Mémoire

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SAfeguard BIodiversity and improve Climate Adaptation in catchment areas under pressure: tools and Solutions (SABICAS)

Identification of barriers and drivers to NbS project implementation and realization of a GIS project as base for an interactive map with communication purposes

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Submitted to the Environmental Sciences and Management Department in part of the fulfilment of the requirements for the MSc in Environmental Sciences and Management – Integrated Water Resources Management

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Greetings

First of all, I would like to thank Leonard Sandin, my internship supervisor, for giving me the opportunity to take part in such an interesting project as SABICAS. It was a very enriching experience to see how a project of this size and team works.

Secondly, I would like to thank the Freshwater ecology and Nature-based solutions sections for welcoming me into their team. In addition to working in a pleasant environment, they always tried to help in any way they could. I learned a lot from them both as a professional and as a person.

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ABSTRACT

The confluence between the Gausa river and the main river Gudbrandsdalslågen (Norway) is experiencing flooding events on a yearly basis. Flood mitigation measures have been constructed but are threatening the biodiversity of floodplains' ecosystems. To avoid this kind of inconveniences, alternative strategies such as nature-based solutions, aiming to assess environmental, social and economic challenges by mimicking nature, are being explored. However, the concept remains unknown to the public and local people tend to doubt about its efficacity.

The present master thesis describes nature-based solutions and aims to summarizes barriers that could prevent the implementation of NbS projects as well as communication-related drivers and strategies that could enable it.

The second objective is the quantification and visualisation of the changes in land use that happened in the delta of the Gausa through time (1947-2019) by analysing aerial images in QGIS in order to communicate efficiently with project partners, stakeholders and broader audience. The end product is a mapping project meant to be used as communication tool.

This work has been produced in the framework of SABICAS, a project funded by the Norwegian Research Council (https://www.sabicas.no/).

RÉSUMÉ

La confluence entre la rivière Gausa et le fleuve Gudbrandsdalslågen (Norvège) subit des inondations chaque année. Des mesures d'atténuation ont été construites mais menacent les écosystèmes des plaines inondables. Pour éviter ce problème, des stratégies alternatives telles que les « nature-based solutions[1] » (NbS), visant à relever des défis environnementaux et socio-économiques en imitant la nature, sont étudiées. Cependant, le concept reste inconnu du public et les populations locales ont tendance à douter de son efficacité.

Le présent mémoire décrit les « nature-based solutions » et vise à résumer les obstacles qui pourraient empêcher la mise en œuvre de projets NbS ainsi que les facilitateurs et stratégies liés à la communication qui pourraient la rendre possible.

Le second objectif est la quantification et la visualisation des changements d'occupation du sol qui se sont produits autour du delta de la Gausa au fil du temps (1947-2019) via l'analyse d'images aériennes dans le logiciel QGIS. Le produit final est un projet cartographique destiné à être utilisé comme outil de communication ayant pour but de communiquer efficacement avec les partenaires du projet, les parties prenantes et le grand public.

Ce travail a été réalisé dans le cadre de SABICAS, un projet financé par le Conseil norvégien de la recherche (https://www.sabicas.no/).

[1] Solutions basées sur la nature

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LIST OF ABBREVIATIONS

NbS	Nature-based solutions
CEPA	Communication, Education and Public Awareness
CLC	Corine Land Cover
EbM	Ecosystem-based management
EEA	European Economic Area
EFTA	European Free Trade Association
EU	European union
GMOs	Genetically modified organisms
GIS	Geographic Information System
GSM	Global System for Mobile Communications
UFZ	Helmholtz-Zentrum für Umweltforschung
IWRM	Integrated Water Resources Management
IUCN	International Union for Conservation of Nature
NGOs	Non-gouvernemental organisations
NOK	Noorse Kroon/Kroner (Norwegian Krone)
NIBIO	Norsk institutt for bioøkonomi
NINA	Norsk institutt for naturforskning
NIVA	Norsk institutt for vannforskning
NEA	Norwegian Environment Agency
RBD	River Basin District
SABICAS	Safeguard Biodiversity and improve Climate Adaptation in catchment areas under pressure: tools and Solutions
SLU	Saint Louis University (Swedish University of Agricultural Sciences)
SABIMA	Samarbeidsrådet for biologisk mangfold
UNFCCC	United Nations Framework Convention on Climate Change
UNF	United nations
WFD	Water Frame Directive
WP	Work package

Introduction

People living in the surrounding of the delta between the Gausa and the Gudbrandsdalslågen rivers, in Lillehammer (Norway) are experiencing floods on a yearly basis and facing extreme water-related hazards on rarer occasions (Lillehammer kommune, 2022; Solheim et al., 2020).

These hazards have various consequences affecting the well-being of inhabitants and the health of ecosystems such as material damages (Eckman et al., 2011), topsoil washing and crops destruction, pollution transport, erosion and turbidity, etc. In addition, it represents a real danger to people's lives and significant repair costs (*The Lågen Plan*, n.d.).

The current mitigation measures used to face flooding events in this area are mostly grey solutions such as constructing embankments and removing sediments from the riverbed (The Lågen Plan, n.d.). The problem with this type of strategies is that they can cause increased flooding and pose a threat to the biodiversity of floodplains.

Many threats to wetlands ecosystems exist (climate change, floods, pollution, land use changes, flow alteration, invasive species, population growth, competition for water) and some of them are also responsible for increasing the magnitude of floods (Archambeau et al., 2021). In addition to climate change, the main causes of this intensification are changes in land use, alteration of flow, erosion and deposition of sediment, and some flood mitigation measures themselves.

To avoid accentuating these phenomena, alternative strategies called "nature-based solutions" are being explored. Nature-based solutions (NbS) are innovative concepts intending to assess environmental, social and economic challenges (e.g., climate change issues) by mimicking natural ecosystems processes. They are cost-effective alternative strategies aiming to provide a lot of benefits (social, economic) while supporting biodiversity.

Even though, they have been becoming more popular in recent years, not everybody is convinced when it comes to implementing these kinds of measures in his/her hometown. Why would people be reluctant towards solutions that could simultaneously protect biodiversity and benefits themselves? There are a lot of reasons such as unawareness, uncertainties regarding the effectiveness, perceptions, costs, administrative issues, lack of supportive policies, etc.

