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GIS-modeling of riparian vegetation: A case study in ecosystem services in and along Lierelva as indicated by macroinvertebrates

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Abstract

Lierelva is a river located in SE-Norway in Auskog-Holand municipality. It has a large drainage area and joins Lake Bjorkelangen in the south.

This study has two major purposes: (1) determine the various types of riparian vegetation along Lierelva using ArcGis; (2) explore how ecosystem services and ecological relationships of riparian vegetation affect River Lierelva and the surrounding communities based on macroinvertebrates. Additionally, information on land-uses and management practices was discussed. The macroinvertebrates that were obtained were analyzed in terms of diversity, abundance, distribution and richness.

In the first of the thesis, general information about riparian vegetation, ecosystem services and anthropogenic impacts/threats are represented. The data derived of GIS modelling were systemized and presented. The data showed that four main CORINE classes of riparian vegetation (arable land, pasture, forest and urban fabric) surround Lierelva. A worrying trending of conversion of intact forests to other land-uses was evident from the data. Based on data from the analysis of macroinvertebrates, high figures for species abundance, species richness, species diversity and ASPT Index were detected in samples close to intact forests. On the contrary, relatively low figures were recorded for samples close to agricultural, pasture land-uses and urban fabric. This trend is attributed to the ecosystem services such as erosion prevention, water purification, temperature regulation etc. provided by intact forests. Finally, the results obtained were interpreted in the discussion part regarding how surrounding communities benefit from these ecosystem system services. Also, a comparison of the average ASPT Index with water quality chart/tables was done to determine the overall water quality of Lierelva.

It was concluded that, Lierelva has reasonable amount of riparian vegetation along its banks and that their presence is vital to the river ecosystem and the surrounding communities. The water column remains unpolluted and the river ecosystem is not suffering from the negative effects of degradation of riparian vegetation yet. The major sources of organic and inorganic pollution are anthropogenic**,** sedimentation and nutrient deposition, which will all increase at the current rate of forestlands conversion. Enactment of good policies coupled with strong stakeholder involvement can help stop their degradation.

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Chapter 1

1.0 Introduction

1.1 Background

The world depends extensively on natural ecosystems for sustenance: providing food, shelter, minerals, timber, pharmaceutical and cosmetic products (Haines-Young and Potschin, 2010). In addition to these goods, natural ecosystems perform vital life-support services without which humans cannot survive (Daily, 2003). Some of these essential services include waste decomposition, pollination, flood mitigation, detoxification of pollutants, air and water purification, oxygen production, climate regulation, regeneration of soil fertility, among several others. These services are produced through series of natural cycles or phenomena involving interaction between both biotic and abiotic aspects of natural ecosystems on a wide range of space and timescales (Chapin et al., 2011).

With growing human population, the dependence on ecosystem services is expected to more than double. This is increasingly altering the capacity of the ecosystem services to keep providing essentials for human needs. This has necessitated a need for an improved understanding of ecosystem services and interactions, which can then be incorporated into policies, guidelines and management plans to ensure their longevity (Carpenter et al., 2009). Equipped with such rounded knowledge helps in making informed decision regarding all aspects of life such as economic, socio-culture and health amongst others.

Ecosystem services are, however, still faced with ambiguity in definition and subjection to human interests. This has led to the underestimation of the value of ecosystem services and destruction of underlying ecological systems that generate them. Human reserve the right to determine which services are beneficial or not, have potential or not, deserves to be protected or not, and more. As a result, some ecosystem services are given attention whereas others are neglected. Moreover, if humans are opposed to certain conservation measures because they are space consuming, expensive, time consuming etc., they might not be implemented, which can have negative effects on the natural environment (Young, 2000).

Because of the increasing threats to these systems, there is a critical need to identify and monitor ecosystem services both locally and globally. Determining the economic value of ecosystem services offers stakeholders such as resources managers, planners, government decision-makers with information such as national atlas of ecosystem services, interactive maps, and predictive models (Jordan et al., 2010). This can assist the stakeholders to assess management options, costs, and constraints in the context of ecological benefits, to sustain, enhance, and be accountable for valuable ecosystem services, and to measure the worth of ecosystem services to human health and well-being (Jordan et al., 2010).

Riparian zones are long known to be of importance to riverine ecosystems and the adjoining terrestrial ecosystem (Pusey and Athington, 2003). Riparian zones are strips of vegetation that border water bodies (Grebner and Siry, 2013), which serve as interface between the waterbodies and upland ecosystem. Despite all the benefits that are derived from riparian vegetations, their importance is often overlooked or underestimated. This is because people do not understand their roles in natural ecosystems and these areas are sometimes seen as a blight along the majestic waters of the rivers (La Notte, et al., 2017). Also, perceived threats of riparian vegetation to other land-uses such as agriculture and property development makes the concept unpopular. It is then important to address how we can better document, understand and protect and preserve riparian vegetations.

1.1.0 Riparian Vegetation Classification

Riparian vegetation classifications offer integrated information systems that can be used to communicate and interpret current land use, which is helpful in future choices, developing and monitoring for improving management (Crawford, 2003). Standard classification is necessary to capture the variability and diversity of riparian vegetation (Kovalchik and Clausnitzer, 2004). Many different classification systems are used throughout the world, however, the CORINE systems is mostly used in Europe. CORINE stands for “coordination of information on the environment”. It was introduced in the European Union in 1985 as a prototype project working on many different environmental issues. The database that was generated is used in most areas of Europe. The CORINE Landcover system contains land cover in 44 classes, and presented as a cartographic product, at a scale of 1:100 000. The aim of this systems is to provide consistent localized geographical information on the land cover of the 12 Member States of the European Community (European Environment Agency, 1995). This was necessary because information regarding land cover at national levels in Europe had always been heterogenous, fragmented and unavailable (EC, 1992a). This uniform and standard database combined with other geographical information such climate change, soils, demographics can be used in planning and implementation of environmental policy in the region.

