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Evaluating Impacts of Eucalyptus Plantation on Macroinvertebirate Assemblage in the Aquatic Environment, South Western Ethiopia

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IMPACTS OF EUCALYPTUS PLANTATION ON MACROINVERTEBIRATE ASSEMBLAGE IN THE AQUATIC ENVIRONMENT, SOUTH WESTERN ETHIOPIA

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Declaration

This master thesis work is part of Ecological Modeling of Aquatic Resource (PI: Dr Argaw Ambelu).

I declare that this research paper is my original work and has not been presented for a degree in any other university and that all sources of materials used for the research paper have been correctly acknowledged.

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ABSTRACT

Streams are important pathways for flowing of energy, matter, and organisms through the landscape. Stream water quality monitoring program relay on the chemical, physical, biological content of water and concentration of material present in the fresh water which is affected by a wide range of natural phenomena and human influences for aquatic life support existence. River water quality and aquatic biota could be affected by many riparian and non-riparian factors. Riparian vegetation cover and type are one of the riparian factors affecting the aquatic environment. Replacement of native vegetation by exotic plant species like Eucalyptus is one of the factors that result changes in the stream hydrology, organic matter dynamics and litter quality. The main objective of this study was to investigate impacts of Eucalyptus plantation on macroinvertebirate assemblages in the selected tributaries of Gilgel Gibe River in southwestern Ethiopia. A cross-sectional study of physicochemical and macroinvertebrates composition of streams in tributaries of Gilgel Gibe River, was carried out during January to May 2015, to assess their ecological status. Water samples and macroinvertebrates were sampled from 20 sampling sites (12 sites with Eucalyptus dominated and the rest with none Eucalyptus riparian vegetation). Physicochemical parameters were measured onsite and in the laboratory. To evaluate the effect of leaf litter on water quality, leaf of Eucalyptus globules, Croton merostachyus, Ficus sure and Salix subserrata were collected from the riparian zones of the streams. The leaves were air dried. 75 l water samples were brought from the selected tributary of Gilgel Gibe River by plastic container. The air dried leaves were added to a water sample and physicochemical parameter changes were monitored May to June 2015 for one month. Non-metric Multidimensional Scaling analysis was used to test the level of similarity between none Eucalyptus, Eucalyptus, macroinvertebrates and water quality parameters. Besides, types of vegetation, physicochemical and macroinvertebrate relationship were analyzed using canonical correspondence Analysis (CCA) and Test statics Analysis. The total of 3133 macroinvertebrate individuals belonged to 36 families and 9 orders were identified. The Most abundant orders were recorded in none eucalyptus vegetation was Ephemeroptera 44% followed by Tricoptera 16%, *While in Eucalyptus vegetation stream the most abundant macroinvertebrates recorded Ephemeroptera 18% followed by Odonata 17%. The water sample contains leaf litters of Eucalyptus grandis, Croton macrostachyus, Ficus sure and Salix subserrata were affecting the physicochemical parameters. For all sampled water the pH of Salix subserrata and Eucalyptus grandis leaf litters were less than seven while the pH of Croton macrostachyus and Ficus sure were above seven. For all water samples contain these leaf litters the electrical conductivity and TP were increased from time to time, but the EC of Croton macrostachyus more abrupt than the other leaf litter decomposition. In conclusion the water quality under the streams of none Eucalyptus vegetation was positively correlated TN, pH, and TP. However, Eucalyptus plant species have to be planted in the specific area where streams are not closely found.*

Key words: Macroinvertebrate, Non-Eucalyptus, Eucalyptus, water quality, leaf litter

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ACRONYMS

ANOVA	Analysis of Variance
CCA	Canonical correspondence analysis
CPOM	Coarse particulate organic matter
DO	Dissolved Oxygen
ECT	Ephemeropetra, Coleoptera, Tricoptera
EOT	Ephemeroptera, Odonata, Tricoptera
EC	Electrical conductivity
EPA	Environmental Protection Authority
ET	Ephemeroptera, Tricoptera
FAO	Food and Agricultural Organization
FPOM	Fine Particulate Organic Matter
MOA	Ministry of agriculture
MOH	Ministry of health
MOM	Ministry of Mine
MOWR	Ministry of water resource
MVA	Multivariate analysis
NMDS	Non-metric multidimensional scaling
PCA	Principal Component analysis
SPSS	Statistical package for the social sciences
TN	Total Nitrogen
TS	Total Phosphorous
TSS	Total suspended solid
WHO	World health organization

CHAPTER ONE: INTRODUCTION

1.1. Background of the study

Ecological diversity and climatic variation in Ethiopia were to a large extent explained by its highly variable topography. Environmental change and variable topography is increasingly becoming most of the critical domestic and global environmental policy concerns (Bezabih *et al*, 2010). Environmental change is now a global phenomenon with growth, poverty, food insecurity, and instability implications because of significant dependence on the agricultural sector for production, employment, and export revenues. Ethiopia is seriously threatened by environmental change, which contributes to frequent drought, flooding, and rising of average temperatures. Therefore, as environmental changes and hazardous substances increases, water quality and biological diversity in water ecosystem decreases (Solheim *et al*., 2010).

Water quality is defined as in terms of the chemical, physical and biological content of water and concentration of material present in the water which was affected by a wide range of natural and human influences (Geneva, 1996). Water pollution were existed due to so money types of pollutants such as sedimentation, fertilizers, sewage, runoff, erosion, dissolved oxygen, PH, temperature, decayed organic materials, pesticides, toxic and hazardous substances, oils, grease and other chemicals, detergents, heavy metals, increasing urbanization and industrialization generates a point and non-point source of contamination and litter of vegetations are serious problem worldwide. These are the major causes of destruction of water quality of rivers and streams (Geneva, 1996).Water quality has become a major concern across Ethiopia, long term monitoring of surface water quality and it is critical in determining if aquatic systems are being degraded (Albers, 2007).

Macroinvertebrates are considered to be as an indicator species; a species that can help to identify the state of the habitat condition it currently occupies. Macroinvertebrate studies are often used to evaluate overall water quality since these organisms can incorporate the impacts of short term variations over long time periods (Albers, 2007).

The biodiversity of aquatic ecosystem is affected by different parameters such as; light, certain stressors, mining abstraction, temperature, depth and nutrients. From different major factors impacting on freshwater biodiversity the loss of habitat especially the loss of riparian vegetation and different aquatic and riparian vegetation type (Dosskey *et al*., 2010) is the most common. The loss of riparian vegetation has been shown to have numerous impacts on freshwater ecosystems that can affect species diversity and major shifts in benthic community structure due to alterations in water flow regimes, increased sediment and nutrient loads, light levels, species relationships and homogenization of biodiversity, increased erosion and siltation (Press, 1995) and other environmental variables (Hession *et al*., 2008). However, reforestation of the riparian zone potentially decreases the negative impacts on stream hydrology and levels of sedimentation, and increase distribution of macroinvertebrate (Bruijnzeel, 2004). In the case Eucalyptus plants have been planted resulted in the homogenization of freshwater faunas and macroinvertebirate at regional and local scales (Rahel, 2010; Heino *et al*., 2009).

Eucalyptus, a genus of more than 500 species, has become the most planted in the world (Gessesse, 2011). Today Eucalyptus plantations cover at least 12 million ha throughout the tropical zone, 90% of which have been established since 1955 G.C. The Eucalyptus genus was introduced to East Africa in the late 19th and early 20th century and by the early 1970s the area of Eucalyptus in Ethiopia, Rwanda, Uganda, Kenya and Sudan had reached 95,684 ha (FAO, 1979). During this time, the largest plantations were in Ethiopia and Rwanda, covered 42,300 ha and 23000 ha, respectively. In Ethiopia the genus was introduced during the reign of Emperor Menilek II (1868-1907) in 1894/95 (Gessesse, 2011). In the 1970s, the plantation area around Addis Ababa was about 15,000 ha while in other parts of the country approximately 76,000 ha of plantations had been established. Know a day's, about 55 species of Eucalypt have been grown in Ethiopia, of which between five and ten are widely planted. In Ethiopia, the most widespread species include *Eucalyptus* camaldulensis, *Eucalyptus citriodora*, *Eucalyptus globules*, E*ucalyptus* grandis, *Eucalyptus saligna*, and *Eucalyptus tereticornis* (Gessesse, 2011).

Eucalyptus globulus and *Eucalyptus* grandis are the major species planted in the highlands of Ethiopia. Eucalyptus growing in Ethiopia is mostly confined to the highlands, where there are suitable moisture and temperature regimes (FAO, 2014).

The negative impacts of Eucalyptus are a global concern. Gessesse (2011) tried to provide impartial views by commissioning several global, regional and country level studies. Plantations of *Eucalyptus* grandis are known to negatively affect aquatic systems (Myrtaceae et al, 2010). The replacement of the native vegetation by Eucalypt monocultures leads to changes in the stream hydrology, organic matter dynamics and litter quality; all factors have been concerned in the scarcity of macroinvertebrate communities in streams (Enge *et al*., 2002).

Different researchers were evaluating the impacts of Eucalyptus plantation on stream have focused on the effects on toxicity of the leaf litter on the consumers (Enge *et al*., 2002). The linkage of oils from Eucalyptus leaves resulted to increased feeding rates, whereas transferring of oils to older leaves was also resulted in decreased feeding rates (Sridhar *et al*., 2015).

1.2. Statement of the Problem

Currently conservation of aquatic ecosystem was a worldwide problem and it's a critical one. As we know that biodiversity is the means of genes, species in aquatic ecosystems and provides businesses a good services for ecosystem (Canhoto, 2006). Unpolluted aquatic ecosystem is the most comfortable habitat for those organisms inhabits the aquatic systems. However, this time population growth, extensive agriculture adjacent to aquatic passageways and plantations can seriously affect the aquatic species and their habitats. Exotic plantations in the nearby of streams can affect the water quality and macroinvertebrates. Eucalypt leachates may affect the ecology of macroinvertebrates in summer pools (Legendre and Gallagher 2001). As Sponseller *et al* (2001); Benstead *et al* (2003); Andrew (2010); Callisto *et al (*2014) reported that, the larvae survival, consumption, growth and completion of the life cycles were all are negatively affected by eucalypt solutes in the water. The phenols of Eucalyptus leaf may have a determinant effect on the macroinvertebrates consumption behavior and performance (Canhoto, 2006). The presence of phenolic compounds in the media or adsorbed to alder leaves surface, lowering their nutritional value, may have been responsible for reducing or suppressing (according to the leachate concentration) consumption (Sandin & Verdonschot, 2006).

Streams which are covered by Eucalyptus plant have lower diversity of macroinvertebrates (Basin *et al*., 2008). There are different expected reasons which affect the abundances, richness, composition and evenness of species in the stream. The first reason is changing of forest practices will affect the dynamics of organic matter available for aquatic macroinvertebrate, the structure of stream community and water quality and the second reason is the deplete soil nutrients by Eucalyptus trees. These are some problems on the composition macroinvertebrate which is located in southwest streams of Ethiopia. Beside to this some groups of macroinvertebrates have been significantly positive relationship with that of Eucalyptus afforestation and some of others are negatively relationship with Eucalyptus plant and some of them are positive relation with other native plant species.

In the previous study there was no studied comparison between the distribution of shredders, collector/gatherer, collector/filterer, scrapers and predators with regarding to riparian and exotic plant leaf litter decomposition(Connor & Grant, 2015). The impacts of Eucalyptus plants are aggravated to different country like Iberian Peninsula, Central Portugal (Canhoto, 2006) except in Ethiopia. This situation is not yet studied in Ethiopia, where Eucalyptus tree is widely used. In this study find the impacts of Eucalyptus plant on scraper, predators, collectors and gatherers compared to other plant species. Therefore, in this research the effect of Eucalyptus and other vegetation leaf litter on water quality and macroinvertebrate assemblages in the streams of southwestern Ethiopia were assessed.

1.3. Significance of the study

The impact of Eucalyptus plantation on the assemblage of aquatic biodiversity and comparison the effect of different leaf litter decomposition on physicochemical characteristics of water has not yet studied in Ethiopia. Due to this extent the problem of lower diversity of aquatic species is not well documented. Therefore, the study outcome can provide information about positive and negative impacts of different plantation on diversity of macroinvertebrate. The Ministry of

Health (WOH), Ministry of Water Resource (MOWR), Ministry of Mine (MOM), mineral and energy, Environmental Protection Authority (EPA), Ministry of Agriculture (MOA) and other concerned body can get brief information related to their official objectives of biodiversity in the selected tributaries of Gigel Gibe River southwestern Ethiopia. In general this study could be tried to fill the gaps of information about diversity of invertebrate associated with exotic and native plants and effects of different leaf litter on water quality.

CHAPTER TWO: LITRATURE REVIEW

2.1. Stream Ecosystem

Freshwater ecosystems are regarded as one of the rarest ecosystems on the planet (Dudgeon *et al*., 2006; Sala *et al*., 2000). Freshwater ecosystems represent 0.01% of all water on the planet covering a total of 0.8% of the Earth's surface (Jackson *et al.*, 2001) contained within this 0.8% are an estimated 100,000 species with a potential increase of 50,000-100,000 species residing within groundwater (Andrew, 2010). Streams are channels of flowing water that are smaller in size than rivers. These ecosystems include various communities of plant and animal species. The headwater streams are important in the function of riverine ecosystems Benthic (Chakona, 2005) and aquatic macroinvertebrates living in them are concerned in many different ecological processes in the streams.