On one hand, many barriers are related to communication issues and could partly be solved by using strategies to improve communication between stakeholders. On the other hand, enablers exist and can help to overcome some of these barriers.

The present master thesis aims to make an overview of the barriers preventing the implementation of nature-based solutions and the drivers which can facilitate it. Strategies to overcome these barriers by using the drivers, such as CEPA (Communication, Education and Public Awareness) will also be discussed.

CEPA is a concept including guidance and strategies to communicate efficiently with project's stakeholders and the public in order to reduce biodiversity losses. The proposed techniques consist in understanding context, issues, barriers and drivers to incorporate them into strategies aiming to rise interest in biodiversity conservation and motivation to act for it.

As mentioned before, the delta of the Gausa river has been affected many times by floods and forms an interesting case study to show NbS in action and the purpose of SABICAS (SAfeguard BIodiversity and improve Climate Adaptation in catchment areas under pressure: tools and Solutions), a project funded by the Norwegian Research Council (https://www.sabicas.no/). Prior to any implementation of NbS, stakeholders living in that very place must be convinced about the worthiness.

In the framework of this project, I will design a mapping project of the delta of the Gausa river by analysing images in QGIS in order to communicate efficiently with project partners, stakeholders and broader audience. The objective is to primarily visualise changes in land use through the analysis of aerial pictures dating from 1947 to 2019.

Communication between the scientific community and the public is not in great shape right now. The aim of the mapping project is to create a bridge between researchers working on SABICAS and the targeted audience(s). This project is meant to allow people to see what you, as a scientist, might otherwise spend hours trying to explain.

The end product is a GIS (geographic information system) communication tool and, additionally, a quantification of the changes of land use that have been made around the delta and the changes of the river width.

1. Contextualization

This chapter has several purposes:

The first one is giving an overview of the SABICAS project, explaining the context and the objectives. This first sub-chapter will be based on the final proposal written for the project and the website (www.sabicas.no).

After that, I will focus on describing the place of interest, the delta between the Gausa river and the main river of Gudbrandsdalslågen. In this part, I will make a brief outline of the localization and then I will explain the current problems and solutions related to water management identified in this zone.

Finally, I will briefly mention the threats to biodiversity and water-related issues that are encountered within the area of interest.

1.1. SABICAS project

SABICAS is the acronym for "*Safeguard Biodiversity and improve Climate Adaptation in catchment areas under pressure: tools and Solutions*". The project's main goal is the development of a catchment-based and user-friendly toolbox aiming on optimizing the use of NbS at catchment scale.

The aims of creating such toolbox are helping safeguard biodiversity and improving climate adaptation and water quality by accelerating the spreading of NbS uses. It will provide knowledge and solutions, facilitate dialogue and decision-making among stakeholders, and overcome prioritisation barriers. The end-product will consist of recommendations of NbS designs and prioritisations rules and will be co-developed with stakeholders.

The three priorities are:

- Identifying the effectiveness of NbS in resolving land use conflicts and increasing knowledge about NbS and Ecosystem-based Management (EbM) efficiency
- Quantifying impacts of land use on biodiversity of Norwegian river ecosystems and interactions with climate change at a catchment scale
- Developing the aforementioned toolbox

In practice, the project is structured in six "*work packages*" that have their own tasks and objectives.

- WP1 "*Engagement, co-creation, and Living Labs for catchment based NbS*" will be hosting the stakeholders and co-create processes allowing the needed collaborative environment needed to tackle the complex project's scope
- WP2 "*Impacts of land use on river and riparian biodiversity under different climate scenarios*" will evaluate the effects of land use on biodiversity

- WP3 “*Safeguarding biodiversity and improving climate change adaptation using NbS*” will assess the effects of NbS on biodiversity
- WP4 “*Tackling the barriers, promoting drivers – NbS into management*” will address barriers and enablers in implementing NbS into the landscape
- WP5 “*Catchment integration and toolbox development*” will integrates the obtained results into a coherent tool designed for managers and stakeholders to optimize NbS use in the landscape
- WP6 “*Project management*” is responsible for communication, dissemination and exploitation.

The project relies on different processes such as collecting existing data and knowledge (about biodiversity, land use, NbS, actors, hazards, barriers and drivers, etc.), modelling, or setting up study and demonstration areas (Living Labs). However, it will also require collaboration with the stakeholders by organizing workshops, activities, interviews, and surveys.

The expected impacts are, among other things, the improvement of the ecological status of the Norwegian rivers; the increased development of NbS use and design; the decrease of flood risks, erosion and habitat loss; the augmentation of pollinators, fish populations, and other ecosystem services; the development of stakeholders’ engagement and ecotourism.

This is a four-year project running from 2021 to 2025 implying collaboration between the following research and non-research partners: NIVA (The Norwegian Institute for Water Research) as leading partner, River Basin sub-district Halden River, NINA (The Norwegian Institute for Nature Research), Sabima (The Norwegian Biodiversity Network), NIBIO (Norwegian Institute of Bioeconomy Research), Agricultural Extension Office Østfold, NGI (Norwegian Geotechnical Institute), Innlandet County Authority, UFZ (Center for Environmental Research, Germany), AU (Aarhus University, Denmark) and SLU (Swedish University of Agricultural Sciences, Sweden).

Regarding the geographical location, two catchment areas have been chosen as study cases: Haldenvassdraget in Southeast Norway and Gausa in Innlandet. The studied NbS for these two zones are restoration of wetlands and river plains.

In the context of this master project, the focus will be on the Gausa river. I have been involved in the WP2 with the objective of quantifying and making visible the habitat changes over time at the delta between the Gausa river and the Lågen river with QGIS.

SABICAS

*Figure 1: Sabicas logo (*SABICAS*, n.d.)*

1.2. STUDY CASE: GAUSA CATCHMENT

1.2.1. LOCATION

To present the location of interest, I will proceed by giving overall information about Norway, Innlandet, and then I will describe the precise location of the Gausa watercourse.