1.1.1 The complex ecological interactions

Intricate and delicate relationships exist between riparian vegetation and the riverine ecosystem around which they surround. Many players are involved ranging from the microscopic organisms in river sediments to the large terrestrial animals that live in the vegetation. These interactions provide numerous ecosystem services to the river, the vegetation and surrounding communities. These services or benefits are often only obvious to people in the field of ecology. Therefore, these services are often ignored, underestimated or exploited. The multidisciplinary approach of incorporating economics into environmental issues is proposed as a way of explaining this ecological issue. All identified ecosystems services of riparian vegetation such as erosion prevention, climate regulation, air purification among others are given economic values. The value of ecosystem services can be calculated by multiplying a set of ecosystem services by a set of corresponding shadow prices (Howarth and Faber 2002). This approach can help people to appreciate ecosystem services in monetary terms which is easily understood. Calculating the economic value of the riparian vegetation along waterbodies will give the factual importance, fill in the knowledge gaps, thereby eliciting concerted efforts from stakeholders to preserve the natural resources (Stoeckl *et al.*, 2011).

1.1.2 Macro invertebrate as environmental indicators.

Macro invertebrate can be used as indicator of the state of ecosystems (Pinel-Alloul *et al.*,1997). The response and history of assemblage of macroinvertebrates to variations in an ecosystem can indicate an ecosystem under stress or its resilience and resistance toward disturbance both anthropogenic and natural. Certain macroinvertebrates are highly sensitive to pollution whereas others are tolerant. For instance, the decline in the assemblage of pollution sensitive organisms can indicate an introduction of pollutants into the river ecosystem. Information such as biological oxygen demand (BOD), pH and clarity can all be determined by examining aquatic macroinvertebrates. The presence of certain invertebrates can tell the water quality of an ecosystem when their Average Score Per Taxon (ASPT) Index is referenced (Payakka and Prommi, 2014).

Determining various classes of riparian vegetation along a waterbody, the kind of ecosystem services they provide and their economic worth and how landuse-landcover practices are affecting them using the macroinvertebrates as indicator is very prudent. The focus of this study will be on riparian vegetations along Lierelva located in Lier. The riparian zone will be studied to ascertain its effects on the river and surrounding communities. I hypothesize that riparian zone renders ecosystem services to Lierelva and the surrounding communities.

1.2 Research objectives

Riparian vegetation and water bodies are of central importance to any terrestrial ecosystem. Understanding the complex interactions that exist between them is a step in protecting these delicate ecosystems. Many studies focus on water pollution, water volume regulation and riparian vegetation degradation. This study will be one of the few utilizing GIS data in studying ecosystems. This study is built around questions such as: What ecosystem services are derived from riparian vegetation along water bodies? How do ecosystem services of the riparian vegetation affect water bodies and surrounding communities? What ecological interactions exist between riparian vegetation and water bodies?

The aim of the study is to:

- determine the various types of riparian vegetation along Lierelva using ArcGis.
- explore how the ecosystem services of the riparian vegetation affect River Lierelva and the surrounding community.
- determine the ecological relationships that exist between rivers and riparian vegetation by sampling macroinvertebrate from different stretch of the river representing different types of land use in the riparian zone.