The different ecological processes in the streams are include that energy flows, nutrient cycling and turnover of organic material, degradation of leaf litter, the energy were produced from the entering of riparian zone (Wallace & Webster, 1996). These processes could be affected by land use, which affects the physical and chemical characteristics of water bodies and the composition of the aquatic biota (Hepp *et al.*, 2010). Water characteristics and species diversities are regulated by both natural and anthropogenic factors and Eucalyptus leaf litter (Andrew, 2010). Therefore, vegetation restoration and management in none Eucalyptus zones is widely recommended and promoted in agricultural areas to, in part, improve chemical water quality in streams (Dosskey *et al*., 2010). Different stream could be important for transport of water from the watershed to channel, transport of wood and sediment to create diverse bed form and dynamic equilibrium, and transport of water in the channel and on the flood plain (Hostach *et al*., 2014).

2.2. None Eucalyptus vegetation

The riparian zone is the place where aquatic systems merge with the terrestrial environment. Virtually all rainwater runoff must pass through the zone before moving into adjacent aquatic/estuarine systems (Graça *et al*., 2002). A principle impact of continuing deforestation is surface water and river water contamination by fertilizer (200 kg/ha on average) and agrochemicals, which are used to manage the Eucalyptus plantations (Leicach *et al*., 2010). Headwater streams are maximally influenced by none Eucalyptus vegetation through shading and as the source of organic matter inputs, because the ratio of shoreline to stream bottom area is high. Macroinvertebrates has need to the shelter and food from their habitat, so these riparian vegetation habitats provide and tend to congregate in areas that provide the best shelter, the most food, and the most dissolved oxygen (Barbour *et al*., 1998). None Eucalyptus vegetation also facilitates the removal of suspended sediments, adhering phosphorus, balancing temperature of stream ecosystems and retaining particulates (Hostache *et al*., 2014).

Riparian vegetation plays important roles in maintaining suitable habitat for fish community. It provides shade and cover, promotes bank stability, enhances physical channel features, provides large wood recruitment, filters sediment, and serves as a major source of nutrients to support in stream fauna and flora. Most riparian restoration projects are intended to improve one or more of these functions (Fessler, 2015). None Eucalyptus forest buffers are natural stream side forest made of tree, shrub, and grass plantings. This buffer is important for controlling of non-point source pollution of waterways from adjacent land, reduce stream bank erosion, protect aquatic environments, and enhance wildlife (Smith, 2012). None Eucalyptus areas are adjacent to perennial, intermittent, and ephemeral streams, lakes, and estuarine-marine shorelines (Nicola & Peter, 2011). None Eucalyptus forest buffers are also recognized as a "separation zone" between a water body and a land use activity for the purposes of protecting and mitigating the threat of costal problems on human infrastructures (Nicola & Peter, 2011). Healthy riparian areas are critically important for ecological zones that provide; water quality protection, structural support for stream banks, and stabilization of water flow in streams and rivers and habitat for aquatic and terrestrial wild life (Barbara, 2003).

2.3. Eucalyptus Vegetation

The word Eucalyptus comes from Greek words "Eu" and "Kalypta" with the meaning of "Well" and "Cover" respectively and together gives a meaning of eucalyptus "well cover". Therefore the name Eucalyptus refers to the small cap covering the closed flower, ever green flowering tree and shrubs concerning the specific habitats (Hailemicael, 2012) pointed out the name for

Australian Eucalyptus was introduced by the French botanist Charles Louis and Heritier De Burutelle after the middle of eighteen century and they gave a suggestion that eucalyptus species appeared for the first time at the coast of eastern Australia. This has an implication for the current Eucalyptus species hopefully to say that almost all Eucalyptus species are originated from Australia and neighboring islands. The total numbers of eucalyptus species are estimated to be more than 500, native to Australia and neighboring countries (Gessesse, 2011); about 30 species are widely grown as exotics around the world. According to Hailemicael (2012) Eucalyptus growing in Ethiopia is mostly confined to the highlands, where there are suitable moisture and temperature regimes.

Native vegetation in different riparian areas has been heavily degraded and largely replaced with exotic species. This is mainly due to clearing, increased nutrient levels and modification of flow regimes in the waterways (Jansen *et al.*, 2010). The replacement of diverse native plant forests by eucalyptus plantations changes the timing, quality and quantity of leaf litter inputs to streams, which has the potential to affect the activity of decomposers and thus ecosystem functioning (Ferreira *et al*., 2006). The main intentions of various researchers are to test whether stream detritivores under exotic plantations (Eucalypt Plantations) show impaired growth, or content of protein, lipid, carbon and nitrogen compared with aquatic macroinvertbrate under native deciduous forests and to test the hypothesis whether afforestation with *Eucalyptus* grandis affects litter dynamics in streams and the structure of macroinvertebrate aquatic communities, the authors have been compared streams flowing through eucalyptus and deciduous forests, paying attention to. Eucalyptus forest streams accumulated more organic matter than deciduous forest streams. Decomposition of both Eucalyptus and none Eucalyptus leaf litter was higher in streams flowing through deciduous forests. The Eucalyptus forest soils were highly hydrophobic resulting in strong seasonal fluctuations in discharge (Larrañaga *et al*., 2009 & Pozo, 2009; Graça & Canhoto, 2006).

2.4. None Eucalyptus and Eucalyptus Vegetation on macroinvertebrate diversity

Benthic macroinvertebrates like shredders feed on organic material such as leaves and woody material, and help to convert this matter into finer particles, collectors/filter feeders feed on fine organic particles that have been produced by shredders (Rasmussen, 2012), scrapers that is attached to rocks and plants and predators were live on live prey (Chakona, 2005). Streams which are running through Eucalyptus plantations in Portugal had lower diversity of aquatic hyphomycetes (invertebrates) than streams running through deciduous forests (Manuel et al., 2002). This could be explained in part by the lower diversity of CPOM. Some species of aquatic diversity have substrate preferences (Gulis, 2001), so more diverse resources may support a higher number of species. Coarse particulate organic matter (CPOM) provided by riparian trees are source of energy and carbon for aquatic communities in small woodland (Pozo *et al*., 1998).

Impacts of Eucalyptus plantation can be response in the detritus pathway of the ecosystem and will impact the shredder assemblages most strongly. Benthic invertebrates are estimated to process 20 – 73% of the leaf litter that falls into headwater streams thereby releasing bound nutrients into solution. Besides this breaking down leaf litter, grazers, shredders, deposit and suspension feeders also consume algae, fungi, bacteria and protozoan along with the detrital material (Chakona, 2005). Since benthic macroinvertebrates are important prey for both aquatic and terrestrial consumers (Merritt & Wallace, 2004), they are link to microbial loop with upper tropic levels. This prevents nutrients taken up by microbes, which are not readily available to upper tropic levels, from being lost from the ecosystem. Benthic macroinvertebrates also accelerate the transfer of nutrients from the sediments to the overlying water in lakes as well as to the riparian zones along streams (wallace & webster, 2006). Eucalyptus afforestation might affect aquatic communities because of seasonal differences in litter fall reported from Australian eucalypt forests and because Eucalypt Leaves have been referred to as being of poor quality by Australian researchers (Bunn, 2001).

Eucalyptus streams have lower density and biomass of stream macroinvertebrates, particularly of shredders, and taxon richness was also negatively affected (Manuel *et al*., 2002). *Eucalyptus* is an evergreen tree and its leaves have high contents of oils and toxic compounds (polyphenols)

Farmers whereas native riparian trees show none of these characteristics (Tadele & Teketay, 2014). The main difference between riparian vegetation and Eucalyptus vegetation was on taxon richness and abundance of shredders is that the antibiotic properties of Eucalyptus oils could interfere with microbial decomposition and invertebrate feeding (Chakona, 2005).

2.5. None Eucalyptus vegetation and stream water quality

The restitution of none Eucalyptus vegetation and minimization of nutrient input and organic waste discharges would considerably improve the ecological quality in the Gilgel Gibe watershed in Ethiopia (Ambelu *et al*., 2010).

Eucalypt leaves have low nitrogen levels compared too many native leaves and thus contribute fewer nutrients to the streams (Pozo et al., 1998). None Eucalyptus buffers are important for good water quality and ecological functions. None Eucalyptus vegetation zones help to prevent sediment, nitrogen, phosphorus, pesticides and other pollutants from reaching a stream. Riparian buffers are most effective at improving water quality when they include a native grass or herbaceous filter strip along with deep rooted trees and shrubs along the stream (Carr & Neary, 2006). *N*one Eucalyptus vegetation is a major source of energy and nutrients for stream communities. They are especially important in small, headwater streams where up to 99% of the energy input may be from woody debris and leaf litter. Overhanging riparian vegetation keeps streams cool, this is especially important for North Carolina's mountain trout populations (Carr & Neary, 2006).

Leaves in streams are decomposed by the joint actions of physical factors (leaching of soluble compounds and physical fragmentation) and biological breakdown (mediated by decomposers and detritivores). Although fungi and bacteria colonize leaves before they reach Rivers, aquatic rapidly replace the terrestrial decomposers. The biomass of aquatic macroinvertebrates may account for up to an estimated 8–16 % of the total leaf mass. Aquatic life produces enzymes capable of breaking down plant structural polysaccharides whose subunits are then incorporated into fungal biomass (Steve,2014).

The effective use of vegetation for water quality protection and improvement requires a broad understanding among land and water resource managers of the varied ways that riparian vegetation can affect water chemistry (Beketov, 2004). Riparian vegetation also facilitates the removal of suspended sediments, adhering phosphorous and retaining particulates (Correll, 1997). The riparian vegetation balances the temperature in a healthy aquatic system. Because a major goal of many riparian vegetation is to increase stream shading so that during the summer time water temperatures may be reduced, thereby improving rearing habitat. If this vegetation is removed from stream and river, water temperature, ambient temperature were increased due to penetration of light, and turbidity from exposed soil also increase (Carr & Neary, 2006). From the water perspective TN and TP have been motivated and increased due to nutrient loading, sedimentation, acidification, and the introduction of toxic contaminants as a result of runoff water, within stream and river watersheds which were dominated by agricultural production rapid eutrophication (Leng, 2008). Plant debris from riparian vegetation is a major source of organic matter to stream channels, particularly in headwater streams. As (Dosskey *et al*., 2010) estimated that a riparian forest contributed 93% of the total organic matter load exported annually in stream flow from a 12.6 km2 watershed and up take rate of TN from none Eucalyptus vegetation have ranged as high as 170KgN/ha/year.

Total nitrate, total phosphorous and sediment concentration level were reduced due to the reason of long-term clearing and cultivation of annual crops in a riparian zone followed by restoration to grass vegetation yielded a 35% reduction in nitrate concentration in groundwater and 83, 73, and 92% respectively, in overland flow through the riparian zone in the three years following restoration (Dosskey *et al*., 2010).

Eucalyptus plantation is also affecting the water quality. The expansion of Eucalyptus plantation on lands reduces water availability for irrigation due to soil hydrophobicity (water repellency) and its deep and dense root network (Service et al., 2008). Plantations of Eucalyptus grandi are known to negatively affect terrestrial and aquatic systems (Service *et al*., 2008; Sandin & Verdonschot, 2006). Several studies in the Iberian Peninsula demonstrate that the replacement of the native deciduous vegetation by eucalypt monocultures led to important changes in stream hydrology means increasing of TSS, EC and turbidity, organic matter dynamics and litter quality; all factors have been implicated in the impoverishment of fungal and invertebrate communities in streams (Sandin & Verdonschot, 2006; Mori, 1999). According to Mori (1999) results, Eucalyptus plantations around water sources significantly affect the flow of springs, and the disappearance of springs, evidently due to Eucalyptus plantations, and as a result, the biological diversity has disqualified any further plantations of Eucalyptus around water sources such as streams or rivers.

Most studies evaluating the impacts of Eucalypt plantations on stream detritivores have focused on direct effects of the low quality and/or on toxicity of the leaf litter on the consumers (Canhoto, 2006). However, the leaves' impact on stream communities may extend to their release of soluble organic and inorganic compounds by leaching. This factor is change water quality. Leaching in Eucalyptus can last for up to 7 days, with mass losses up to 25% of the leaf mass and a concomitant decrease in leaf caloric value (≈17%) and phenolics (Muszyńska *et al*., 2014).

2.6. Ecological role of Eucalyptus vegetation

Eucalyptus is the most broadly planted hardwood genus in the world, covering more than 19 million hectares, with growth rates that routinely exceed $35\,m^3\,ha^{-1}\,year^{-1}$ (Albaugh *et al*., 2013). These fast-growing plantations can be grown under a range of different climates for products that include pulp and paper, charcoal, fuel wood, and solid wood products such as poles, furniture, and timber construction. Given their fast growth rates and coppicing ability, eucalypts have also been identified as potential feed stocks for lignocellulosic befouls. Being endemic to Australia, Southeast Asia, and the Pacific, eucalypts are grown mainly as exotic species. Consequently, there is much concern about their water consumption, from many countries around the world (Bekele, 2015).

Eucalyptus is considered as a multipurpose tree. In forestry, the term "multipurpose tree" means that the tree can be used in many functions, for example (Ndambi & Ndzerem, 2006) found in al l country including Ethiopia described that the expansion of Eucalyptus plantation on lands previously used for crops, utility wood, furniture, fencing farm barrier, construction pole, firewood, charcoal, woodchips, board particle, wood-cement board, and paper pulp. Eucalyptus is an exotic species. Its origin is in Australia. This species are known by its fast growing, easy to care, drought tolerant, and can be grown in poor and less fertile soils. Eucalyptus plantations in several countries have been the subject of criticism because of their high water use and other negative environmental impacts (FAO, 2009).

The demanding for wood, water, and energy continues to grow, providing a challenge to increase the productivity of forest plantations within water constraints. Eucalyptus species managed as short-rotation crops for bioenergy are of increasing interest in many parts of the world. In countries where eucalypts are introduced species, there is a need to understand key environmental issues, for example, water use, related to the management and growth of these trees. One way in which information needs can be identified and prioritized is to draw on the knowledge and experience gained from decades of water research in South Africa (Mjoli & Services, 2010).