Norway

As related to above, the Gausa river is in Norway ("*Norge*" in Norwegian). Norway or the Kingdom of Norway is a country of Northern Europe, more precisely located in the western part of the Scandinavian Peninsula. Its total area is 385 178 km² of which approximately 5 % is surface water or about 16 000 km² (OECD, n.d.). The country is bordered by the Barents Sea, the Norwegian sea, and the North Sea, and has land borders with Sweden, Finland, and Russia.

The current population is 5 500 995 inhabitants of which 1/5 lives around Oslo (*Norway Population 2022 (Demographics, Maps, Graphs)*, n.d.; *Oslo Population 2022 (Demographics, Maps, Graphs)*, n.d.). For comparison, the territory of Norway represents almost thirteen times the size of Belgium while its population is half the size. The population density is 15 inhabitants/km², but it is not representative when you know that most people (80 %) live in urban zones where density is much larger. The biggest cities are Oslo, Bergen, Trondheim, Stavanger and Bærum (Encyclopedia Britannica, n.d.).

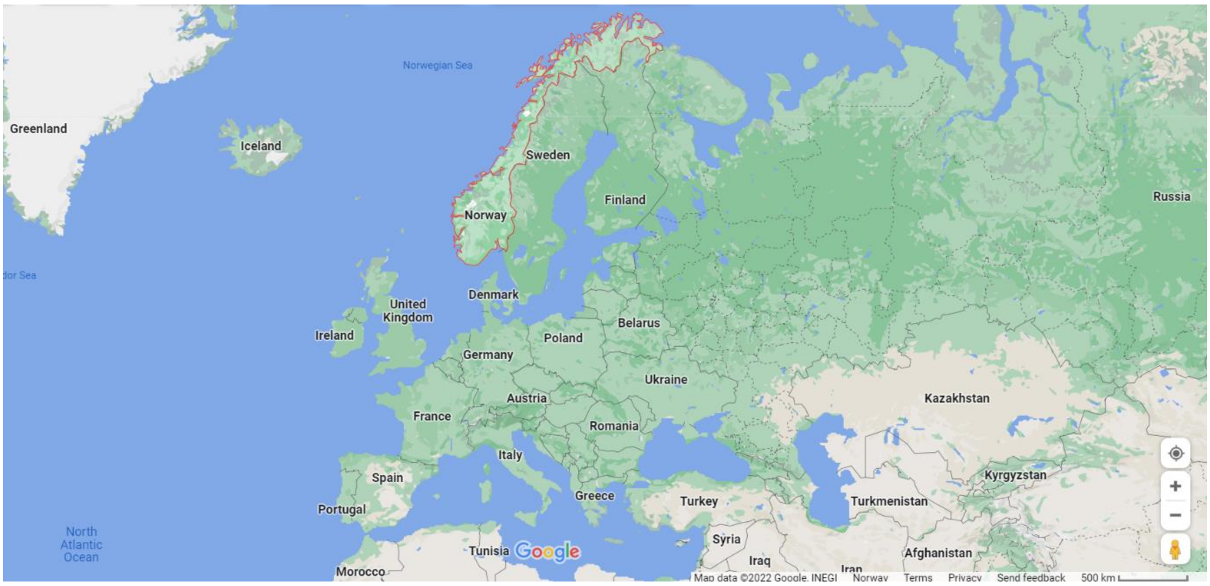

Figure 2: Location of Norway

©Norway - Google Maps (2022.04.12)

There are two official languages; Norwegian in Oslo for example and the Sámi languages, a set of dialects spoken through Norway, Sweden, Finland, and Russia (UiT The Arctic University of Norway Library, 2020).

Figure 3: Norwegian flag

©https://thornews.files.wordpress.com/2014/08/flag-of-norway-

The official currency is the Norwegian Krone (NOK). On April 12th (2022), 1,00 € was equivalent to 9,55 NOK (*Valutakurser*, n.d.).

The Norwegian flag is red with a blue-white cross. The colours signify freedom and remind the Danish and Swedish flag´s colours (Rasin, 2020). This is related to the fact that in the past Norway belonged to Denmark then has been involved in a partnership with Sweden before having its own independence in 1905 (Rasin, 2020; WorldAtlas, 2021).

The country is a constitutional monarchy with a Parliament. The current monarch and Prime Minister are King Harald V and Jonas Gahr Støre.

Innlandet County

Since 2020, Norway counts eleven different counties : Troms og Finnmark, Nordland, Trøndelag, Møre og Romsdal, Innlandet, Vestland, Viken, Vestfold og Telemark, Rogaland, Oslo and Adger (Nikel, 2020).