Chapter 2

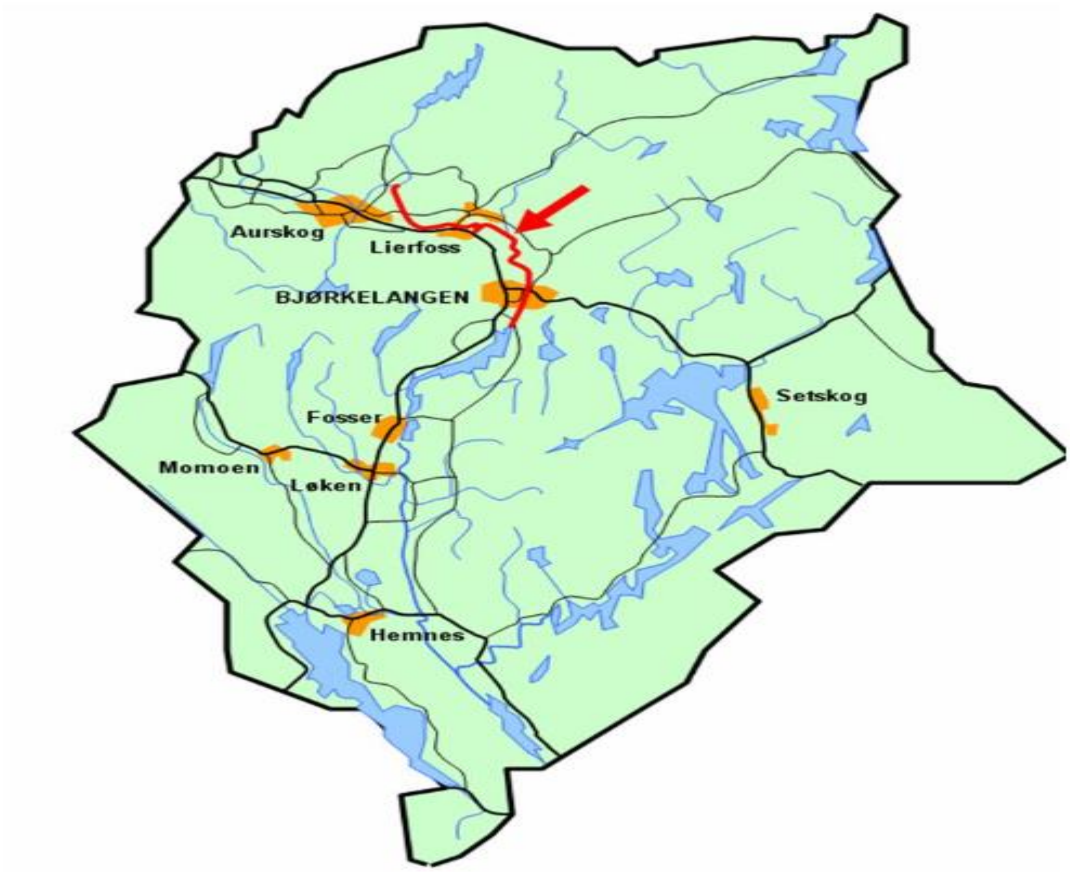
2.0 Method

2.1 Study Site

The project site is Lierelva in the Auskog-Holand municipality in the Viken County. Lierelva has a total length of 16.8km^2 and catchment area of 23.4km^2 (coordinates of 59^{0} $56^{'}25^{''}$ N 11^{0} $29^{'}$ $34^{'}$ S). It stretches from Lokshaug in the north into Lake Bjørkelangen in the south meandering through the bottom of its main valley in the eastern part of Auskog. Some of Lierelva's various side channels include Toverudbekken, Kvernbekken and Gorrelva. Due to erosion and sedimentation, river materials include both suspended materials and bed loads. The suspended materials mostly consist of fine particles (clay, silt and organic material) whereas the bed loads may consist of sand and coarser particles.

This site was specifically chosen for this project because of the reasonably thick riparian zone, which is under threat from anthropogenic sources. In 2016, Mjåland (2016) reported that River Lier was polluted by oil spillage from a car care business nearby, which contaminated the water column and aquatic life. There is extensive tree cover degradation from logging activities, encroachment resulting from property development and farming. It is also one of Norway´s fishing hotspots for crayfish, *Astacus fluviatilis*. Moreover, most of the river flows through highly fertile agricultural landscapes leading to nutrient enrichment and coloration due to runoff and erosion.

Figure 1: Map showing the channel of Lierlva, pointed with red arrow.



2.2 Sampling procedure

Sampling of Micro-invertebrates

Micro-invertebrates were sampled using the kick sampling method (Brua *et al*., 2011). Four sample points (S001, S002, S003 and S004) were identified to represent the whole length of the river and the various riparian vegetation classifications. Each sample point was further divided into three sub-sample points and sampled separately to make a total of twelve samples. Samples were collected using a standard kick net of $1\times 1m^2$ mesh. The samples were put in rubber bags and filled with ethanol to preserve the micro-invertebrates. The samples were each labelled with their unique identification codes, date of sampling, location and GPS coordinates. They were immediately kept in coolers and transported to Norwegian University of Life Sciences laboratory to be refrigerated.

2.3 Identification of Micro-invertebrates

All three samples from the same sample points were mixed on one tray and ethanol was added. Micro-invertebrates were then examined under magnifiers and microscopes to identify their physiological characteristics. They were then classified (family and/or order) and counted. Their Average Score per Taxon (ASPT) values were determined using the family scoring chart shown in appendix A (Salur et al., 2016).

2.4 Landcover Classification

2.4.0 Materials

Various data was utilized for the input modelling in the GIS study. GIS stands for Geographic Information Systems. These data types were grouped into two, namely; remote sensing (RS) data and reference data. The study was based on the utilization Landsat obtained in the year 2017. The satellite image was downloaded from the U.S. Geological Survey (USGS) database. The selection of this imagery used based on the availability and suitability related to cloud cover (the acceptable cloud cover should not be more than 10%). The reference data used were collected from the world topographical maps, field photographs and land cover types of the study area. Geographical Positioning System (GPS) points were also sampled for all the different land cover types and used for training data during the classification. The vector data showing the administrative boundaries were also used to define the area of study.

Table 1: Data used for the GIS modelling.

RS Data	**Date Acquired**	**Resolution**	**Source**
Landsat 8	10.04.2019	30m	USGS Geospatial Data Sources

Reference Data		**Scale**	**Source**
Topographic Map		Approximately 1:4000	ESRI
Corine Data		1:100,000	Copernicus
GPS points	4 points		

2.4.1 Landsat Image

The satellite image was obtained from the USGS database with 196/18 as the path/row scene. The Landsat imagery used was in the summer season. This was to avoid snow and obtain clear imagery for the extraction of relevant classes relying on identification vegetative state.

2.4.2 Software Used

The research employed ArcGIS 10.7.1 for the satellite imagery classification around the Lierlva. It was used for pre-processing and satellite imagery classification.

2.4.3 Image Pre–Processing

The satellite images were processed geometrically and radiometrically to ameliorate errors coming from sensors, the earth's curvature and atmospheric effect. Landsat images were resampled using the Nearest Neighbour Algorithm. The Nearest Neighbour resampling method was used because of its simplicity and its capability to keep the original values of the original image. Subsequently, the images were projected to the Universal Transverse Mercator (UTM) system zone 32N.

2.4.4 Generating Subsets

Since the satellite images had a larger area of extent, subsets were generated for the areas of interest. They were extracted from the shape files of the county Akershus. The single bands were stacked to obtain composite bands for onward analysis excluding the thermal bands.

2.4.5 Satellite Image Classification

In this study, the supervised method was applied since the creation of training samples aids in enhancing the accuracy of the classified images. The Leo Breiman Random Forest (RF) classifier has received intensive attention due to the fact that it produces reliable results and it has high speed of processing. The research did not apply the traditional parametric statistical approaches which depend on the assumption of normal data distribution. The RF algorithm is not limited by statistical assumptions and thus was adopted for the study.