CHAPTER THREE: OBJECTIVES OF THE STUDY

3.1. General Objective

- To investigate impacts of Eucalyptu*s* plantation on macroinvertebirate assemblage in streams

3.2. Specific Objectives

- To evaluate the macroinvertebrate composition in streams under eucalyptus tree plantation
- To compare effects of different leaf litter decomposition on physicochemical characteristics of water.

3.3. Research questions

The following leading questions were addressed through the discovery of this research.

1. What is the macroinvertebrate assemblage in streams under Eucalyptus vegetation?

2. Is there any variation in macroinvertebrate assemblages between streams under Eucalyptus tree plantation with other vegetation types?

CHAPTER FOUR: METHODS AND MATERIALS

4.1. Description of Study Area

The study was conducted in Jimma zone on selected tributaries of Gilgel Gibe River, southwestern Ethiopia (located latitude 7^0 25'-7^0 55'and longitude 36^0 30' - 37° 22' East). The Climate of Jimma is tropical rain forest region, with a temperature of 16.4℃ and an average of 116.7mm annual precipitation while the altitude ranges from 1096 to 3259m above sea level (Ambelu, 2010). The selected streams for the study that are flowing under Eucalyptus plantations and other vegetation are located in this region. The longitude, latitude and elevation of each sampling site were recorded using a GPS (global positioning system) reading. (Figure 1) indicates the studies area and the location of sampling stations.

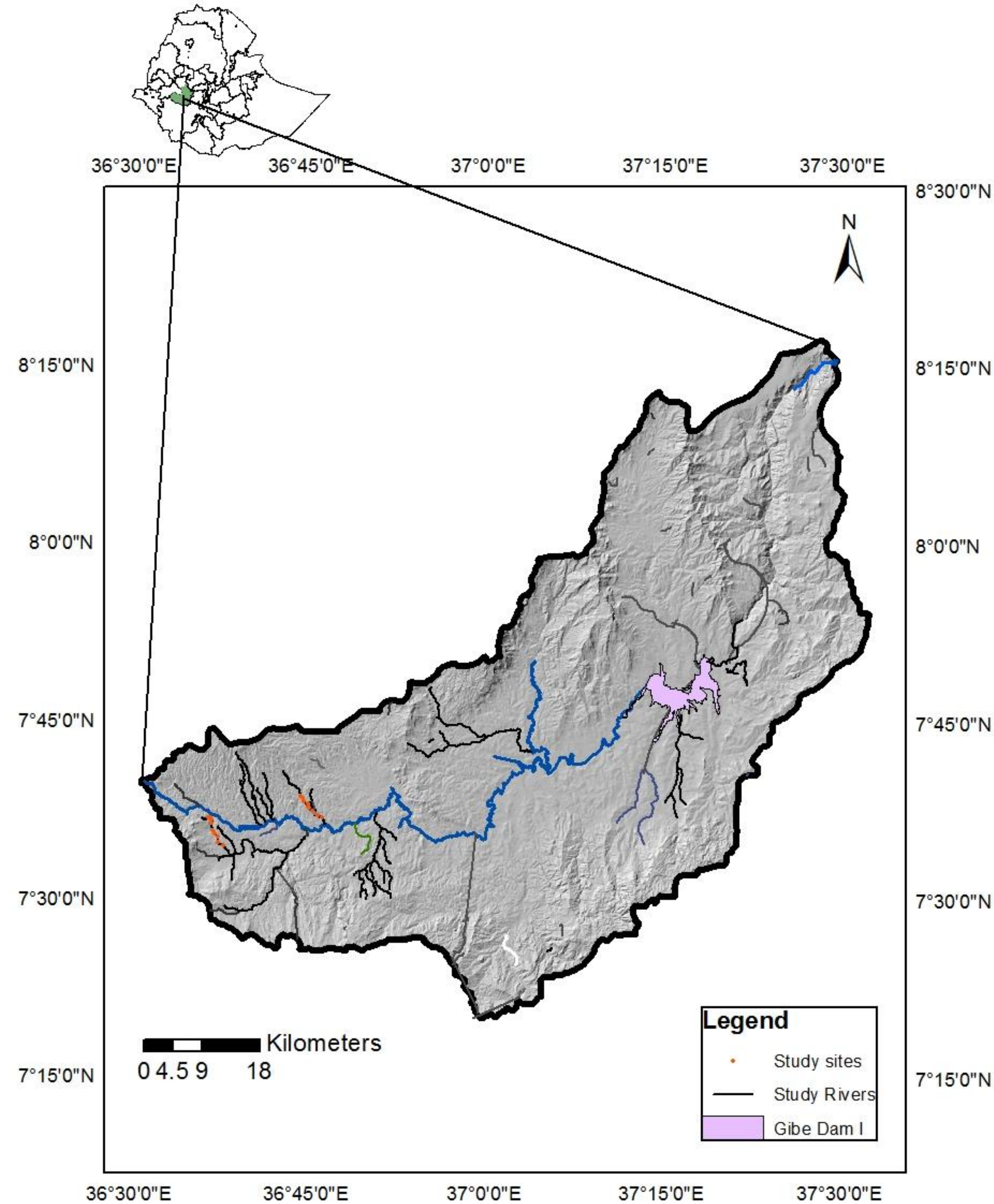

Figure 1: Location of the study area and selected tributary of Gilgel Gibe River, southwestern Ethiopia, 2015.

4.2. Study design

Comparative cross-sectional study design was followed from January to May 2015 at selected tributary streams of Gilgel Gibe River.

4.3. Study variables

Independent variable

- Macroinvertebrate assemblages

Dependent variables

- Turbidity
- Electrical conductivity
- Temperature
- pH
- Dissolved oxygen
- Total suspended solid
- Total Nitrogen
- Total Phosphorous
- Habitat condition
- Non-Eucalyptus vegetation
- Eucalyptus Vegetation

4.4. Study sites selection

Study sites were selected based on the fulfillment of the inclusion and exclusion criteria.

4.4.1. Inclusion criteria

To compare the water quality and macroinvertebrates diversity of stream between the two groups (streams under Eucalyptus and none Eucalyptus trees), sites which have similar status in habitat condition, land use and anthropogenic activities were selected.

4.4.2. Exclusion criteria

Sites were excluded from the study when there is unique feature from the comparative group in terms of land use, habitat condition, anthropogenic activities and physiographic conditions (Mackenzie & Kleynhans, 2007).

Based on the above criteria, 12 sites located under Eucalyptus and eight sites under none Eucalyptus vegetation were selected (Table 1). The minimum distance between the sampling sites were 200m.

Table 1: Site characteristics of the study area in terms of vegetation, land use and habitat condition.

S/N	Streams sample Station	Dominant vegetation	Land use (Mackenzie & Kleynhans, 2007)	Habitat condition (Barbour, 1999)
1	Kechema upper stream (K1-K3)	None Eucalyptus	Minimally impacted	Very good
2	Kechema downstream (K4-K9)	Eucalyptus	Minimally impacted	Very good
3	Bore upper stream (B1-B5)	None Eucalyptus	Minimally impacted	good
4	Bore downstream (B6-B11)	Eucalyptus	Minimally impacted	good

Habitat assessment (HAB) score categorization criteria: optimal (excellent= 161-200), sub optimal (very good=121-160), marginal (good=60-120) and poor= 0-59 and land use score scale is 0 to 5 (0= None; 1= Low; 2=Moderate; 3=Large; 4=Serious; 5 =Extreme impacted)

4.5. Data collection

4.5.1. Macroinvertebrates sampling and identification

The kick-net was placed in the stream at opposite direction to the course of to the stream flow and collect it. Sampling was involved all habitat types with in 10m stretch of the stream flow within five minutes of sampling time. After five minutes the contents of the net were transferred to a bowl, sufficient water was added and the supernatant was poured through a sieve to retain macroinvertebrates. Then, they were subsequently transferred to sorting in order to observe and pick them up with forceps. All macroinvertebrates were transferred into bottles containing 70% ethanol for preservation. The sample containers were labeled with full information for the sac of avoid confliction or an error, so that each sample have been a unique identity meaning a container that had a sample type, sampling date with month and time collection were written on the sample bottle. Finally the bottles containing macroinvertebrate specimen were transported to laboratory of Department of Environmental Health Science and Technology, Jimma University for identification, counted and assigned to their taxonomic family level of macroinvertebrate under a light microscope and standard macroinvertbrate identification keys (Figure 2). All macroinvertebrates were fully examined using a light microscope to family level using the available taxonomic keys. All specimens were assigned to one of four major functional feeding groups, shredders, predators, collectors and filterers according to (Bouchard, 2004 & Cummins, 1984).

A **B**

C D

Figure 2: Sample collection and laboratory investigation. A=kick sampling, B = on site sorting, C and D=laboratory identification of the sample for macroinvertebrates (picture taken by PI, 2015).

4.5.2. Water sampling

From each selected sampling site, water quality parameters were measured onsite and in the laboratory. Onsite measurement was done for dissolved oxygen (DO), temperature, pH and electrical conductivity (EC) using multi-parameter probe (HQd4 single input Multi-Parameter

Digital Meter, Hatch) at each site and turbidity was measured using a wagtech (turbidity meter Wag-WT3020) after shaking the sample.

i. Total suspended solids

Total suspended solid was filtered using 47mµ fiber glass, gravimetric method (vacuum gas pump) and measured volume of (100mL) well mixed. Dried at 105^0C for 1 hr in an oven and cooled in desiccators to balances temperature and weighted before and after.

ii. Phosphate

The phosphorous (orthophosphate) was determined using stannous chloride method. A blank solution was prepared in a similar way with distilled water. 4 ml of ammonium molybidate and 0.5 ml(10 drops) of stannous chloride solution added then stopper and mixed by inverted each flask to six times. The samples were allowed to stand for 10 minutes but before 12 minutes measured using a DR 5000 spectrophotometer at 690 nm.

iii. Nitrate nitrogen

Nitrate nitrogen was determined using phenoldisulfonic acid method; after filtration 20 mL of sampled was evaporated to dryness over a hot bath water and then 2 ml of phenoldisulfonic acid reagent was added and rubbed the residue thoroughly to insure dissolution of all solids and 20 ml of distilled water was diluted with stirred by glass road materials and 7 ml of NH_4OH added then the sample was measured using DR5000 spectrophotometer at 410nm. At each sites sample water were collected and stored in ice box until returned and nitrate- nitrogen(described as nitrate) and orthophosphate-phosphate(described as phosphate) were measured in Jimma university Environmental Sciences and Technology laboratory following the standard methods (APHA *et al*., 1995) . Furthermore, the stream width and depth, and current velocity of stream were measured with tape water and flow meter respectively.

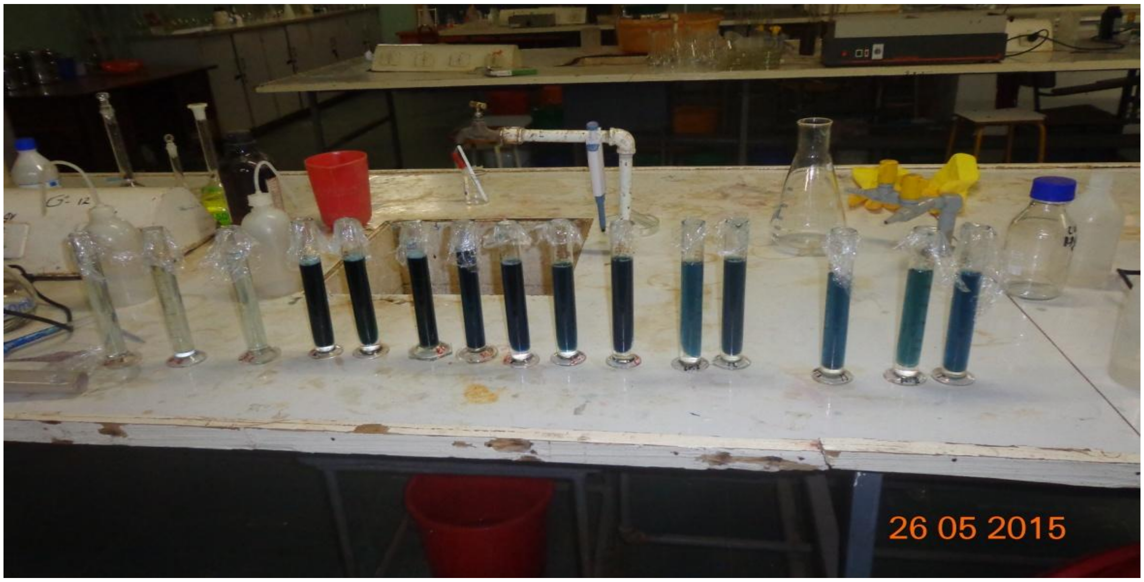

Figure 3: Analysis of TP and TN

4.6. Experimental arrangement for leaf litter type and water quality at lab scale

4.6.1. Leaf litter preparation

Common leaf litters were collected from Gilgel Gibe River. These leaves were *Eucalyptus grandis* (Bahirzafe*), croton macrostachyus* (Bissana*), Ficus sure forssk* (Shola) *and Salix subsessrata (*Ye'akaya zafe) were collected and inserted to the jack. The leaf has to be air dried. The leaves in the jack were transported to the laboratory of Department of Environmental Health Science and Technology, Jimma University for comparison of the water quality parameter which was affected by four different leaves. Each leaves were measured 100g by beam balance in triplicate way and inserted to plastic jar and were lived for four weeks. 12 samples of triplicate of 100g of 4 different leaves were prepared (Figure 4).