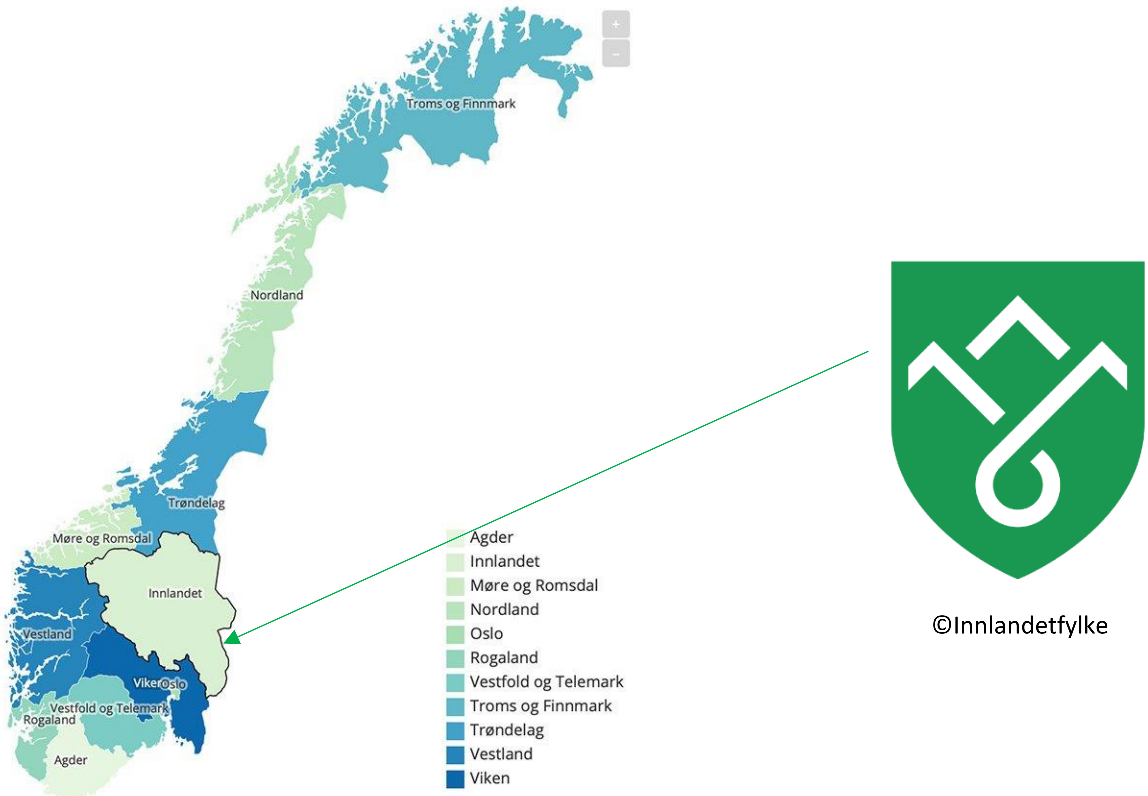

Figure 4: County of Innlandet & County flag

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In the context of this report, I will only be interested in Innlandet. A county located in South central Norway. Its area is 52 590 km² and represents 17 % of the Norwegian´s territory and its population is 370 905 inhabitants (2021) (‘Innlandet’, 2022). This county is the result of the union of the former Counties of Hedmark and Oppland where the Gausa watercourse is located, and two municipalities of the former Viken County (Nikel, 2020). Its current [County] Gourvernor is Knut Storberget (*County Governor of Innlandet*, n.d.).

Lillehammer Region and municipalities of Gausdal and Lillehammer

As illustrated on the figure below, the county is divided into 10 regions and is composed of 46 municipalities within Gausdal and Lillehammer that are both part of Lillehammer Region and crossed by the Gausa river (Innlandet fylkeskommune, n.d.; Lillehammer Regionen, n.d.). The mayors of these municipalities are respectively Anette Musdalsien (centre party) (Strutt, 2022) and Ingunn Trosholmen (labour party) (Lillehammer kommune, 2022).

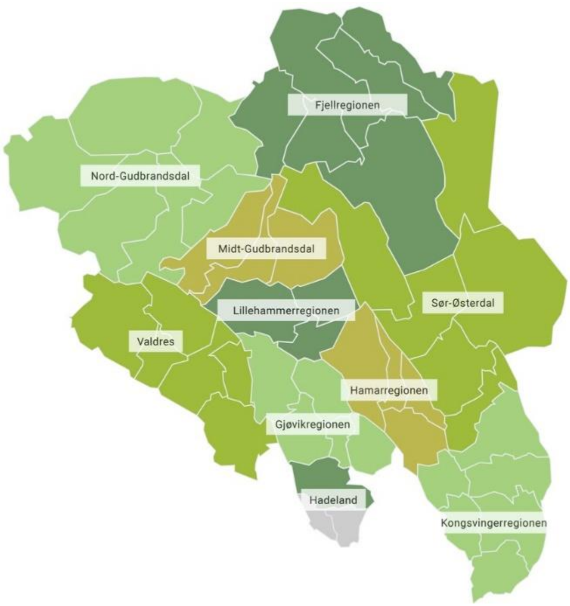

Figure 6: Regions of Innlandet

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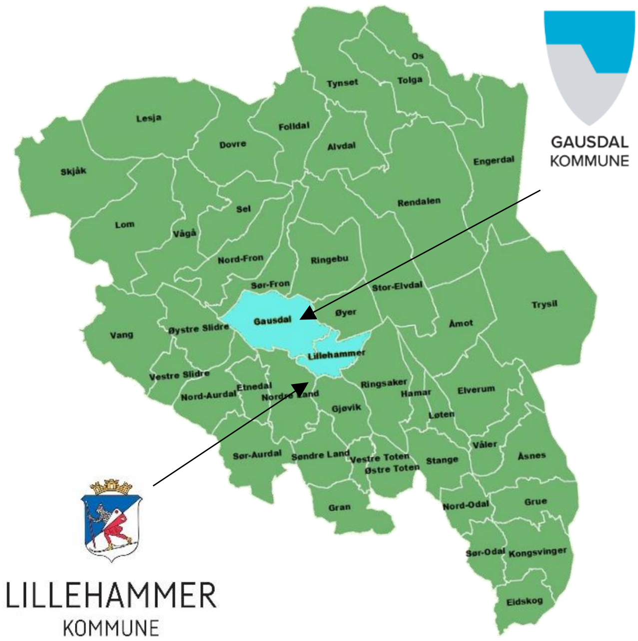

Figure 5: Municipalities of Innlandet and location of the municipality Gausdal and Lillehammer

©Innlandetfylke ©Lillehammer kommune ©Gausdal kommune

The Gausa river takes its source in the municipality of Gausdal and flows into the Lågen watercourse next to Lillehammer in the municipality of the same name.

Gausa river

The Gausa river is about 60 km long and its catchment area is 932 km² (*SABICAS*, n.d.), spread on the municipalities of Lillehammer, Gausdal, Ringebu, Sør-Fron and Nord-Fron.Gausa is one of the most important tributaries of the main river Gudbrandsdalslågen.