2.4.6 Selection of appropriate classification scheme

The Corine Land Cover (CLC) nomenclature with a scale 1:100,000; a Minimum Cartographic Units (MCU) of 25 hectares and a geometric accuracy better than 100m. it is a 3-level hierarchical classification system with 44 classes. Broadly on the first level, the categories are artificial surfaces, agricultural areas, forest and natural areas, wetlands and waterbodies. The CORINE classification scheme based on the second level was thus used in this study as illustrated in the Table below.

Table 2: Land Use Land Cover Classes

Land Cover Category	**Description**	
Arable Area	Non-irrigated arable land	Permanently irrigated land
Pasture	Grassland	
Forest	Broad-leaved forest Mixed forest	Coniferous forest
Urban Fabric	Continuous Urban Fabric	Discontinuous Urban Fabric

2.4.7 Selection of Bands

The multiple bands (without the thermal bands) were stacked together to obtain a composite band. The most important color composite bands are the natural color and false color composites. A third way of visualizing satellite imagery was the use of arbitrary colors. Additive color composite is the most popular way of visualizing satellite images composed of a minimum number of three bands by assigning each to the primary colors namely Red, Green and blue (RGB).

2.4.8 Selection of Training Areas

Ancillary data (google historical maps and topographical maps) aided the selection of the training areas in the study area.

Chapter 3

3.0 Results

3.1 Identification of macroinvertebrates

At sample point S001 with coordinates 59^0 55'26.07N 011^0 29'56.48E, the sediments were mostly composed of rocks. The most abundant macroinvertebrates identified from the samples from this site were of the family *Oligichaeta* with 19 individuals, *Lepidostomatidae* with 15 individuals, and the least *Siphlonuridae* with 2 individuals. The Shannon Diversity Index calculated here was 2.16. The immediate land use on this section is pasture.

Species	**Number of Individuals**	**Family Score**
Siphlonuridae	2	10
Ecdyonuridae	5	10
Potamanthidae	8	10
Nemouridae	4	7
Hydropsychidae	5	5
Aeshnidaes	8	8
Perlodidae	3	10
Leuctridae	4	10
Oligichaeta	19	1
Lepidostomatidae	15	10
Simuliidae	3	5
ASPT Score		**7.8**

Table 3: Macroinvertebrate assemblage from sample site S001 with its family score and ASPT Index.

At sample point S002 with coordinates 59^0 55’55.33N 011^0 29’41.67E, here the bottom sediments are mainly rocks interspersed with coarse sand, and as a result there is little sediments deposition. The adjoining landcover is mainly forest. The most abundant organisms isolated from this sample were *Ecdyonuridae, Limnephilidae, Oligochaeta* respectively. The bottom sediment here consisted mostly of organic material and soil. The Shannon Diversity Index is 2.17.

Species	**Number of Individuals**	**Family Score**
Ecdyonuridae	21	10
Amphinemura borealis	3	7
Limnephilidae	18	7
Oligochaeta	15	3
Tipulidae	2	5
Potamanthidae	7	10
Ryacophila nubile	7	7
Philopotamidae	5	8
Heptageniidae dalecarlica	4	10
Odonata forcipatus	5	10
Lepidostomatidae	15	10
ASPT Score		**7.9**

Table 4: Macroinvertebrate from assemblage sample site S002 with its family score and ASPT Index.

The sample S003 with coordinates 59^0 54’ 16.24N 011^0 34’17.94E, the bottom sediments in this location was mainly mixture sand and clay with the adjoining landcover being arable land. The most abundant macroinvertebrate was of the *family Baetis sp* with 52 individuals, followed by the species Anabolia nervosa with 30 individuals, with least abundant being of *Asellus aqauticus* and

Taeniopteryx. The bottom sediment was made up of organic material and sand. The Shannon Diversity Index is 1.72.

Species	**Number of Individuals**	**Family Score**
Anabolia nervosa	30	7
Platycnemis peniipes	3	6
Amphinemura sulcicolis	6	7
Gomphidae	9	8
Asellus aqauticus	2	3
Ephemera vulgate	3	10
Taeniopteryx	2	10
Baetis sp	52	4
Simuliidae	6	5
Oligochaeta	5	1
Rhyacophila nubila	2	7
ASPT Score		**6.2**

Table 5: Macroinvertebrate assemblage from sample site S003 with its family score and ASPT Index.

At sample S004 with coordinates 59^0 53'58N 11^0 34'02E, the sediments mostly consisted of organic material and soil. The most occurring macroinvertebrates from this site were of the family *Ecdyonuridae* followed by *Limnephilidae* and the least being *Nemouridae*. The Shannon Diversity Index is 1.55. The immediate riparian vegetation falls in the class of forest.

Species	Number of Individuals	Family Score
Limnephilidae	17	7
Oligochaeta	8	1
Ecdyonuridae	75	10
Siphlonuridae	3	10
Philopotamidae	6	8
Corixidae sp	3	5
Hydropsychidae	3	5
Nemouridae	2	7
Polycentropodidae	7	7
Elmidae	9	5
ASPT Score		**6.5**

Table 6: Macroinvertebrate assemblage from sample site S004 with its family score and ASPT Index.

(*A summary of information about every sample site is found in appendix B).*

3.2 Description of Landcover Classification

The examination of the classification was through both physical observation and GIS tools. There was some type of landcover and land use along every stretch of the river, mainly plants such as trees, shrubs, agricultural fields and grassland. The few developments that dotted along the river are farmhouses, peat extraction businesses and scattered residences. No urban fabric (development) was found on the bank of the river, however they fell within the 100m ranged that was buffered. Most of the forest cover is found toward the northern part of the river.

The ArcGIS data showed that total landcover was 294.21ha with 38,76% (area of 114.030) covered by arable land, followed by pasture with which covers 38.05% (area of 111.96 ha), forest covers 21.66% (area of 63.72%) and urban fabric with 1.5% (area of 1.5%).