Figure 4: leaf litter measurement

4.6.2. Sample water arrangement

From the selected tributary of Gigel Gibe River, 75 litter water samples were brought by plastic container and transported to the laboratory of Department of Environmental Health Science and Technology, Jimma University for water quality analysis. Five liter water samples were monitored in triplicate way to under taken follow up for the water quality change under this specific leaf litter. We have totally 15 water samples in plastic jar. The detail arrangement was explained here (Figure 5).

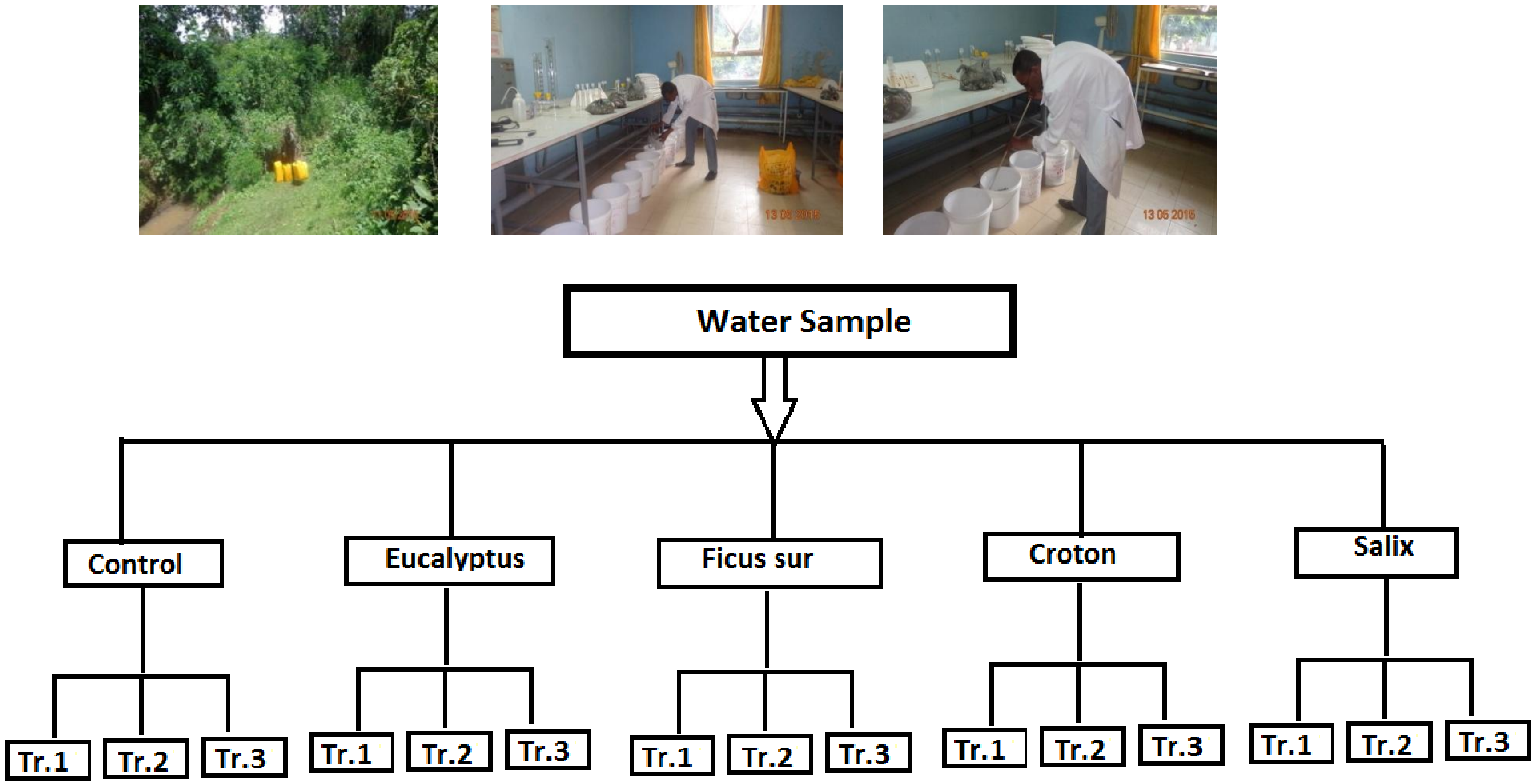

Figure 5: water sample, mixing of leaf litter with prepared water and experimental diagrams explain the arrangement of the four different leaves tests for thirty days at laboratory scale, Sam= sample

4.6.3. Monitoring of the experimental water in the laboratory

The water quality parameters, turbidity, DO, EC, PH, Water temperature; TN and TP were measured before the water mix with that of selected leaves. Each leaves were inserted in to each plastic jar which were contain five liter water and recorded the first day results of water quality parameters after 12 hour. This measurement is monitored for one month. The water parameters DO, EC, pH, turbidity and water temperature were measured for one month within three days gap while TN and TP were measured for one month within seven days gap (Figure 6).

Figure 6: measuring of parameters

4.7. Habitat quality assessment

Physical habitat information was taken at each sampling site with visual estimate measurement technique. The US-EPA rapid bio-assessment protocol (HABSCORE) was used to assess the habitat status of the sampling sites of selected tributaries of Gilgel Gibe River catchment area. During each sampling campaign, the habitat status was assessed, as the habitat condition is temporarily variable due to variation in vegetation cover, river bank stability, and epifaunal substrate and channel flow regime.

The selected habitat assessment protocol is onsite-based assessment method design to an overall evaluation of the habitat stream habitat characteristics that are relevant to aquatic biotic communities (Barbour *et al*., 1999).The measurements of habitat qualities of study sites were measured based on qualitative estimates of selected habitat characteristics.

HABSCORE were calculated using 10 metrics, which are epifaunal substrate, Pool Substrate characterization (low gradient), embeddedness, velocity/depth regime, channel flow status, channel alteration, sinuosity, river bank stability, vegetative protection, riparian zone width (Barbour *et al*., 1999). Each of these metrics were scored from 1-20 and summed up to give a total habitat score of maximum 200. Based on the habitat scores, sampled sites were classified in to four habitat classes, i.e. poor (<60), marginal (>60-120), sub optimal (>120-160) and optimal (>160-200) habitat condition (Barbour *et al*., 1999).

4.8. Data analysis

4.8.1. Descriptive statistics

Descriptive statistics were employed to analyze the general information of physicochemical data used by stepwise forward selection method the most environmental indictors using past software package version 2, Statistica and IBM SPSS version 20.

4.8.2. Macroinvertebrate indices

Diversity indices

The diversity indices were organized for measurements of biodiversity in water ecosystem depends on the degree of pollution. Macroinvertebrates diversity was computed using different indices such as: Shannon index (H), Simpson index of diversity (1-D), Brillouin index, Fisher-alpha and Margalef’s index.

i) Abundance (N)

Is the total number of individuals counted in a sample or study site. Abundance can also used to express the abundance of sensitive taxa in a sample, for example: Ephemropetra, plecoptera or Trichoptera abundance.

ii) Richness index(S)

The taxa Richness method measures the total number of species present in a sample. Is calculates using formula=(S-1)/log2M where S is the No of species in samples which is collected from sampling sites and M is the No of unit or single species of the all species in those sampling site and use SPSS version or tool for statistical data analysis and ANOVA for identification of difference of the impacts of Eucalyptus and other plantation.

iii) Simpson Index 1-D

It's a diversity indices derived by Simpson in 1949. Simpson index values (D) are between 0 – 1. The final result of Simpson is subtracted from 1 to correct the inverse proportion. Simpson's diversity index is a measure of diversity. In ecology, it is often used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the abundance of each species (Simpson, 1949).

Simpson's index of dominance was calculated:

Simpsons D=Σ ni (ni-1)/N (N-1)

Where, ni = the total number of individuals of a particular species.

N = the total number of individuals of all species.

Simpson's index of diversity: 1 – D

iv) Shannon Index "H"

This index is an index applied to biological systems by derived from a mathematical formula used in communication area by Shannon (Spellerberg & Fedor, 2003). Shannon diversity index is the most preferred index among the other diversity indices because that incorporates the richness and evenness of macroinvertebrate. A high H′ indicates that more diverse communities. The index values are between 0.0 – 5.0. The values above 3.0 indicate that the structure of habitat is stable and balanced; the values under 1.0 indicate that there are pollution and degradation of habitat structure.

H' = -Σ [(ni / N) x (ln ni / N)] or –Σ *pi lnpi*

Where

Pi= the proportion of individual (of a given species) represented by each taxon.

The minus sign in the equation is incorporated to ensure that the calculated diversity is a positive value. High value of H' is representative of more diverse communities and good water quality.

For the community with 'S' species of macroinvertebrates, the maximum possible value of Shannon index (H max) is ln(S) and is sometimes termed as richness.

H: Shannon Diversity Index

ni: Number of individuals belonging to i species

N: Total number of individuals

v) Brillouin Index

When the randomness of a sample cannot be guaranteed, the Brillouin Index HB is preferable (McGill, 2011) to the H': biological

HB= $\frac{LnN - \Sigma Ln\ ni}{N}$

Where N is the total number of individuals in the sample, ni is the number of individuals belonging to the i^{th} species and s the species number.

I_{BrMax} is the maximum value of $I_{Brillouin}$, when all species are equally abundant.

vi) Margalef Diversity Index "Ma"

It has no limit value and it shows a variation depending upon the number of species in the sample. Thus, it's used for comparison the sites and which provides a measure of species richness and sampling size and effort to normalize for sample size.

Ma=S-1/lnN,

Where, S= the number of taxa (the total number of species) and

N= the number of individuals (the total number of individuals)

vii) Evenness Index "J"

It was derived from Shannon index by Pielou in 1966 as (Tuomisto, 2012) cited. *Ecologists widely* The ratio of the observed value of Shannon index to the maximum value gives the evenness index result. The values are between 0 – 1 and is independent of logarithmic base. When the value is getting closer to 1, it means that the individuals are distributed equally or being complete evenness (Tuomisto, 2012).

J = H / Hmax

Where

J: Pielou evenness index

H: The observed value of Shannon index

Hmax :lnS

S: Total number of species

viii) Fisher- α

Fisher alpha ∂=N (1-X)/X, ∂ is mathematical description that relationship between the number of taxa and the number of individuals Fisher as (Oksanen, 2015) cited.

Where X is estimated from iterative solution of S/N= ((1-x)/x) (-ln(1-x))

S is taxa richness

4.8.3. Test statistics

Different statistics were used to for the sake of comparison the relationship between multiple variables and two independent variables. We test if there is the difference the diversity of macroinvertebrate between Eucalyptus and none Eucalyptus stream. For this analysis is Mann-Whitney U test is very important.

The Mann-Whitney U test is a non-parametric test that is used to compare difference between two independent variables. Usually the Mann-Whitney U test is used when the data is ordinal (numerical). We have to been analyzed using Mann-Whitney U test the diversity of macroinvertebrate along the two vegetation type; Eucalyptus and none Eucalyptus vegetation. Mann-Whitney U test, check the assumption (hypothesis) of variables. When analyzing the data using SPSS Statistics, one or more of assumptions are violated (i.e., is not met) (Nachar, 2008).

Null hypothesis (H0), there was no relationship between vegetation types with water quality.

$$U = n_1 n_2 + \frac{n_2(n_2+1)}{2} - \sum_{i=n_1+1}^{n_2} R_i$$

Where:

U= Mann-Whitney U test

n_1= sample size one

n_2= sample size two

R_i= rank of the sample size

4.9. Multivariate statistical analysis

Multivariate analysis was used to analyze stream physical habitat variables and catchment variables. A multivariate approach describes patterns and associations between macroinvertebrate communities and the environment (Mereta, 2013).

i) Canonical correspondence analysis (CCA)

CCA is also a multivariate method to elucidate the relationships between biological assemblages of species and their environment. It is appropriate when the length of gradient is put down between 3SD and 4SD (Hejcman, 2006).

4.9.1. Non-Metric Multidimensional scaling (NMDS)

NMDS is a means of visualizing the level of similarity of individual cases of a dataset. It refers to a set of related ordination techniques used in visualization in particular to display the information contained in a dominance matrix (Holland, 2008).

4.10. Ethical Consideration

Ethical clearance was obtained from ethical committee of Jimma University, College of Health Science. Permission paper was obtained from different concerned authorities and offices.

4.11. Data quality assurance

All important data quality control under each activity were measured; like method calibration, evaluation of composition of invertebrate capability to perform data analysis, determination of method detection level, daily assessment of limitation and the existing of limitation of counting invertebrate or other problem were perform based on standard method for the assessment of abundance of biodiversity in streams under Eucalyptus and other plantation.

CHAPTER FIVE: RESULTS

5.1. Physicochemical characteristics of water quality

Across the 20 sites examined, the pH value of the streams under none Eucalyptus vegetation was ranged from 7.44 at site K1 to 7.81 at site K2 whereas the streams under Eucalyptus vegetation was ranged from 6.03 as site K5 to 7.05 at site k9. The value of TSS in the streams under none Eucalyptus vegetation was ranged from 11.2g at site B1 to 28.2 g at site K1 whereas in stream under Eucalyptus vegetation was ranged from 16.4g at site K5 to 109g at site B11. Electrical conductivity of the stream under none Eucalyptus vegetation was ranged from 113.5µS/cm at site K2 to 205µs/cm at site B5 while; in the stream under Eucalyptus vegetation was ranged from114.6 at site k6 to 206.3 at site B10. The rest detail summary of environmental variables at all sampling sites are shown in (Table 2).

Table 2: Summary statistics of environmental variable in the sampling sites.