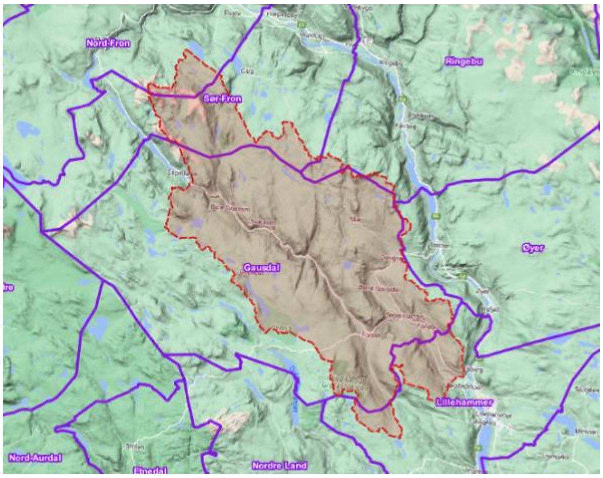

Figure 7: Gausa catchment (NVE)

The highest point is 1466 m above sea level, meaning that it is a mid-to-high altitude watercourse (*SABICAS*, n.d.).

The average water discharge is 18 m³/second (*SABICAS*, n.d.).

The main land uses consist of managed forests and agriculture dominated by improved grassland and animal husbandry. Small urban areas are also found in a more marginal way (*SABICAS*, n.d.).

The confluence between the river Gausa and the main river of Gudbrandsdalslågen is repeatedly experiencing problems during floods which is threatening local infrastructures, farms and housing (Solheim et al., 2020). Moreover, the deposing of eroded sediments from Gausa at the confluence zone changes the river bottom configuration and increases flood problems (Solheim et al., 2020). The Gausa has a riparian forest valuable for biodiversity with endangered species (Miljødir, n.d.; Solheim et al., 2020).

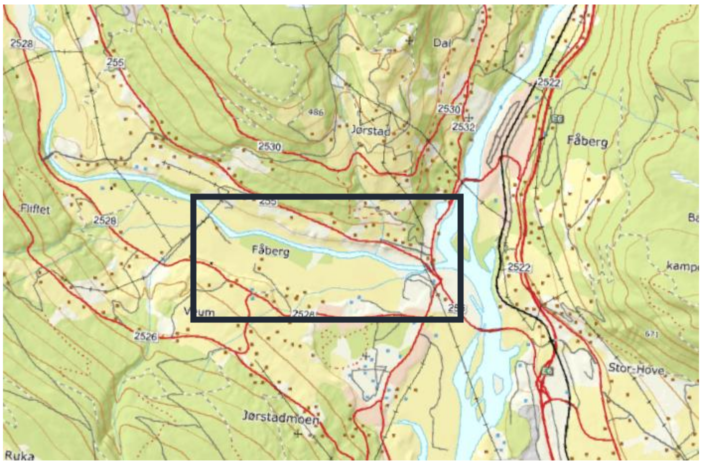

Figure 8: Topographic map of the delta of the Gausa

The area observed in the frame of this thesis is about 25 km² including around 5 km² of potential riparian zone with 1,7 km² being actual riparian zones, with a particular interest for the delimited zone in black on the figure n°8.

The river is popular for fishing and protected against hydro-power development but still, many interventions have been done in the past (channelization, flood protections, roads, etc.) (*SABICAS*, n.d.).

1.2.2. Threats to biodiversity

Floodplains are dynamic ecosystems varying with the sediment's deposition and the erosion, inundations, and interacting with groundwater bodies (Tockner et al., 2008). According to Junk & Welcomme (1990) quoted in Tockner (2008), the definition of floodplains is "*areas of low lying land that are subject to inundation by lateral overflow water from rivers or lakes with which they are associated*".

Due to continuous supply and accumulation of nutrient-rich sediments from upstream areas and lateral sources, floodplains are the most biologically productive areas. Floodplain ecosystems are highly rich in species, provide valuable ecosystems services and are of great value for humanity (Museth et al., 2011).

It is known that floodplains also provide a range of services determining their economic value. Except for biodiversity that is already mentioned, they have functions such as flood retention, nutrient sink, pollution control possibilities, groundwater recharge, carbon sequestration, food and resources production, and recreational and aesthetic value (Tockner et al., 2008).

Despite their biodiversity richness and the fact that they provide services for ecosystems and their cultural and economic importance, wetlands and especially flood plains are one of the most threatened ecosystems in the world and are particularly degraded (Olson & Dinersteind, 1998 in Tockner et al., 2008; Tockner et al., 2008). They're intensively used, and their ecosystems are threatened due to alteration of the natural flow regime, habitat alteration, species invasions and pollution (Museth et al., 2011).

They are facing multiple stressors through the world that cause losses of their surface and changes in their plant and animal communities (waterbirds, fishes, invertebrates (Tockner et al., 2008). The geomorphology of floodplains is dynamic, and thus fixing riverbanks is detrimental to river functioning, highly dependent on the flow regime. Biological diversity tends to be higher in floodplains with a natural hydrological regime than in rivers with flow control (Harner & Standford, 2003; Ward et al., 1999; Tockner et al., 2008; quoted in Tockner et al., 2008).

Hereunder is a list of threats to floodplains, the following threats have all been identified in Gausa and will be explained in greater details:

- Competition for water (Tockner et al., 2008)
- Invasive species (Museth et al., 2011; Tockner et al., 2008)
- Land(use) transformation (Gundersen et al., 2016; Kabisch et al., 2016; Sarabi et al., 2019; Tockner et al., 2008)
- Alteration of the flow regime (Gundersen et al., 2016; Museth et al., 2011; Tockner et al., 2008)
- Increase in human population (Tockner et al., 2008)
- Pollution (Museth et al., 2011; Tockner et al., 2008)
- Climate change (Kabisch et al., 2016; Sarabi et al., 2020; Tockner et al., 2008)
- Floods (Tockner et al., 2008)

Flow modifications (dams, embankments, bypass channel, etc.) due to human activities have the effect of reducing flood peaks as well as flooding frequency and duration (Museth et al., 2011; McMahon & Finlayson, 2003 quoted in Tockner et al., 2008) and homogenising the water flow. It reduces the connectivity between the river and its floodplains and affects the sediment transport (Sarabi et al., 2019; Tockner et al., 2008). In general, flood mitigation measures preventing the river to flood naturally and move laterally such as coping strategies, floodwalls, etc., are harmful (Gundersen et al., 2016).

Although the introduction of exotic plants and animals in floodplains increases the overall diversity, it is often responsible for the decline of native species (Tockner et al., 2008). Furthermore, pollution from wastewater or industries is sometimes too high for some species to live (FAO, 1999 quoted in Tockner et al., 2008).