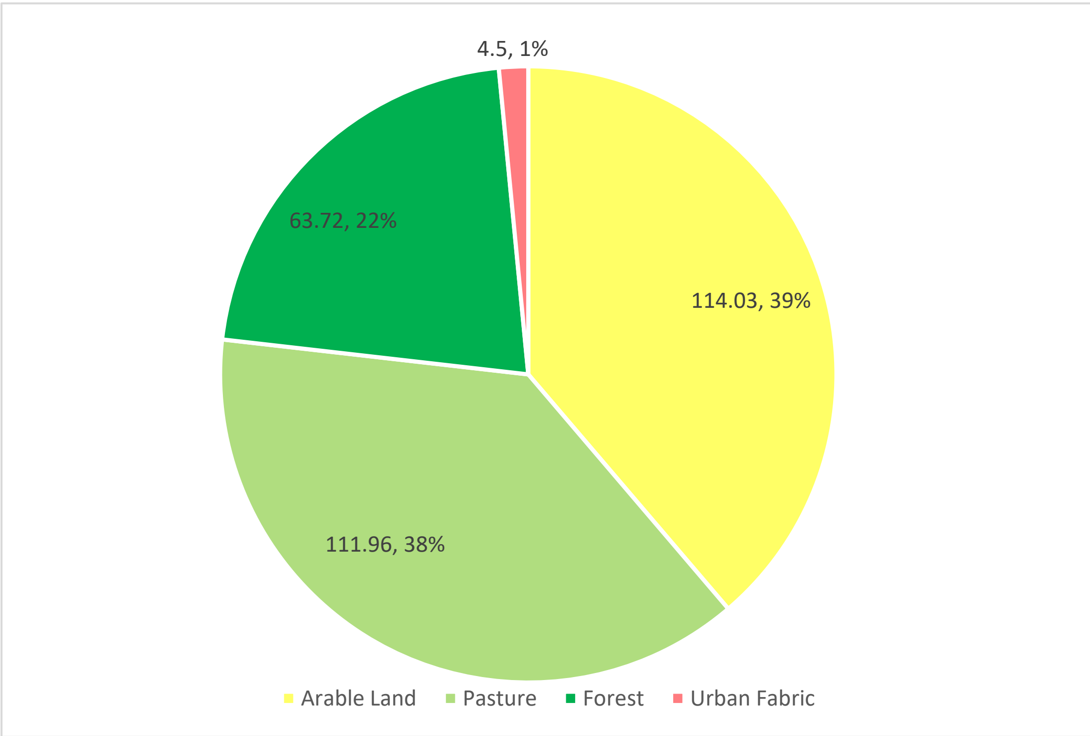


Figure 2: A pie chart showing the statistics of landcover classification based on GIS data.

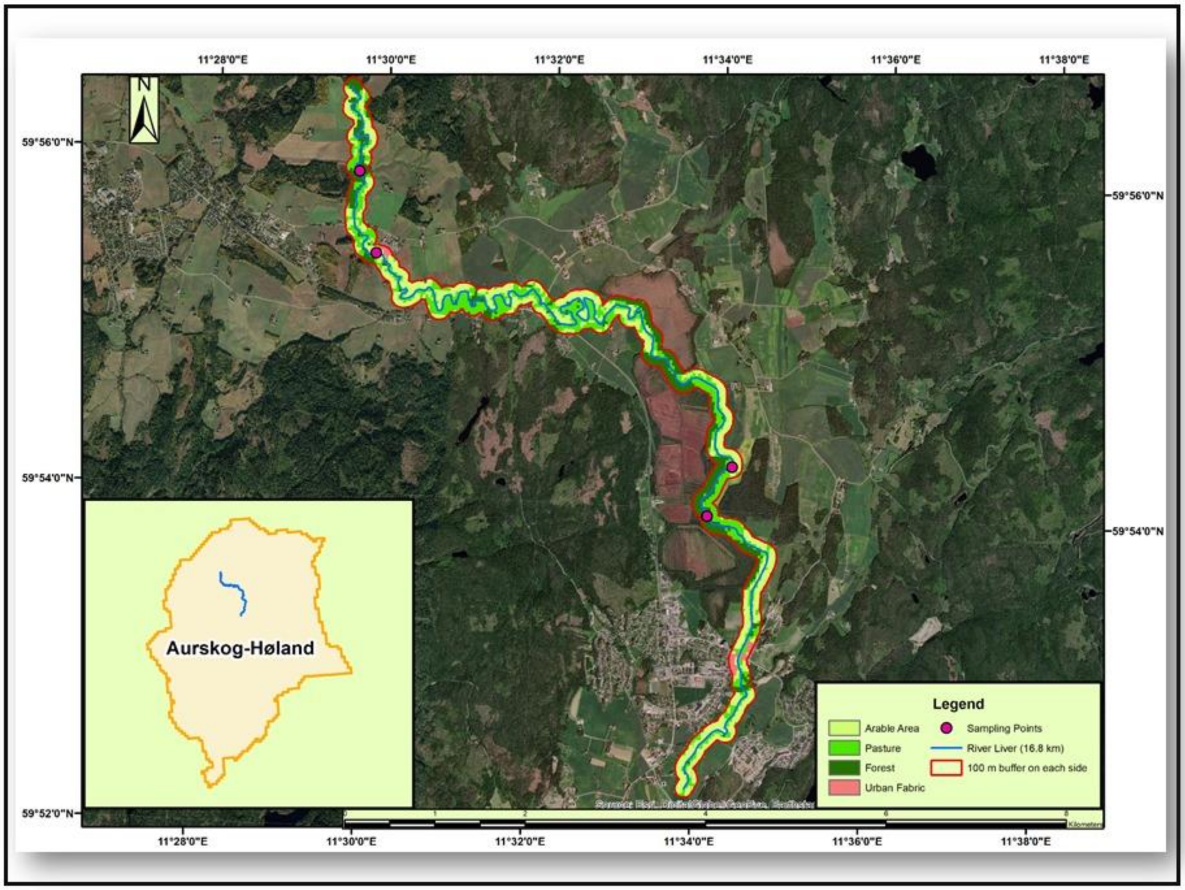


Figure 3: A map chart showing Lierelva and its surrounding land use within 100m radios out from the edge of the river.