Vegetation type	site	PH	Depth(m)	Width(m)	Turb(NTU)	Temp(°C)	DO(mg/L)	EC(µc/cm)	TN(mg/L)	TP(mg/L)	TSS(g/L)
None Eucalyptus	K1	7.44	0.35	4	28.4	20.8	7.27	114.1	2.56	0.04	28.2
	K2	7.81	0.24	4	20.1	19	7.76	113.5	2.54	0.02	20
	K3	7.66	0.24	4	20.9	20	7.98	115.5	2.51	0.03	16
	B1	7.72	0.01	1.9	21.6	18	6.41	186.9	0.99	0.07	26.4
	B2	7.76	0.05	1.6	17.3	17.5	6.58	186.5	0.92	0.07	21
	B3	7.59	0.05	1.5	16.22	17.5	6.83	186.4	1.4	0.09	23.2
	B4	7.75	0.06	1.3	13.47	20.7	6.37	196.4	0.93	0.01	11.2
	B5	7.66	0.05	1.7	13.24	21.2	6.15	205	4.43	0.12	13
Eucalyptus	K4	7.02	0.27	2.2	22.2	19.1	7.3	115.3	2.04	0.03	31
	K5	6.03	0.37	1.9	21.8	19.6	7.17	116.5	1.82	0.04	16.4
	K6	7.05	0.3	3	21.4	18.9	7.37	114.6	2.46	0.06	54
	K7	7.04	0.27	2.3	20.3	18.9	7.17	116.4	2.02	0.01	54
	K8	7.02	0.34	2.2	20.4	18.5	7.25	117.3	2.27	0.01	44
	K9	7.05	17.3	2.45	22.6	19.3	7.26	116.5	2.25	0.01	38
	B6	7.00	0.4	1.9	17.6	20.2	6.56	213.6	0.43	0.05	43.3
	B7	6.04	0.05	2.1	12.69	18.9	6.92	191.2	0.58	0.04	32
	B8	7.04	0.09	1.8	6.92	18.7	7.36	200.4	0.44	0.03	44
	B9	7.01	0.05	2	10.24	18.7	5.57	205.2	0.69	0.04	38
	B10	7.02	0.05	1.8	8.62	18.2	4.73	206.3	0.75	0.04	58
	B11	7.01	0.03	1.9	30.4	19.8	4.95	189.1	0.88	0.01	109

Where Turb= turbidity, Temp= temperature, DO= dissolved oxygen, EC= electrical conductivity, TN= Nitrate nitrogen or total nitrogen, TP= Total phosphorous, TSS= total suspended solid, M= meter, mg/L= Milligram per liter, g= gram, NTU= nephelometric turbidity units, µS/cm= Micro siemens per centimeter, °C= degree centigrade

5.2. Macroinvertebrates description

From 20 sampling sites a total of 3133 individual macroinvertebrates belonging to 36 families and 9 orders were identified from all representative habitat types of the study sites. From the 9 orders encountered, Ephemeropetra was the dominant taxa group with the relative abundance 62% followed by Odonata 20% and Trichoptera 19% as indicated in Table 3.

Table 3: percentage of macroinvertebrates order of Bore stream and Kechema stream in the Gilgel Gibe watershed, southwest Ethiopia, 2015.

Veg.	Site	Eph	Hemi	Trico	Odon	Coleo	Diptera	pleco	Molusca	Aranae
None Euc	K1	1.15	0	0	0.29	0.13	1	0	0	0.06
	K2	5.1	0.09	0.96	0.96	0	0.7	0	0.09	0.03
	K3	0.7	0.64	3	0.13	0	0.8	0	0	0.22
	B1	5.1	0.42	0.03	0.64	0.96	1.6	0	0.44	0.13
	B2	10.4	0.5	9	0.2	0.06	1.34	0	0.03	0.06
	B3	6.54	0.06	1.76	0.13	0.3	2.8	0	0	0.06
	B4	7.8	0.13	0.2	0.086	0.25	1.76	0	0.22	0.1
	B5	6.8	0.22	1	0.32	0.03	0.7	0	0	0.03
	Total	**43.59**	**2.06**	**15.6**	**2.756**	**1.73**	**10.7**	**0**	**0.78**	**0.69**
Euca	K4	1.99	0.03	0.45	0.03	0.03	1.5	0	0	0.26
	K5	0.22	0.06	0.06	5.6	0	0.3	0	0	0
	K6	0.96	0.03	0.22	0.06	0.03	0.3	0	0	0.06
	K7	0.7	0	6.7	0.3	0	0.03	0	0	0.03
	K8	0.61	0.09	0	0.32	0	0.22	0	0	0
	K9	4.45	0.06	0.61	0	0	1.38	0	0.09	0.16
	B6	0.7	0	0	0.4	0	1.47	0	0	0
	B7	3.98	0.3	0.03	0.03	0.03	1.73	0	0	0.03
	B8	1.9	0.06	0	0.5	0	0.38	0	0	0
	B9	0.8	0.03	0	9.6	0.09	0.51	0.03	0	0
	B10	0.44	0.03	0	0.13	0.03	0.8	0	0.96	0.03
	B11	1.4	0.13	0	0.13	1.8	0.03	0	0	5.3
	Total	**18.15**	**0.82**	**8.07**	**17.1**	**2.01**	**8.65**	**0.03**	**1.05**	**5.87**
	Grand total	**61.74**	**2.88**	**11.58**	**19.856**	**3.74**	**19.35**	**0.03**	**1.83**	**6.56**

*Eph –indicatas Ephemeroptera, Hem-Hemipetra, Trico-Tricoptera, Odon-odonata,Cole-coleoptera, Dip-Diptera, Pel- plecoptera, Molu-Molusca and Aran- Aranae.

5.2.1. Macroinvertebrate dominance

Majority of the macroinvertebrates collected were Heptagenidae (58%), Baetidae (57%), Baetidae (55%), Chironomidae (57% and 51%) and Caenidae (55%) in site of K1, K6, K9, B6, B7, B8 and B10. Except for K1, the rest (K6, K9, B6, B7, B8 and B10) were from streams under Eucalyptus plantation (Table 4).

Table 4: percentage of number of macroinvertebrate taxa in Bore stand Kechema stream in the Gilgel Gibe watershed, southwest Ethiopia, 2015.

Vegetation type	sampling site	Number of taxa	Total abundance	Dominant taxa	Abundance(% dominance)
None Euca	K1	9	50	Heptagenidae	29(58)
	K2	17	224	Baetidae	93(41.52)
	K3	17	87	chironomidae	20(23)
	B1	17	263	Heptageniidae	83(31.56)
	B2	16	399	Baetidae	149(37.34)
	B3	14	364	Heptageniidae	87(23.9)
	B4	15	352	caenidae	125(35.5)
	B5	12	266	caenidae	121(45.5)
Eucalyptus	K4	12	135	Baetidae	50(37.03)
	K5	9	37	chironomidae	8(21.6)
	K6	9	51	Baetidae	29(56.86)
	K7	11	55	Hydropsychidae	21(38.2)
	K8	9	39	Baetidae	12(30.76)
	K9	12	209	Baetidae	115(55.02)
	B6	4	81	chironomidae	46(56.79)
	B7	9	191	caenidae	110(57.59)
	B8	9	93	caenidae	51(54.84)
	B9	7	79	coenagrionidae	30(37.97)
	B10	10	49	chironomidae	25(51.02)
	B11	11	110	chironomidae	52(47.27)

*K indicates kechema stream, B indicates Bore stream.

From the total number of macroinvertebrates order Ephemeropetera was dominant with the family of Baetidae and Caenidae in both streams were flow under Eucalyptus and none Eucalyptus vegetation. Order Diptera also dominant with the dominant family of Chironomidae in both streams were flow under Eucalyptus and none Eucalyptus vegetation (Table 5).

Table 5: Percentage of dominant order and taxa in selected tributary stream of Gigel Gibe River, Southwestern Ethiopia, 2015 along Eucalyptus and none Eucalyptus vegetation

Types of vegetation	Order	% of Order	Family level	% of Dominant taxa
None Eucalyptus	Ephemeroptera	43.59	Beatidae	34
			Caenidae	33.7
			Heptagenidae	32
	Tricoptera	15.6	Haydropsychidae	96
	Diptera	10.7	Chronnomidae	52
			Simulidae	15
Eucalyptus	Ephemeroptera	18.15	Caenidae	53.4
			Beatidae	4.8
			Heptagenidae	4.8
	Odonata	17.1	Coenagrionidae	61.26
			Corduliidae	14.41
			Aeshenidae	9.9
	Diptera	8.65	Chironomidae	94.06
			Simulidae	4.79

5.2.2. Distribution of Macroinvertebrates along vegetation type

From 20 sampling site the percentage of ECT macroinvertebrate diversity along the stream under none Eucalyptus vegetation was recorded 71.15% followed by 18.5% in stream under Eucalyptus vegetation. The percentage of ET in the streams under none Eucalyptus vegetation was recorded 69.13%, while streams under Eucalyptus vegetation 12.67%. The percentage of Chironomidae in the stream under Eucalyptus vegetation was recorded 25.14% followed by 9.34 % in the stream under none Eucalyptus vegetation (Figure 7).

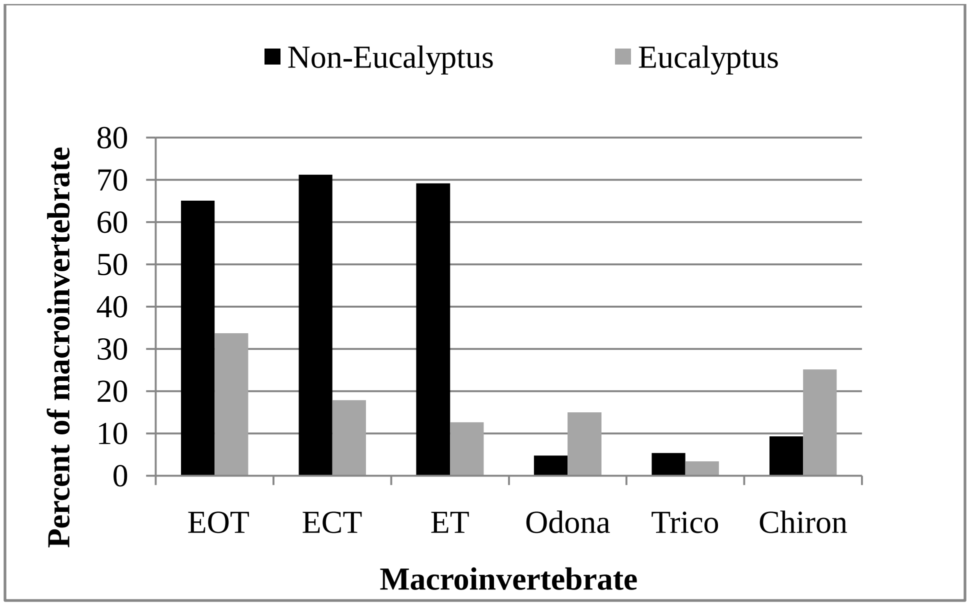

Figure 7: Percentage of EOT, ECT, ET, Odonata, Tricoptera and Chironomidae along vegetation type in Kechema and Bore streams of Gilgel Gibe River, southwestern Ethiopia, 2015.

5.2.3. Diversity measures

Based on the diversity analysis, macroinvertebrates abundance in streams under none Eucalyptus vegetation was ranged from 50 at site K1 to 399 at site B2; whereas, in streams under Eucalyptus vegetation was ranged from 37 (K5) to 209 (K9). The taxa richness of streams under none Eucalyptus vegetation was ranged from 9 families at site K1 to 17 families at site K2, K3 and B1 whereas in the streams under Eucalyptus vegetation was ranged from 4 at site B6 to 12 at site K9. The Shannon diversity index in the stream under Eucalyptus vegetation was lowest at the site B6 (1.01) and higher at the site of K5 (1.76) whereas in the stream under none Eucalyptus vegetation was lowest at site B5 (1.62) and higher at site K3 (2.3). The rest diversity index is explained in detail in Table 6.

Table 6: The richness, abundance, dominance and diversity indices of macroinvertebrate community of selected tributary of Gilgel Gibe River, southwestern Ethiopia, 2015.

Vegetation type	site code	Taxa richness	Individuals	Dominance (D)	Simpson (1-D)	Shannon (H)	Brillouin	Margalef	Eveness(J)	Fisher_ α
None Euca	**K1**	9	50	0.37	0.63	1.48	1.27	2.05	0.68	3.20
	K2	17	224	0.23	0.77	1.86	1.75	2.96	0.66	4.27
	K3	17	87	0.14	0.86	2.30	2.04	3.58	0.81	6.31
	B1	17	263	0.17	0.83	2.09	1.99	2.87	0.74	4.06
	B2	16	399	0.25	0.75	1.69	1.63	2.51	0.61	3.34
	B3	14	364	0.16	0.84	1.97	1.90	2.20	0.75	2.89
	B4	15	352	0.20	0.80	1.91	1.84	2.39	0.71	3.18
	B5	12	266	0.28	0.72	1.62	1.55	1.97	0.65	2.58
Eucalyptus	**K4**	12	135	0.24	0.76	1.72	1.59	2.24	0.69	3.18
	K5	9	37	0.14	0.86	2.07	1.76	2.22	0.94	3.79
	K6	9	51	0.37	0.63	1.43	1.23	2.04	0.65	3.17
	K7	11	55	0.24	0.76	1.78	1.55	2.50	0.74	4.14
	K8	9	39	0.17	0.83	1.95	1.66	2.18	0.89	3.67
	K9	12	209	0.35	0.65	1.52	1.43	2.06	0.61	2.77
	B6	4	81	0.42	0.58	1.01	0.95	0.68	0.73	0.88
	B7	9	191	0.42	0.58	1.16	1.10	1.52	0.53	1.96
	B8	9	93	0.35	0.65	1.42	1.29	1.77	0.65	2.46
	B9	7	79	0.29	0.71	1.41	1.30	1.37	0.73	1.85
	B10	10	49	0.34	0.66	1.46	1.24	2.31	0.63	3.80
	B11	11	110	0.35	0.65	1.38	1.26	2.13	0.58	3.04

The richness and alpha values indices were large in the streams under none Eucalyptus vegetation than the streams were flow under Eucalyptus vegetation. On the other hand, the remaining diversity indices of macroinvertebrates were almost that have the same values (figure 8).