Land use changes can take different forms and have different consequences. Urbanisation increases the percentage of impervious surface (Sarabi et al., 2019) and harvesting as well as deforestation diminish the rainfall interception, leading to more runoff that facilitate the transport of pollutions (field washing). Other flow regulations such as levees, dikes, roads, railroads, close to the river channel can contribute to disconnect it from the floodplain (Museth et al., 2011).

Population growth and conflict for water are related (Ruangpan et al., 2020; Tockner et al., 2008). In this case, the main problem would be a land use related conflict. When the river and riparian zones would need more space, it is tricky to ask a farmer who needs the same space for his crop to free up the land (Gundersen et al., 2016; Solheim et al., 2020).

Finally, climate change has several hydrometeorological impacts such as increasing the risk of drought and raising the minimum temperature, resulting in the water level being lower and its temperature higher. Climate change also means more frequent and less predictable floods (Museth et al., 2011). It is planned that return periods of extreme precipitation events will decrease and if it could be a mean of reconnection with the parent river, it more frequently implies damages to the floodplains (Tockner et al., 2008).

The mentioned threats lead to the alteration and fragmentation of the habitat (Sarabi et al., 2019), species extinction, etc., and all these phenomena result in the deterioration of floodplains and their ecosystems.

It is important to leave flood zones undeveloped or restore their natural dynamic to give more room to rivers in the future. Developing and implementing of non-structural flood management policies based on ecological principles would benefit both river ecosystems as well as human society (Museth et al., 2011).

As usual with environmental issues, every threat cannot be taken separate from each other because they are connected. It is important to see the entire situation because solving one issue without thinking about the others might be the source of new issues or of the increasing of the existing one.

For example, floods harming biodiversity (washing effect[2]): An easy solution could be building protection measures, but it could harm the existing ecosystems by altering the flow and the habitat. The figure below illustrates interactions between the different threats and impact on ecosystem's loss, and how complex they are.

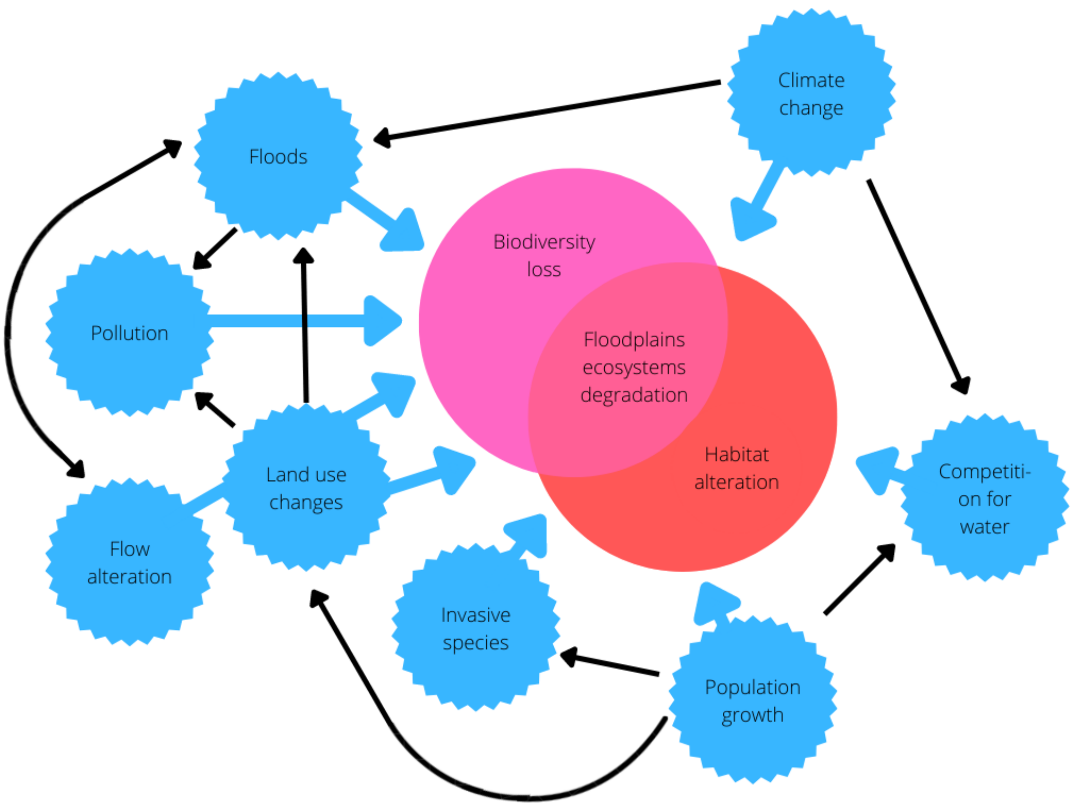

Figure 9: Representation of the threats to floodplains ecosystems[3]

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[2] The washing effect refers to the fact that extreme floods could carry away the species present in the area.
[3] On the figure, each blue circle with an arrow represents a threat that negatively impacts the floodplain's ecosystems. The black arrows represent the interactions between the different threats. The difference of

1.2.3. Floods and landslides

Causes

People from Lillehammer and its surrounding are facing water-related hazards such as floods and landslides on a yearly basis (Solheim et al., 2020). They have been exposed several times to extreme flooding events and it seems that the frequency is likely to increase (Gundersen et al., 2016). The main flood peak in Gausa generally occurs during the month of May, mainly due to the melting snow that can be combined with heavy spring precipitations (*The Lågen Plan*, n.d.).

It goes without saying that the magnitude of flooding events is probably increased by the changes that have been made to the watercourse as well as the climate change. In total, five main factors contribute to increase the scale of these events:

- Climate change
- Land use modifications
- Flow alteration
- Erosion and sediments deposit
- Inefficient flood mitigation measures

As mentioned before, climate change has some well-known impacts such as increasing the overall temperature and diminishing the return period of high precipitations events. We can easily imagine that, combined with the annual snow-melting period, these factors can lead to significant floods (Museth et al., 2011).