Chapter 4

4.0 Discussion

4.1 General trends of landcover-land use (LCLU)

The results of the study revealed that much of the riparian zone of Lierlva is covered by arable land, pasture, forest and urban fabric. This is similar to a study by Johannessen and colleagues (2015) who stated that the landcover of Lierlva in the Buskerud county consisted of forest, agricultural area and some urban areas. The agricultural area consisted of plant production such as cereal, vegetables, and fruits, and animal farming. Likewise, the landcover of rivers in Norway included forested and agricultural areas (Skarbøvik and Bechmann, 2010). Research from four areas in Europe also reported arable land, pasture and forest areas as common riparian zone landcover land cover for rivers in Europe (Bakker et al., 2008).

A study to determine the ecological status of Lake Vansjø in south-eastern Norway reported that the riparian zone surrounding the lake was dominated by forest (Couture et al., 2018). However, the ArcGIS data indicated that the riparian zone Lierelva was dominated by arable land. This difference in landcover can be attributed to degradation. Clerici and colleagues (2014) reported that forestry is the main cause of landcover change in Europe. The Lier municipality has a thriving logging industry, and this could be the reason for loss of forest cover in the riparian zone along Lierelva. The degradation of forest into agriculture can cause soil erosion and sediment transport (Restrepo et al., 2015). Clearing of the forest for agriculture can increase the pace at which materials move into the river and further increase sediment yield above natural levels. Sedimentation of riverbed over a considerable period can lead to siltation which can reduce water volume and expose aquatic life to increasing amounts of sunlight, affecting them negatively. If the sedimentation materials are of organic origin, increased microbial decomposition may reduce dissolved oxygen levels. Over a long period of time, this can result in anoxic conditions, which will drastically reduce production of aquatic plants and animals.

Farmers would resort to the use of fertilizers to increase the returns on the utilization of the land which can cause pollution to rivers as a result of base flow from agriculture; for example, water runoff will cause excessive nitrate and phosphate into the river and further result in water pollution (Schilling et al., 2008). Nutrient enrichment can be harmful to fishes and other aquatic life; it can cause eutrophication in lakes or slow flowing rivers. Intensive agriculture around rivers can cause degeneration of the river habitants (Wasson et al., 2010), and especially the riparian zone.

My results of the study indicated that pasture covered 38.05% of the Lierelva catchment area. In a study to establish the relative impacts of pressures that degrade ecological status of rivers in Europe, Wasson and colleagues (2010) reported that pastures could have a positive effect in regions of low intensity farming but acknowledged the negative effects of riparian pasture on rivers in an intensive livestock farming area. This effect can be from phosphorus and pesticides from cropland and erosion from cattle trampling.

Research studies have reported positive effects of forest catchment of a river. A study by Miller and colleagues (2011) reported that forest landcover can provide a litter layer that protects mineral soil from erosion. Also, forest landcover generates less overland flow that carries sediments and nutrients to the river. Therefore, it is important for river catchment areas to have large amount of forest landcover for lower nutrient concentration. A study in Belgium by Borges and colleagues (2018) reported that catchment of a river dominated by agriculture, similar to my study, consisted of higher levels of nitrate and CO_2 that can cause water pollution. Whereas a forest populated catchment of a river contains higher levels of O_2.

The landcover around Lierelva also consisted of urban fabric. River urban catchment can be defined as the part of the catchment area with developments such as houses, farmhouses, roads and paved surfaces (Findlay and Taylor, 2006). The urban fabric falls under the discontinuous category, in that, the developments are scarce and dotted in nature. Roads and bridges make most part of the fabric as they connect the neighboring towns. Although the urban fabric of Lierelva in the current study is low (i.e., 1.5%), there can be effects to the river. Urban fabrics around a river can fragment the riparian zone and decrease the quality of water due to high surface run off and periodic stormwater discharge that contains sediments and fecal bacteria (Larned et al., 2004).

The deforestation of forest catchment for land use such as agriculture and urban areas generally influences the ecosystem. For example, forest catchment areas have been reported to offer mitigation benefits for flood events greatly above those for non-forest catchment areas (Sriwongsitanon and Taesombat, 2011). Plant cover holds soil structure together and shields it from strong winds and rainfalls which are factors that enable erosion.

Deforestation can also influence the physiochemical conditions of a river ecosystem by decreasing evapotranspiration, increasing run-offs, sediment yield and nutrients, and affecting hydrology and discharge regimes (Song et al., 2009). Also, conversion of riparian vegetation to agriculture land use affect riverine ecosystem through degradation of riverine habitat and biota. Studies have found that fish species and macroinvertebrate richness and biotic integrity decrease for river landcovers with higher percentage of agriculture but remains relatively stable for river landcovers with higher proportions of forest (Marzin et al., 2013). I will return to explain this more in the section for macroinvertebrates below.

In the extreme cases, conversion of forest catchment area to agriculture can result in biodiversity loss (Larsen and Ormerod, 2010). Continuous clearance of forest cover for other land uses can rid an area of primary forest trees (keystone species) paving way for second plants to grow. This secondary succession can lead to an alteration in the type of plant cover in such areas. Instead of primary forests, there will be secondary and planted forests. This trend is a fact as most Norwegian forests are planted. Most wildlife including different species of terrestrial animals and birds live in riparian vegetation along Lierelva. Riparian vegetation can make all the difference for the survival of wildlife (Hågvar and Bækken, 2005) as they serve as source of food, water, shelter and breeding grounds. Different species of birds especially those with habitat specificity would be the most affected the most by degradation of riparian vegetation (Mononen *et al*., 2016). This is because certain birds only thrive on specific types of trees where they can find food, prey, and for adaption mechanisms.

