676	302903	1208679	2374	15	17.4	2.7	2.7	2.7
87	302920	1208694	302910	1208692	2374	15	8.6	1.8	1.8	
88	302908	1208716	302896	1208696	2379	15	24.4	3.1	3.1	3.1
89	302882	1208713	302887	1208706	2376	15	7	1.7	1.7	
90	302869	1208707	302871	1208699	2375	15	10.5	2.25	2.25	
91	302851	1208703	302848	1208698	2376	15	6	1	1	

Gully 6

				left			Right			Left
No	w1	w2	w3	w4	Middle	D1	D2	D3	D1	D2
1	3.3	3.3			2.3	1			1.3	
2	4.7	4.7			2.7	1.1			1.4	
3	5	5	5		2.3	1.6	0.8		1.6	0.5
4	5	5	5		2.7	1.9	0.6		1.7	0.8
5	5	5	5		2.6	2.5	1		1.4	0.9
6	4.5	4.5			2.4	1.3			1.4	
7	4.4	4.5			2.6	1.8			1.9	
8	4	4	4		2.4	1.6	1.1		2	1
9	4	4			3.3	1.9			1.7	
10	2.8	2.8			2.6	1			1.5	
11	5	5			2.7	1.8	1.2		1.6	
12	4.5	4.5			2.7	2	1.1		1.5	
13	3	3			2.3	1.3			2.1	
14	6	6	6		2.4	1.7	1.1		1.5	0.9
15	7	7	7		2.3	1.3	0.9		1.9	0.7
16	4.8	4.8			1.6	0.7			0.9	
17	3.9	3.9			2	0.9			1	
18	5	5			1.7	1.2			1.3	
19	3.7	3.7			1.7	0.8			0.7	
20	6	6			1.4	0.9			0.5	
21	3.3	3.3			1.1	0.6			0.6	
22	2	2			0.5	0.3			0.4	
23	6	6			2.5	1.8			1.4	
24	5.7	5.7			1.9	1.6			0.9	
25	3	3	3		2.7	1.9	1.6		2.3	1.9
26	4	4	4		2.6	1.8	1.4		1.7	0.9
27	4	4	4		2.8	2	1.5		2.1	1
28	6	6			2.3	1.9			1.7	

29	6	6	6		2.5	1.6	1.6		1.6	1.3
30	5	5	5		2	2.3	1.8		1.6	1.8
31	7.75	7.75	7.75	7.75	1.7	1.9	2.4	1.3	1.6	1.3
32	9.25	9.25	9.25	9.25	2.7	2.4	2.1	1.7	1.5	1.4
33	8	8	8	8	2.1	2.7	3.2	2.1	2	1.6
34	9.25	9.25	9.25	9.25	2.3	3	2.8	2.4	2	1.8
35	6.25	6.25	6.25	6.25	2.8	2.2	2.2	1.7	2.2	1.6
36	6	6	6		2.3	2	1.1		2.5	1.6
37	3.5	3.5	3.5		2.2	2	1.3		2.8	1.7
38	2.67	2.67	2.67		3.2	1.6	0.9		2.2	1.6
39	5.5	5.5			2.4	1.7			1.7	
40	4.6	4.6	4.6		2.2	2.1	1.2		1.5	0.5
41	8	8			2.7	2.1			1.6	
42	5.45	5.45			2.4	2.2			2	
43	3.8	3.8	3.8		2.2	1.8	2.2		1.9	0.9
44	4.4	4.4	4.4		2.4	2.2	2.3		1.5	1.1
45	5.5	5.5	5.5		2.3	2.6	1.6		1.3	7
46	5.9	5.9	5.9		3.2	2.6	1.6		2.3	0.8
47	8	8	8		2.4	2.8	1.7		2	1.5
48	6	6	6		2.5	2.6	1.5		1.8	1.2
49	5	5	5		1.8	1.8	1.1		2	0.9
50	5	5	5		1.7	1.7	1.2		1.9	0.8
51	5	5			1.6	1.6			1.7	
52	3.2	3.2	3.2		2	1.6	0.7		2	1.3
53	3	3	3		2	1.8	1.2		2.2	1.4
54	3	3	3		2.1	1.9	1.4		2	1.2
55	5	5	5		3.2	1.9	1.8		2.3	1.4
56	4	4	4		3.5	2.4	1		2.6	1.1
57	7	7	7		3.4	3	2		2.7	1.6
58	6	6	6		3.4	2.8	1.4		2.2	1
59	5.3	5.3	5.3		3.3	2.2	1.5		2.8	1.4
60	5	5	5		3.3	2.4	1.1		2.8	1.2
61	7	7	7		3.7	3	0.9		3.1	1.9
62	7.55	7.55	7.55		3.4	2.6	1.4		3.2	2.1
63	8.93	8.93	8.93	8.93	3.4	3	2.6	1.7	3.2	3
64	9	9	9	9	3.5	3.2	2.6	1.3	3.4	3.2
65	8.67	8.67	8.67		3.2	2.7	2		2.9	2.2
66	6.1	6.1	6.1		3.7	2.8	1.2		3.5	1.6
67	9.57	9.57	9.57		3.6	3.3	1.7		3	1.5
68	10.83	10.83	10.83		3.5	2.9	2.2		3.1	2.3
69	6.37	6.37	6.37		3.2	2.2	1.3		2.7	1.8
70	6	6			3.7	2			1.7	
71	5	5			2.5	1.8			1.9	

72	4	4		2	1		1	
73	3.7	3.7		1.4	0.8		1.2	
74	3.3	3.3		0.8	0.6		0.4	
75	4	4	4	3.5	2.2	1	2.7	1.4
76	3	3		2.7	1.4		1.6	
77	3	3		1.8	1.2		1.6	
78	5	5		1.6	1.2		1.4	
79	4	4	4	2.5	2.1	1.3	1.7	1
80	2.9	2.7	2.7	1.8	1.2		0.9	
81	2.5	2.5		2	1.4		1.6	
82	4	4		2.2	1.5		2.3	
83	4.5	4.5		1.7	1.5		1.2	
84	6	6	6	2.4	1.8	1.2	1	0.4
85	6	6	6	2.4	1.8	1.2	2.3	1.5
86	5	5		1.5	0.9		1.2	
87	2.5	2.5		1.5	1.3		1.1	
88	5	5	5	1.7	1.2	0.6	0.9	0.7
89	1.8	1.8		1.6	0.9		0.8	
90	3	3		1.5	1.4		1	
91	2	2		0.3	0.3		0.2	

2 Photos of gullies

BIOGRAPHY

The author, Aimere Yenew was born from his father Yenew Nebeyu and his mother Tadfalech Ayenew on August 1, 1991, in *Bahirzafa Guderkani kebele* of Sekela Woreda, W/Gojjam Zone. He attended his elementary education at Djigrita primary (1-5), Gollem primary (6-7) and Agut (7-8) Elementary School and his Secondary and Preparatory education at Abay Minch Secondary and Preparatory School in Gish Abay Town (9-12). He then joined Debre Markos University College of Agriculture and Natural Resources at December 20, 2010 in Natural Resource Management department and he was graduated in July 6, 2012. After graduation about two years he was unemployed and at this time he employed in Amhara design and supervision work enterprise soil surveyor expert in Bahir Dar. Then after the author joined the School of Graduate Studies of Bahir Dar University College of Agriculture and Environmental Science Summer program in 2017 to study his Master of Science degree in Watershed Management and Soil Water Conservation.