Then, urbanisation (Maletić et al., 2020; Sarabi et al., 2019) and land use modifications can have an impact on the amount of runoff and therefore the quantity of water gaining the watercourse. The spreading of impervious land cover has the effect of decreasing the infiltration in the ground, the evapotranspiration and the drainage because most of the water rapidly flows to the river and downstream (Pavan, 2015).

In addition, the Gausa watercourse has been altered (Museth et al., 2011) several times for different purposes: riverbanks have been constructed to channelize the river and gravel has been removed from the bottom for timber transport; farmers and landowners have been modifying the watercourse shores to protect their lands; flood embankments have been built as mitigation measure, etc. (Gundersen et al., 2016). Regulating and changing the water flow decreases the river's capacity storage and increase discharge allowing further alterations to the river and greater impacts downstream (Gundersen et al., 2016). These changes have an increased erosion and the deposition of the eroded sediments from Gausa at the delta with

importance in the effect on ecosystems is not represented on the figure. Attention, threats can have an effect both on biodiversity loss and habitat alteration, even if the blue arrow leads to only one of the circles.

the Lågen changing the bottom configuration leading to more spreading of the water during flood events (Solheim et al., 2020).

As stated above, different measures have been put into place to protect current uses of the landscape (Gundersen et al., 2016), such as flood protection measures that can do worse than good. For example, floodwalls are only working for a range of flood magnitudes, outside with, floodwalls tend to exacerbate the damage potency of the flood (Archambeau et al., 2021).

Consequences

When it comes to urbanized areas a common consequence of floods is inundations. Inundations implies inconvenience such as flooded basements and wet yards but also more important problems such as damages to infrastructures and agricultural land, ground instability problematic for houses' foundations (Eckman et al., 2011). For example, in Gurdbrandsdalen in 2011 and 2013, floods have washed out topsoil and destroyed paved roads, forest, bridges, dams, and culverts. Moreover, the GSM network collapsed what was problematic and lots of people were personally affected by the floods (Gundersen et al., 2016). In addition to material problems, it is not to be forgotten that inundations represent a real danger for people's life. In total, the estimated cost of the 2013 flood is 1,092 billion NOK (approximately 109,2 million €), representing almost only the reconstruction cost (*The Lågen Plan*, n.d.).

Another problem carried by the flood is the alteration of water quality. Water washes everything on its way, sediments and pollutions, causing erosion (gullying) and water turbidity/pollution (Eckman et al., 2011).

To close the loop, flood-related issues generate a fear of water and mitigation measures that can be harmful for floodplain ecosystems (Archambeau et al., 2021; Sarabi et al., 2019).

Current solutions

The most common solutions to avoid flooding damage currently are constructing embankments and sediments removal (*The Lågen Plan*, n.d.).

Currently, the municipalities' local flood mitigation strategies rely on practical flexibility and coping strategies rather than proactive adaptation to be able to adapt to the future (Gundersen et al., 2016). The mechanism of the Norwegian Natural Perils Pool is one cause of this because hazards' impacts are covered by a state-funded insurance and land is restored to its pre-impact state removing responsibility away from landowner and preventing necessary adjustments to land use practices (Gundersen et al., 2016). Resilience is not really motivated in the case. A lot of maladaptation has been observed, like using standardization and oversimplification of knowledge on a property unit basis to drain the water away from properties as fast as possible instead of allowing it to flood without causing damage like in the past (Gundersen et al., 2016).

Until now management is using a narrow instrumental approach decontextualizing and generalizing concepts of flood management including modification of the watercourse instead of adapting land use to changing environmental conditions (Gundersen et al., 2016).

Noteworthy, individual landowners have the responsibility for securing himself and his property against natural damage, including the implementation of measures to prevent damage from large volumes of water subject to the agreement of the municipality (Lillehammer kommune, 2022).

1.2.4. Policies

Norway is related to the European Union as an EFTA (European Free Trade Association) country through the Agreement on the European Economic Area (EEA). The country is a member of the United Nations and follows the United Nations Framework Convention on Climate Change (UNFCCC). However, the country closely cooperates with the EU to tackle climate change and environmental issues. Norway has ratified the international Paris Agreement on climate change and targets the same 2030 goals as EU.

As a part of the UN, Norway wants to reach the different Sustainable Development Goals of the Agenda 2030 (Ministry of Foreign Affairs, 2016). These have several direct and indirect impacts on biodiversity and freshwater management.

The management of the environment in Norway is organized as it follows:

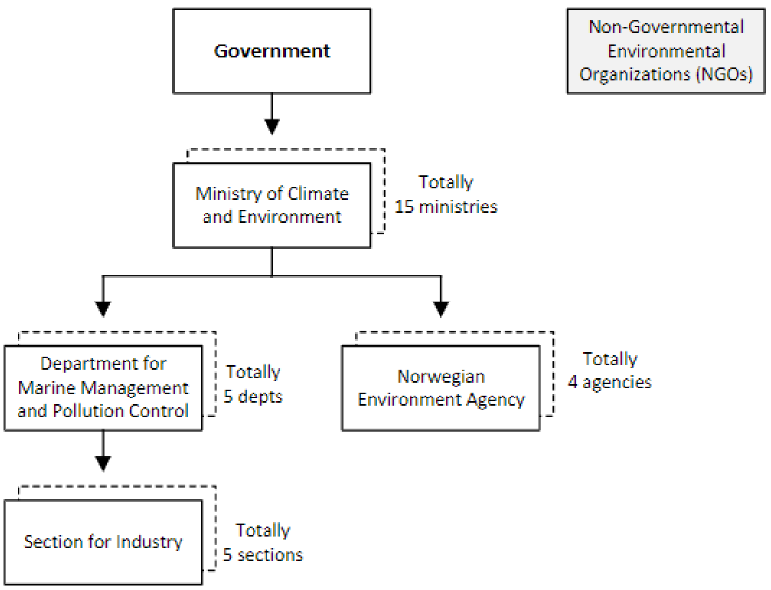


Figure 10: The overall organisation of the environmental management system in Norway (Aakre Haugen, 2016)

The Ministry of Climate and Environment is composed by the following departments and agencies (Aakre Haugen, 2016):

- Marine Management and Pollution Control
- Climate Change
- Cultural Heritage Management
- Nature Management
- Organisational Management
- Norwegian Environment Agency (NEA)
- The Svalbard Environmental Protection Fund
- The Directorate for Cultural Heritage
- The Norwegian Polar Institute

The Norwegian Environment Agency is responsible for climate issues, renewable energies, conservation areas, outdoor recreation, hunting and fishing, pollution and noise, species and ecosystems, cultural landscapes, GMOs, waste, and water and sea. The agency has several roles: monitoring, supervision, and international cooperation.