4.2 Macroinvertebrates analysis

4.2.0 Distribution

All the four sample points had a fair number of macroinvertebrates with an average of ten species per sample. Moreover, for the objective of this project, family level was chosen because the family score was used in calculating the ASPT Score. Nevertheless, the family and order of certain macroinvertebrates were determined. Two samples were located relatively far upstream whiles the remaining two were closer to the lake downstream. Many of the same macroinvertebrates such as *Limnephilidae*, *Baetis sp*, *Simulidae* among others were found in some locations. This can be explained by the fact that most of these macroinvertebrates being winged insects and can fly to different locations, and some of them are carried along by river currents. *Oligochaeta* was found in all the samples that were examined. This is because this subclass is made up of types of aquatic and terrestrial worms. With sand and decomposed organic material being the main sedimentary material of the river bottom, worms would abound. The presence of *Ephemeroptera* species such as *Ephemera vulgata* during the time of sampling, late summer can be attributed to their long-life cycle (over a year). Although, they are most abundant during summer, they can as well live through all season.

4.2.1 Species abundance, species richness and species diversity

Forest cover (S004) had the highest species abundance with a total of 133 individuals. The thriving population on macroinvertebrates in this section of the river may be due to organic material resulting from dead leaves, stems, roots as most macroinvertebrates are fed by this particulate organic matter (POM) (Yoshimura, 2012). Moreover, macroinvertebrates life cycle processes such as egg hatching, larval growth and emergence phenology are influenced by air and water temperatures which are more stable and optimal in forest zones. The forest cover may have prevented macroinvertebrate larva from being baked by sun or overheated by river water. For example, the most abundant species at this section were mayflies, *Ecdyonuridae* with 75 individuals, their larva are known to inhabit small cold brooks shaded by forest (Bauernfeind and Soldan, 2012). All these favorable conditions may have contributed also to the species richness where 10 different species were identified from here.

Arable land (S003) had the second most abundant species with 120 individuals and the highest species richness with 11 different species. The abundance of macroinvertebrates in this section is due to the organic material from the dead or decomposed crop parts, which serve as substrate. However, the conversion of forest cover to farmlands creates disturbance. These disturbances and physical conditions can create heterogeneous substrates that act as patches for aquatic insect populations in streams (Reice, 1994). Consequently, the heterogeneity produces patchiness in stream environmental conditions, including food availability, thereby favoring aquatic insects.

Pasture (S001) had the least species abundance with 76 individuals but with high species richness of 11 different species. The reason could be explained by the rocky bottom at this section of the river. The slippery rocky surfaces provided little surface for attachment making them susceptible to be swept away by river currents to different locations. Again, they may have hidden under the rocks and therefore could not be sampled as much.

Despite the species richness and species abundance, the Shannon Diversity Index shows that, the macroinvertebrates in the river are not very diverse. The highest Shannon Diversity scored were 2.17 and 2.16 by forest (S002) and pasture (S001) respectively. According to the Shannon scale, these two indexes fall in the medium diversity range, which means that the macroinvertebrates were not very diverse. However, this does not conclusively indicate that macroinvertebrates in Lierelva lack diversity. This is because the sampling method, time and location may have favored certain macroinvertebrates over others.

4.2.3 Average Score per Taxon (ASPT) Index

The presence of certain macroinvertebrates may be used an environmental indicator (Rosenberg and Resh, 1993) providing information about the water quality parameters and the river ecosystem. Some invertebrate groups are sensitive to pollution whereas others are tolerant. The ASPT Indexes were calculated to determine how the various landuse practices are affecting the water quality. This is an indirect measurement or calculation of ecosystem services derived from riparian zones.

Pasture, S001 recorded a high ASPT Index (7.8). The assemblage of mayflies (*Potamanthidae, Siphlonuridae, Ecdyonuridae*), stoneflies (*Leutridae*) and dragonflies (*Aeshnidae*) resulted in the high index. They are highly sensitive to pollution and therefore, their presence indicates there is little pollution of the water column (Hadley, 2020). This result was a little surprising. It would be expected that farming activities would harm the water quality in that specific section, thereby producing a low index. However, the reason could be that farmers there use good farming and management practices preventing contamination of the water column. There is also a greater amount of intact riparian vegetation in these sections. Furthermore, I did not have data in animal densities, certainly important regarding the influence on both the vegetation and river course. Both S002 and S004 from forest areas scored high water quality indexes, 7.9 and 6.5 respectively. This is consistent with the fact that forest cover plays roles in ensuring water quality by preventing run offs and providing organic substrates for macroinvertebrates. Arable land, S003 as expected had the lowest water quality index. Most of the macroinvertebrates from here such as blackflies (*Simulidae*), waterlouse (*Asellus aqauticus*) and *Baetis* are either somewhat or very tolerant of pollution which is consistent with the low index recorded. Organic and inorganic pollution, erosion and run-offs from agricultural lands accounts for the low water quality. It is however evident from the pasture that good farming and management practices can be the difference between water pollution or not. Generally, ASPT Indexes were very good indicating that the water column has not be polluted yet. Even the lowest recorded ASPT Index of 6.2 is categorized as a good/moderate status of water quality.

4.2.4 GIS modelling, ecosystem services and surrounding communities

From the GIS data, it is obvious forested land-covers render ecosystem services to Lierelva and the surrounding communities. Maintenance of water quality ensures water availability for households and other useful purposes. This reduces the costs that go into water treatment as treating polluted water is costly than fairly clean water. The ability of riparian zones to buffer floodwaters prevents routine flooding of nearby farms and communities, saving life and properties. The economic losses that would have been incurred during these floods would be huge. The survival of aquatic species depends on riparian zones which implies there would will be a decline biodiversity in their absence. For instance, which is major protein source in many Norwegian could be threatened. Therefore, ecosystem service such as flood prevention, biodiversity conservation, water purification, food provision etc., enjoyed by the communities surrounding Lierelva would decline or even cease with continued degradation of riparian zones. Indirectly, these ecosystem services constitute economic value to the local and the national economies.