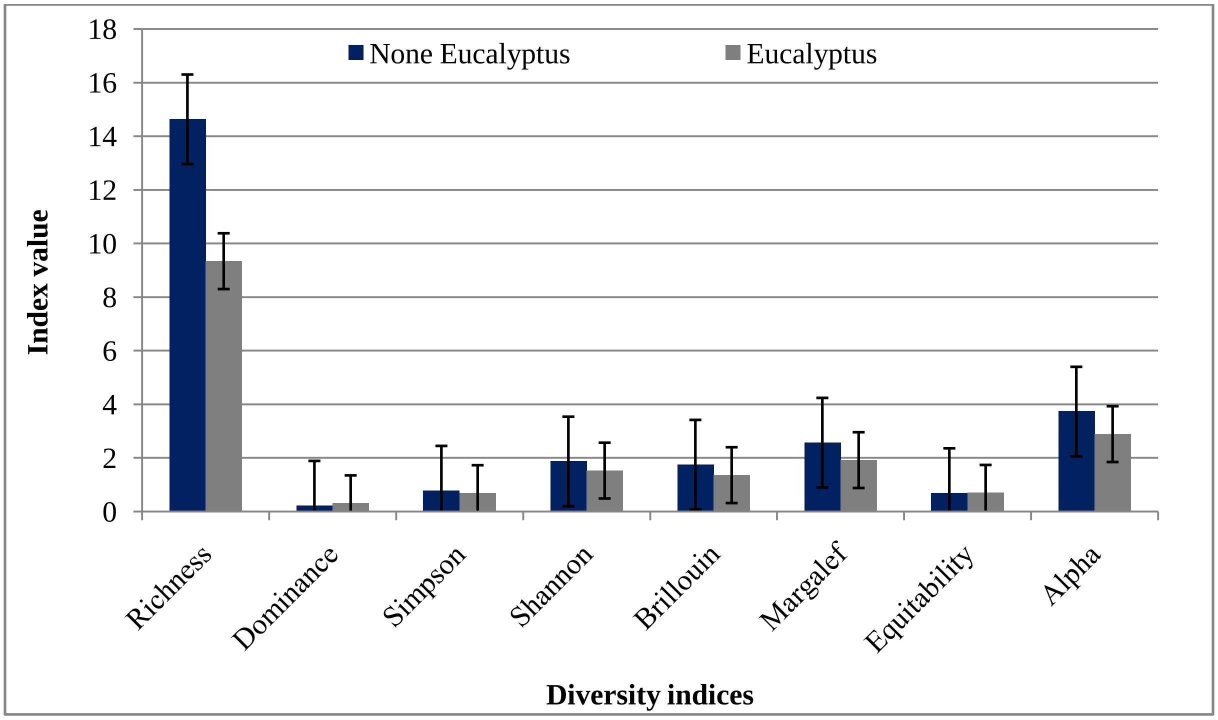

Figure 8: The average value of diversity measures in the two study groups. The error bar indicates the standard deviations among the different diversity indices.

5.2.4. ***Distribution of indices between Eucalyptus and none Eucalyptus sites***

Distribution of the indices is shown using boxplots. As it can be depicted from the boxplots (Figure 9) some indices, such as the Abundance, Simpson, Margalef, Dominance, Brilloun and Shannon were able to discriminate between Eucalyptus and none Eucalyptus sites.

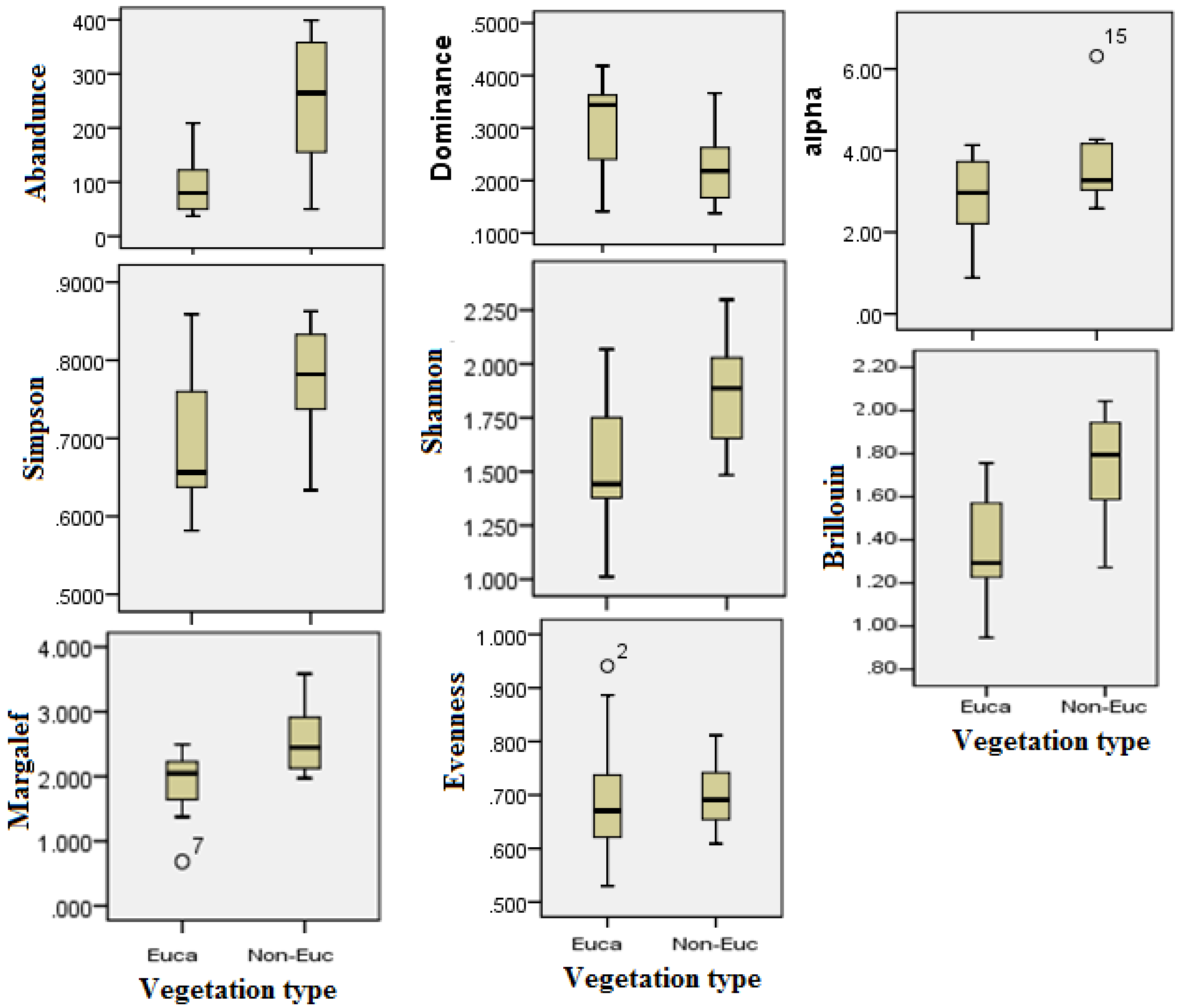

Figure 9: Box plots of indices along vegetation type scale.

Among diversity indices, Richness, Brillouin, individuals, Margalef, %ET, %ECT, %EOT, % Chiron, %Sc and %G/C were significantly discriminate between Eucalyptus and none Eucalyptus plant but the others were not discriminate(Table 7).

Table 7: Index sensitivity to discriminate between Eucalyptus and none Eucalyptus vegetation

Indices	P-value	Discrimination between groups
%ET	0.0004	Eucalyptus and none Eucalyptus
%ECT	0.0016	Eucalyptus and none Eucalyptus
Richness	0.0019	Eucalyptus and none Eucalyptus
% Sc	0.002	Eucalyptus and none Eucalyptus
Brillouin	0.0069	Eucalyptus and none Eucalyptus
Abundance	0.0087	Eucalyptus and none Eucalyptus

Indices	P-value	Discrimination between groups
% Chiron	0.0109	Eucalyptus and none Eucalyptus
%EOT	0.0206	Eucalyptus and none Eucalyptus
Margalef	0.0308	Eucalyptus and none Eucalyptus
%G/C	0.049	Eucalyptus and none Eucalyptus
Simpson-1-D	0.0641	None
Alpha	0.1427	None
%F/C	0.1643	None
%Odon	0.1897	None
Shannon	0.206	None
%Trico	0.237	None
%P	0.3959	None
Equitability-J	0.5371	None

5.2.5. Macroinvertebrate distribution based on functional feeding group

The streams under none Eucalyptus vegetation were majorly dominated by scrapers 25.45% while the streams under Eucalyptus vegetation were majorly dominated by collector-filterer 19.57%. More diversity of macroinvertebrate was recorded in streams under none Eucalyptus vegetation as indicated in (figure 10).

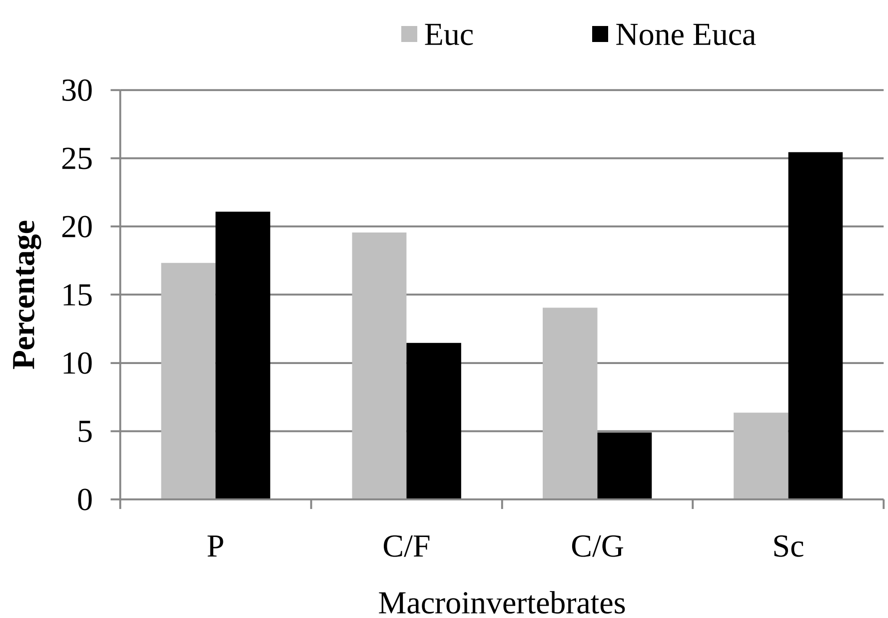

Figure 10: Functional feeding group with the Eucalyptus and none Eucalytus sites, P=predators, C/F= collector filtering, C/G=collector gathering, Sc=scraper,   No more shredder

5.3. Multivariate analysis results

5.3.1. Non-metric multidimensional scaling

NMDS analysis showed that the samples could be categorized in to two different groups. NMDS categorized the streams were flow under none Eucalyptus and Eucalyptus vegetation. NMDS that ordinates the data such that axis one explains R of 0.78 and coordinate two explains R values of 0.27 variance with the stressed value of 0.08. The sampling sites K2, B1, B2, B3, B4, B5 and k9 were grouped in to one group which was flow under the stream of none Eucalyptus vegetation except k9. The sampling sites K1, K3, K4, K5, K6, K7, K8, B6, B7, B8, B9, B10 and B11 were grouped in to another group which was flow under Eucalyptus vegetation except K1 and K3. K1 and K3 were grouped in to Eucalyptus vegetation of sample site as indicated in Figure 12.