4.3 Conclusion

Based on GIS data, Lierelva has reasonable amount of riparian vegetation along its banks. The types of the riparian vegetation as referenced from the CORINE Classification are forest, pasture, arable land and urban fabric. The presence of riparian vegetation is vital to the riverine ecosystem, as it helps regulate water temperature, provides substrate for macroinvertebrates, prevents sedimentation, promotes and conserves biodiversity. Sections of the river with vegetation had better and more macroinvertebrate assemblage and scored a high-water quality index than others. The communities through which Lierelva runs benefit from these ecosystem services. Flood prevention and availability of water for domestic use, industrial or agricultural purposes constitute a great deal of economic value.

The size of riparian vegetation is small compared with other landcovers or land uses. Changes in land uses pattern is accelerating, and the dwindling of vegetation along Lierelva continues. More intact forested areas are being converted for agricultural and development purposes. Converted landcover or land uses make up 77% of the total landcover. Also, timber is the second cause of degradation of riparian vegetation. Logging activities is steadily changing the vegetation from primary vegetation to secondary vegetation.

Despite the unfortunate state of riparian vegetation, the macroinvertebrate numbers and the ASPT Index indicate that Lierelva is not severely suffering the negative effects yet. However, sedimentation and nutrient deposition will pollute the river column and cause problems for riverine ecosystems. Establishment and enforcement of good policies with strong regard for riparian vegetation can help stop their degradation. For example, buffer strips, prohibition of the application of organic or inorganic fertilizers close to waterbodies, afforestation and reforestation will go a long way to help. Stakeholder involvement in such policies will elicit the cooperation that is required for the enrollment of management practices.

4.4 Recommendations

I would recommend that future projects would investigate the economic value of ecosystem services based on data produced in the field, similar to my invertebrate data, and through modelling, similar to my GIS analyses. This approach of incorporating economics into environmental issues makes it easy to communicate difficult ecological problems in monetary terms. This system of ecosystem services pricing helps all stakeholders such as policy makers, farmers, landowners and community residents to easily understand issues surrounding degradation of nature. This simple understanding can be the common grounds for scientists and non-scientists to interact to develop holistic management approaches.

Secondly, water quality test should not only be based on ASPT Index. Further studies should examine other water parameters such biological oxygen demand (BOD), dissolved oxygen (D0), pH, trace elements, dissolved organics among others. Results from these parameters can conclusively determine water quality of Lierelva.

Lastly, investigations should be made into exactly what management and farming practices have positive effects on rivers and riparian vegetation. This is because some measures that are considered to be more positive and effective in promoting functioning of ecosystems counterproductive.

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Appendix A: The family scoring chart of macroinvertebrates used in calculating the ASPT Index.

The index has 85 scoring taxa (score from 1- 10)

Taxa	
Families ex. *Oligochaeta*	Score
Siphlonuridae, Heptageniidae, Leptophlebiidae, Ephemerellidae, Potamanthidae, Ephemeridae, Taeniopterygidae, Leuctridae, Capniidae, Perlodidae, Perlidae, Chloroperlidae, Aphelocheiridae, Phryganeidae, Molannidae, Beraeidae, Odontoceridae, Leptoceridae, Goeridae, Lepidostomatidae, Brachycentridae, Sericostomatidae	10
Astacidae, Lestidae, Agriidae, Gomphidae, Cordulegasteridae, Aeshnidae, Corduliidae, Libellulidae, Psychomyiidae, Philopotamidae	8
Caenidae, Nemouridae, Rhyacophilidae, Polycentropodidae, Limnephilidae	7
Neritidae, Viviparidae, Ancylidae, Hydroptilidae, Unionidae, Corophiidae, Gammaridae, Platycnemididae, Coenagriidae	6
Mesovelidae, Hydrometridae, Gerridae, Nepidae, Naucoridae, Notonectidae, Pleidae, Corixidae, Haliplidae, Hygrobiidae, Dytiscidae, Gyrinidae, Hydrophilidae, Clambidae, Helodidae, Dryopidae, Elminthidae, Chrysomelidae, Curculionidae, Hydropsychidae, Tipulidae, Simuliidae, Planariidae, Dendrocoelidae	5
Baetidae, Sialidae, Piscicolidae	4
Valvatidae, Hydrobiidae, Lymnaeidae, Physidae, Planorbidae, Sphaeriidae, Glossiphoniidae, Hirudidae, Erpobdellidae Asellidae	3
Chironomidae	2
Oligochaeta	1

Appendix B: Summary of landcover classification characteristics

Sampling Code	Coordinates	Classification	Bottom Sediment	Shannon Index	ASPT Score
S001	59^0 55’26.07N 011^0 29’56.48E	Pasture	Rocks	2.16	7.8
S002	59^0 55’55.33N 011^0 29’41.67E	Forest	Organic material	2.17	7.9
S003	59^0 54’ 16.24N 011^0 34’17.94E	Arable land	Organic material	1.72	6.2
S004	59^0 53’58N 11^0 34’02E	Forest	Rocks and soil	1.55	6.5

Appendix C: GIS modelling data on land-cover classification surrounding Lierelva.

Area/ha			Percentage	
111.96	0.380544509	38.0544509	38.05	
63.72	0.216579994	21.65799939	21.66	
114.03	0.3875803	38.75802998	38.76	
4.5	0.015295197	1.529519731	1.53	
294.21			100	

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