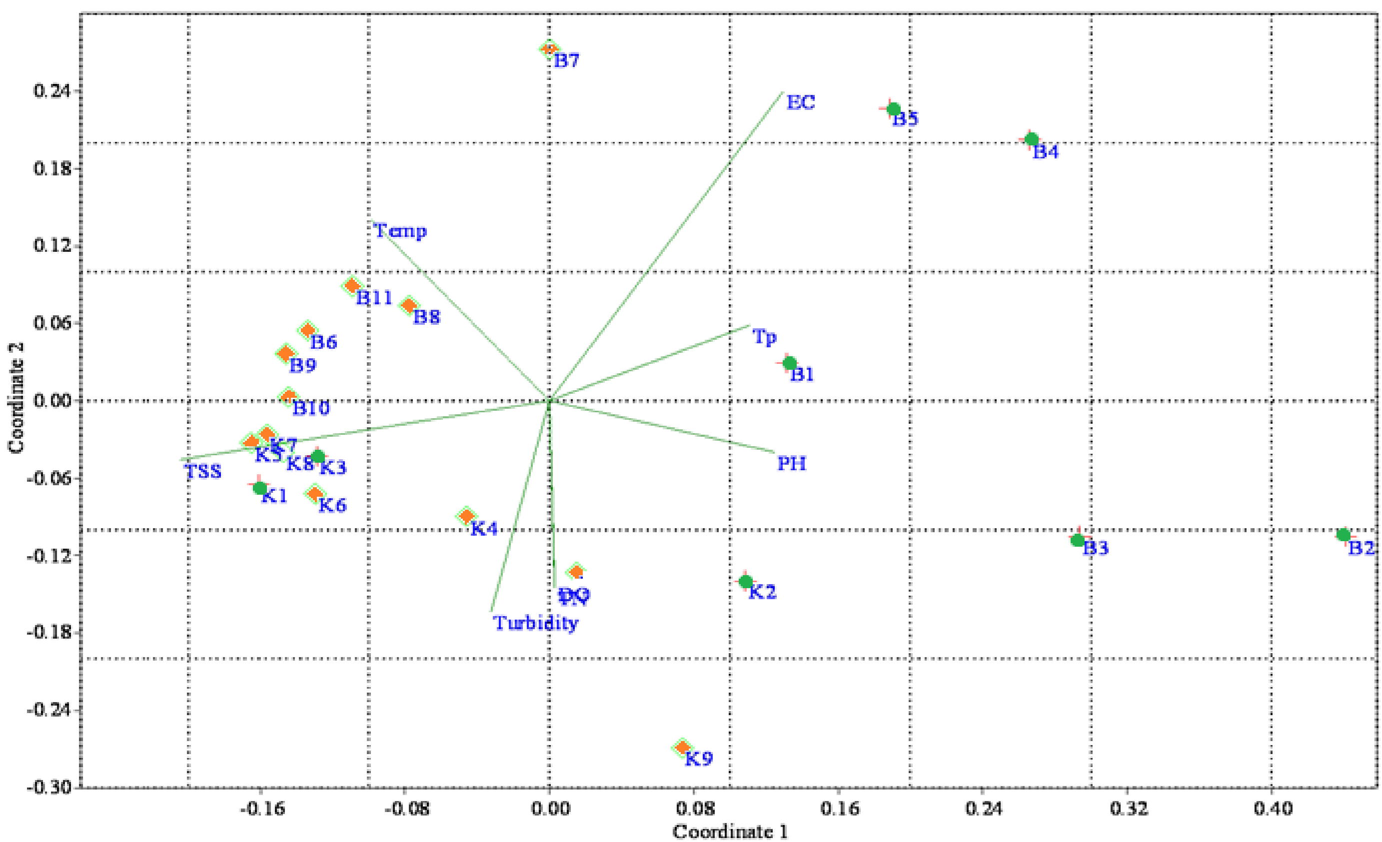

Figure 11: Non-metric multidimensional scaling (NMDS) analysis of environmental data and sampling sites using Euclidian distance.

5.3.2. Relationship between macroinvertebrate community and environmental predictors

The species-environment correlation coefficients explain axis one and two of the CCA bi-plot were 57.74%. From this biplot, the first axis was positively correlated with the environmental variables of TSS, water temperature, TN, turbidity and pH, with the sites of K2, K3, K4, K5, K6, K7, K8 and K9 and with the species of Odonata. CCA axis 2 was positively correlated with environmental variables of TP and EC with macroinvertebrates of Coleoptera and Mollusca along the site of K1, B2, B3, B4, B5, B7 and B11 and negatively correlated with that of TSS, water temperature, TN, turbidity and pH. For this analysis DO were removed because of overlapping with that of TN. In the other hand B6, B8, B9 and B10 positively correlated with environmental variable of TSS and species of Odonta (Figure 13).

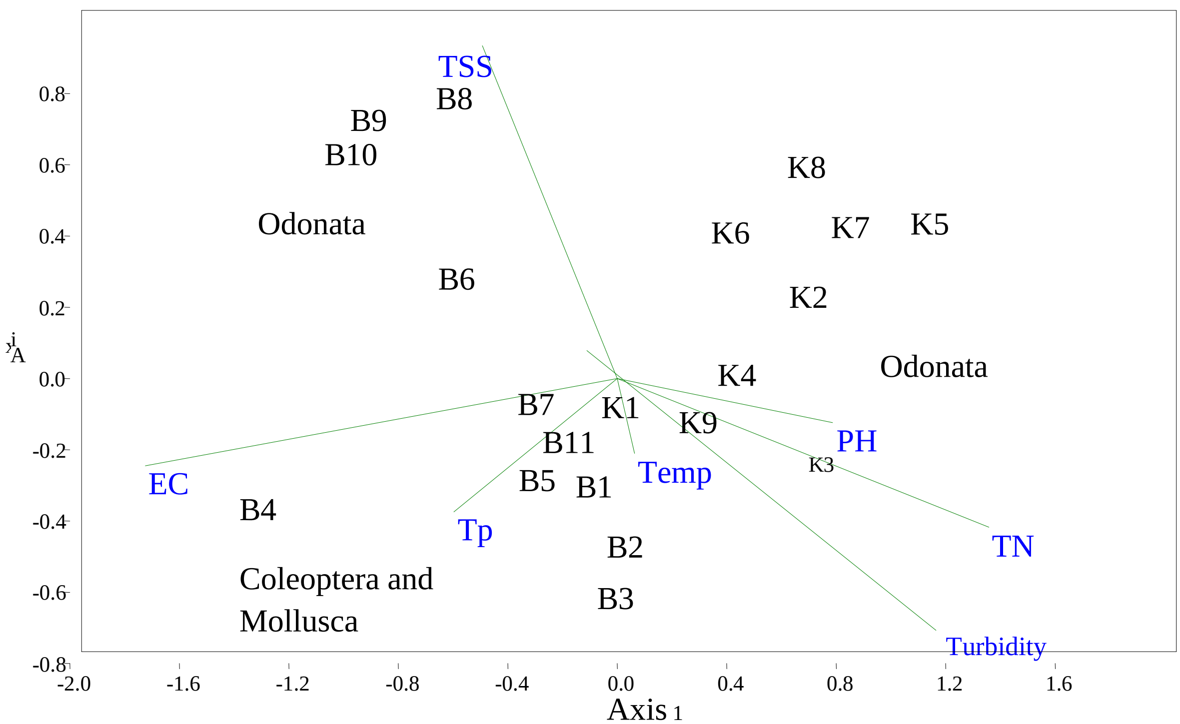

Figure 12: CCA bi-plot showing the distribution of macroinvertebrate with influencing of environmental variables in selected tributary stream of Gilgel Gibe River, southwestern Ethiopia, 2015.

5.4. Effects of different leaf litter on physicochemical characteristics

5.4.1. Control group (water without leaf)

The physicochemical parameter of water without leaf litter in laboratory activity was showed that EC was increased while pH, turbidity, and DO were decreased. TN was decreased while TP was increased within seven days interval as indicated in figure 13.

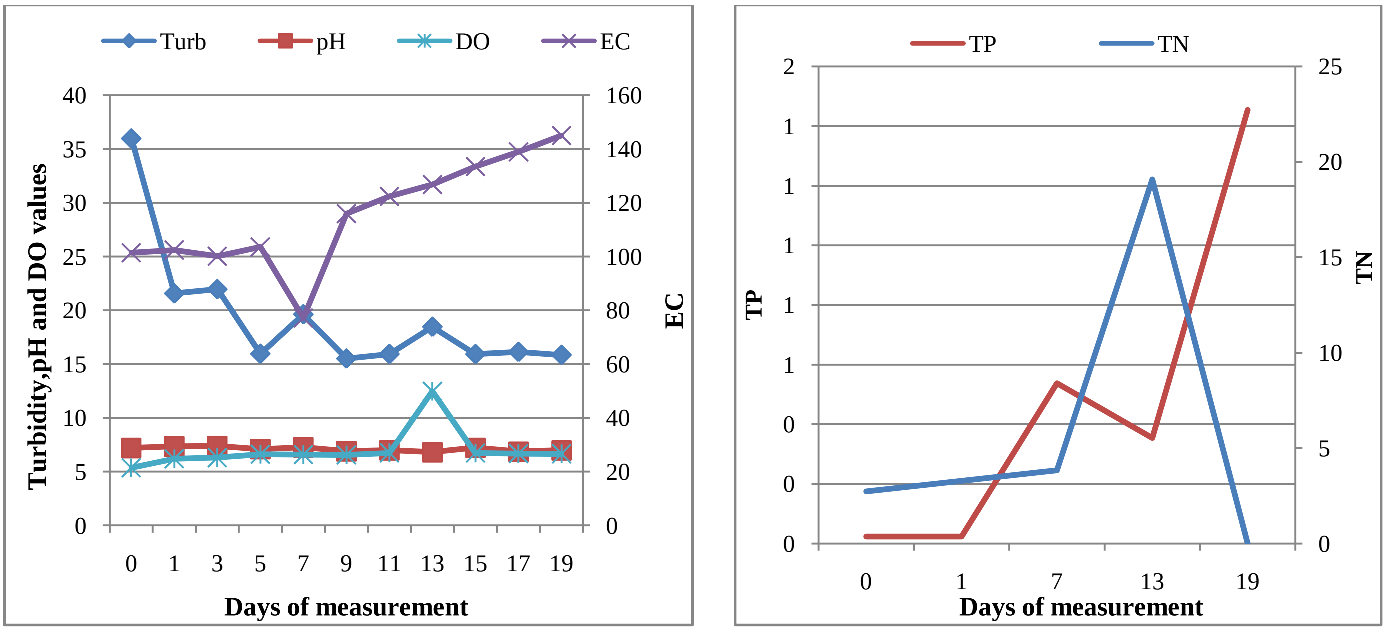

Figure 13: Water quality characteristics of the control water samples

5.4.2. Eucalyptus leaf in the experimental water

The effects of Eucalyptus leaf litter on physicochemical parameter of water shown that the values of EC was increased with decreasing of DO, turbidity and pH within three days interval and TN and TP were increased within seven days interval but TN was decreased in the last day measurement. However, the pH of this experiment was more acidic 4.82-5.48 as indicated in figure 14.

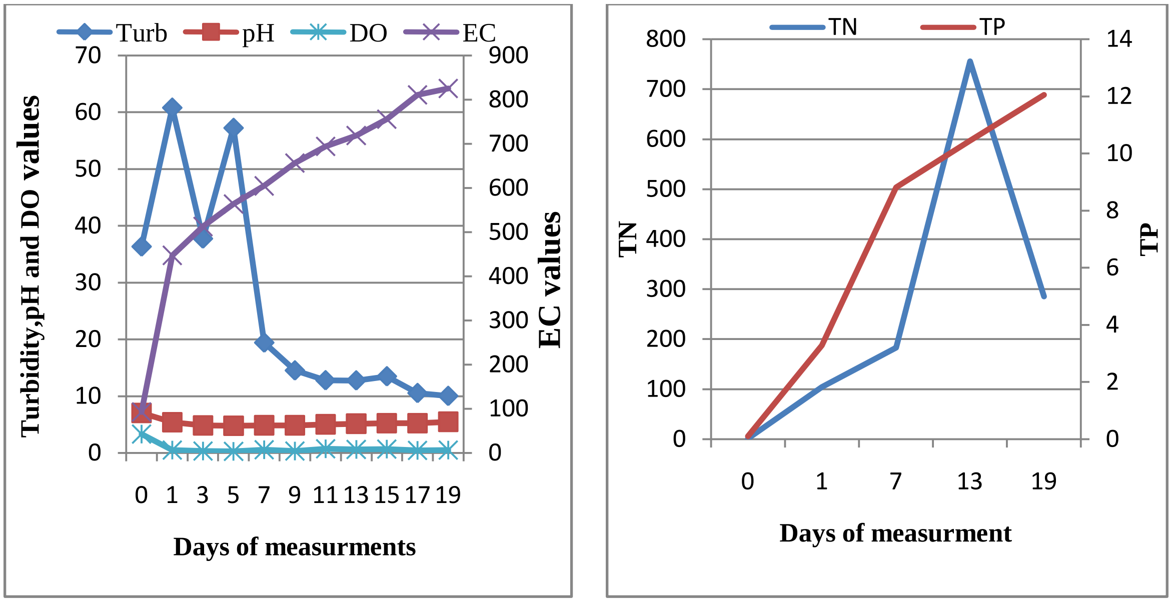

Figure 14: Water quality characteristics of the Eucalyptus leaf water samples

5.4.3. Croton macrostachyus in the experimental water

Croton macrostachyus had increased the values of electrical conductivity from 99 μc/cm to 3007 μc/cm. TN was decreased and TP was increased within 7 days interval, while the rest parameters that are turbidity, dissolved oxygen, pH and DO saturation were decreased as indicated in Figure 15.

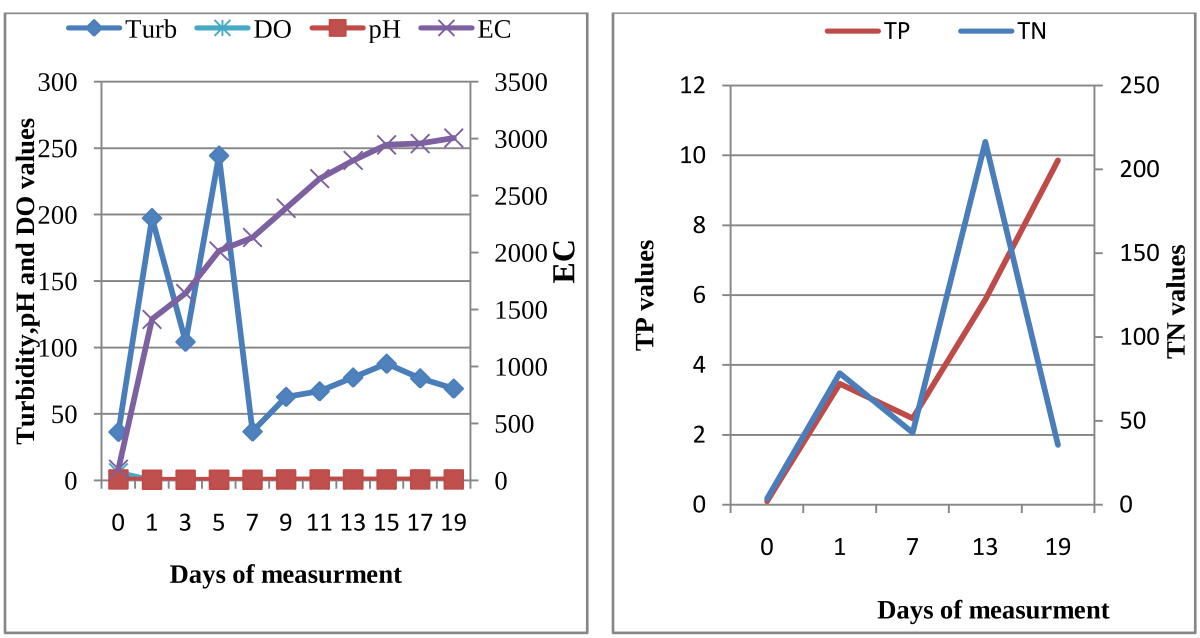

Figure 15: Water quality characteristics of the Croton macrostachyus leaf water samples

5.4.4. Ficus sure in the experimental water

Ficus sure plant leaves had significantly increased the rates of EC which was measured 99 µc/cm to 1660µc/cm whereas, the values of turbidity and DO was decreased . The pH values of water was it ranged between 6.65-7.7. TN and TP were decreased with in seven days interval (Figure 16).

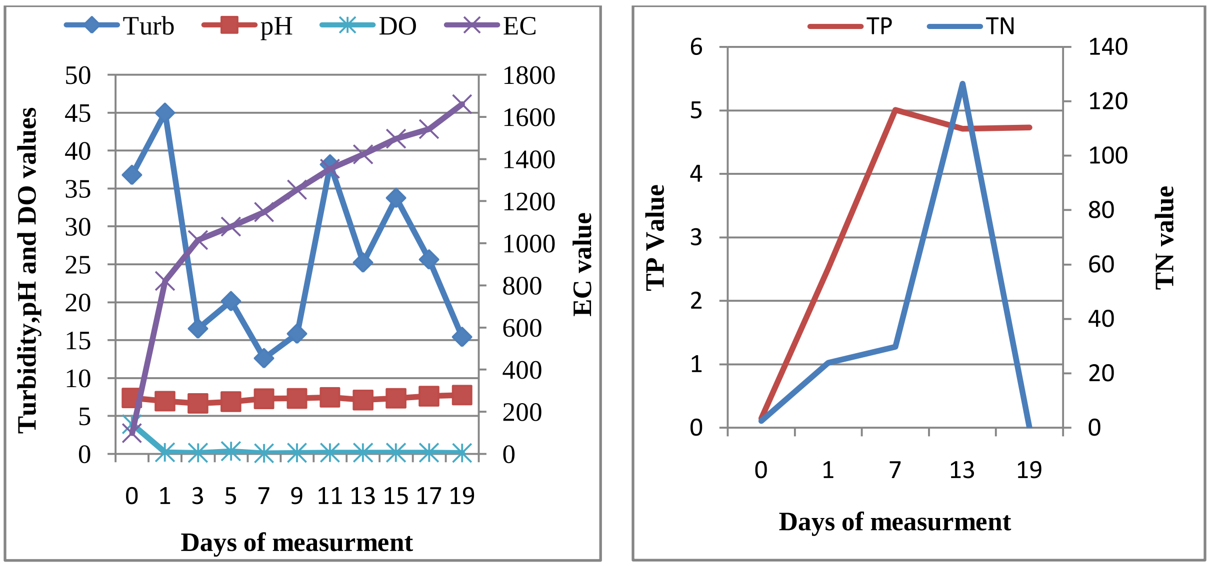

Figure 16: Water quality characteristics of the Ficus sure leaf water samples.

5.4.5. Salix subserrata leaf litter and water

The efffects of salix leaf was almost similar with that of eucalyptus leaf on water physicochemical characterstics. As concentration of electrical conductivity was increased within three days interval for one month whereas the pH value, dessolved oxygen, turbidity were decreased. TN was decreased in the last day where as TP was incresaed when EC increased as indicated in figure 17 .

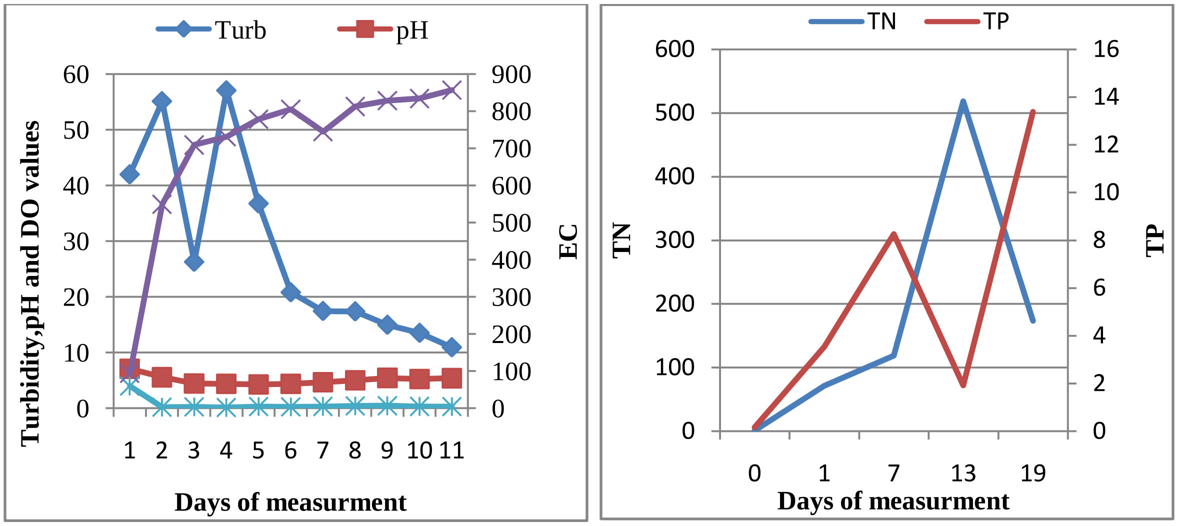

Figure 17: Water quality characteristics of the Salix subserrata leaf water samples

CHAPTER SIX: DISCUSSION

This study investigates the effects of Eucalyptus plant on water quality and macroinvertebrates diversity in selected tributary streams of Gigel Gibe River, Southwestern Ethiopia. Thoughtfully the aquatic ecosystem and diversity of macroinvertebrates are affected by water quality parameters, the availability of exotic plants such as Eucalyptus and the removal of native riparian vegetations (Graça *et al*., 2002; Rios & Bailey, 2006).

In this study, high values of pH, DO, TN, and TP were recorded in the streams under none Eucalyptus vegetation. On the contrary, low values of EC, TSS and turbidity were found. The reason for elevated values of TSS, turbidity, EC in the streams under Eucalyptus tree could be due to the effects of the leaf litter and washing of cloth in the streams. The values of TN, TP and pH were low under the streams of Eucalyptus tree. This might be due to reducing of nutrient cycling by Eucalyptus tree with similar finding of (Poggiani, 2013; Basin *et al*., 2008; Pozo et al., (1997). The values of pH in the streams under none Eucalyptus vegetation was recorded 7.68 while in the streams under Eucalyptus vegetation was recorded 6.86. A laboratory experiment also indicates that the pH value revealed low in Eucalyptus leaf litter. This might be due to phenolic acid released from Eucalyptus leaf litter as it was reported by (Larrañaga et al., 2009) Therefore, in this study the water quality parameters such as pH, DO, TN, and TP were positively correlated with that of streams under none Eucalyptus vegetation with similar result was reported by (Wallace & Webster, 1996). As experimental laboratory results of water samples containing leaf litters shown that the EC and TP were continuously increasing while, turbidity, TN and DO were continuously decreasing until the last day of the experiment. This might be due to the releasing of ions from the leaf litter. In all plant leaf litters TN were gradually decreased. This might be due to the elimination of nitrogen by microorganisms as it was reported by (Martínez *et al*., 2015). Therefore, this experiment clearly shown that the Eucalyptus leaf litters can affect the physicochemical parameters. This could be the main factor that can affect the diversity of aquatic macroinvertebrates.

Low diversity of macroinvertebrates was also recorded under the streams of Eucalyptus tree. In these streams, order Ephemeroptera 18.15% was dominant with dominant family of Caenidae 53.4%, order Odonata 17.1% with the dominant family of Coenagrionidae 61.26% followed by order Diptera 8.65% with the dominant family of Chironomidae 94.06%. This might be due to those macroinvertebrates are pollution tolerant and they can survive under Eucalyptus tree with similar finding reported by Albert (2005). On the hand, in the streams under none Eucalyptus vegetation, order Ephemeroptera 43.59% was dominant with dominant family of Beatidae 34%, order Tricoptera 15.6% with the dominant family of Haydropsychidae 96% followed by order Diptera 8.65% with the dominant family of Chironomidae 52%. Pollution sensitive macroinvertebrates were dominant in the stream of under none Eucalyptus vegetation as it was reported by (Ambelu *et al*.,2010). In non Eucalyptus vegetation such as Ficus sure and Croton macrostachyus leaf litters the pollution sensitive macroinvertebrates were more colonized. In parallel study by Chalchisa (2015) the artificial substrate without leaf litter was more convenient for the colonization of macroinvertebrate as compared to substrate containing leaf litter. Among leaf litters Ficus Sure showed relatively more colonized by macroinvertebrate than the other litters. But Eucalyptus grandi shows a minimum diversity of macroinvertebrate colonization. In contrast, sensitive macroinvertebrates were low colonized in Eucalyptus leaf. The diversity of EOT, ECT and ET macroinvertebrates were more diverse in the stream of none Eucalyptus vegetation than that of streams under Eucalyptus vegetation. This might be due to the variation of electrical conductivity with in vegetation type with similar finding reported by (Mosisch et al., 200). The functional feeding groups of scrapers (25.45%) were dominant in the streams under none Eucalyptus vegetation. In the contrast, Filtering/collectors (19.57%) were dominant in the stream under Eucalyptus vegetation. As study conducted (Canhoto, 2002 & Tiku et al., 2012) reported that pollution sensitive macroinvertebrates were dominant in the stream under riparian vegetation.

Based on the None-metric multidimensional scaling analysis, the relationship between physicochemical parameters and sampling sites using Euclidian distance were determined. NMDS were clearly categorized the streams flow under none Eucalyptus and Eucalyptus plantation. The streams under none Eucalyptus vegetation sites were categorized in to one group and significantly positively correlated with environmental variables of TP, TN, DO and pH. In contrast, the streams under Eucalyptus vegetation were significantly positively correlated with environmental variables of turbidity, TSS, and EC.

CHAPTER SEVEN: CONCLUSTION AND RECOMMENDATION

7.1. Conclusion

Water quality under the streams of none Eucalyptus vegetation was significantly positively correlated with TN, pH and TP. In contrast turbidity, TSS and EC were positively correlated with Eucalyptus tree.

From macroinvertebrate diversity order Ephemeroptera, and Trichoptera were dominantly found in the stream under none Eucalyptus vegetation whereas, Odonata, and Diptera were dominantly found in the streams under Eucalyptus vegetation. However, the occurrence of macroinvertebrate diversity seemed to be more related with the streams under none Eucalyptus vegetation than to the stream under Eucalyptus vegetation.

EC and TP were continuously increasing until the last day of the experiment and continuous decreasing of DO, TN and turbidity were recorded.

7.2. Recommendations

Since the Gibe river basin watershed is located in Omo-Gibe river basin the replacement of none Eucalyptus vegetation by exotic vegetation and riparian zone degradation may have local and regional impacts. Based on the study finding the following recommendations are forward.

- This study also indicted that the exotic plant species (i.e. Eucalyptus plant species) has an impact on the diversity of macroinvertebrate. On the other hand, native plant species were found to be convenient for macroinvertebrate diversity when compared with exotic plant species. Therefore, measures has to be taken by study area Woredas and Zonal Agricultural and Rural development office of Jimma with the concerned stakeholders to buffer the Rivers and Streams by native plant species.

- Eucalyptus plant species have to be planted in the specific area where streams are not closely found.

- We also recommend that to see the effects of leaf litter decomposition in line with water quality and diversity of macroinvertebrates by including larger sampling of different leaf litter.

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site code	QHEI	Quality class	Land use score	Quality class
K1	146	Very good	2	Minimally impacted
K2	162	Very good	2	Minimally impacted
K3	151	Very good	2	Minimally impacted
K4	120	Very good	2	Minimally impacted
K5	124	Very good	2	Minimally impacted
K6	123	Very good	2	Minimally impacted
K7	143	Very good	2	Minimally impacted
K8	132	Very good	2	Minimally impacted
K9	152	Very good	2	Minimally impacted
B1	137	good	2	Minimally impacted
B2	122	good	2	Minimally impacted
B3	101	good	2	Minimally impacted
B4	86	good	2	Minimally impacted
B5	67	good	2	Minimally impacted
B6	64	good	2	Minimally impacted
B7	61	good	2	Minimally impacted
B8	64	good	2	Minimally impacted
B9	64	good	2	Minimally impacted

B10	60	good	2	Minimally impacted
B11	62	good	2	Minimally impacted

HABQ score categorization criteria: optimal (excellent= 161-200), sub optimal (very good=121-160), marginal (good=60-120) and poor= 0-59 and land use score scale is 0 to 5 (0= None; 1= Low; 2=Moderate; 3=Large; 4=Serious; 5 =Extreme impacted)