At national level, Norway have implemented the Water Framework Directive (WFD) as a Framework for Water Management in 2007 commonly called Water Regulation (*Vannforskriften* in Norwegian). They use the River Basin District (RBD), *vannregioner* in Norwegian, as management unit and build River Basin Management Planning as required in the WFD. The national authority responsible for the implementation is the Ministry of Environment (Halleraker et al., 2013).

Norway counts 11 RBD and international RDB shared with Finland or Sweden, each of them having its own authority (*vannregionermyndigheter*) and Water District Board (*vannregionutvalg*) ensuring the participation of the County Council, local municipalities, County departments of Environment and Agriculture, district offices (Water Resources and Energy Directorate, Directorate for Fisheries, Food Safety Authority, etc.) and other reference groups such as citizens, industry, NGOs, etc. (Halleraker et al., 2013).

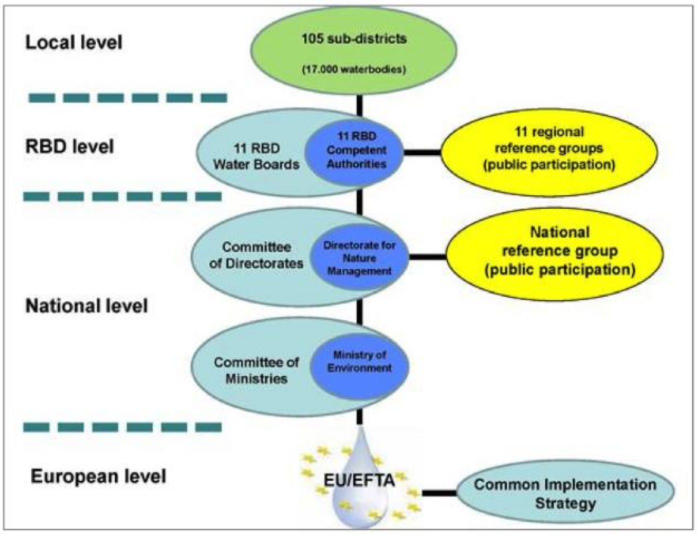


Figure 11: Organisation chart of the WFD implementation in Norway (Halleraker et al., 2013)

A national adaptation strategy called "Climate Change Adaptation in Norway" outlining national policies and guidance has been written and published by the Norwegian Parliament in 2013. This one makes a focus on potential floods and landslides and has planned measures to prevent damage from stormwater and to improve water quality in rivers. Regarding the local character of climate change's impacts, this white paper also gives guidance for municipalities to manage adaptation at a local level. The Norwegian Ministry of Climate and Environment has also published the "*Norway's Climate Action Plan for 2021–2030*", a document containing guidance for flood management as well.

If we focus on the local level, different plans are available such as:

- The Lågen Plan
  Find in :Regional plan for Gudbrandsdalslågen med sidevassdrag (innlandetfylke.no)
- The Regional plan for vannforvaltning i vannregion Glomma 2016-2021
  Regional plan for water management in the Glomma Water District 2016-2021
  Find in: Plandokumenter Innlandet og Viken vannregion - Vannportalen
- The Glomma planprogram 2022 - 2027 (Tilhører Innlandet og Viken vannregion)
  The Glomma planprogram 2022 – 2027 (Belongs to Innlandet and Viken water region)
  Find in: Plandokumenter Innlandet og Viken vannregion - Vannportalen
- Innlandet og Viken vannforvaltningsplan 2022-2027
  Innlandet and Viken water management plan 2022 – 2027
  Find in: Plandokumenter Innlandet og Viken vannregion - Vannportalen
- The Gausavassdraget management plan (2021)
  The Gausa catchment's management plan (2021)
  Find in: <uoff> (statsforvalteren.no)

Even though a lot of guidance and policies have been written recently, Norway still seems to be late regarding the protection of biodiversity.

2. Material and methods

The first sub-chapter provides an explanation of what NbS are and provides some examples. I will end this section by briefly addressing grey solutions and comparing it with NbS.

2.1. Nature-based solutions (NbS)

2.1.1. Definition and objectives

Nature-based solutions are a new umbrella concept consisting of innovative solutions inspired by or mimicking natural processes and ecosystems to address environmental, social and economic challenges (Solheim et al., 2020) such as climate change, food security, disaster management, hydrometeorological hazards risk mitigation and biodiversity and ecosystems loss by generating ecosystem services (Kabisch et al., 2016; Ruangpan et al., 2020; Sarabi et al., 2020). They are an alternative or, at least, a complementary solution to grey infrastructures that use a panel of mitigation and adaptation strategies in order to adapt for future changes, reduce the impacts of climate change and improve well-being (Ruangpan et al., 2020; Sarabi et al., 2020)

According to the European Commission (2013), nature-based solutions match the following description: "*Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. […] NbS must therefore benefit biodiversity and support the delivery of a range of ecosystem services.*"

Such solutions will be used in project involving integrated management of land, water and other natural resources (Siew et al., 2016). If we focus on hydrometeorological hazards such as floods and landslides, NbS aim to reduce risk from these hazards. This means reducing the floods as well as delivering multiple environmental, social and economic co-benefits such as protecting the infrastructures from being damaged or destroyed (Solheim et al., 2020) or increasing opportunities for recreational activities (Ruangpan et al., 2020). One of the biggest challenges in this topic is (re-)creating space for water to retain, decelerate, infiltrate and discharge, especially in already built environment (Pavan, 2015; Ruangpan et al., 2020).

It goes without saying that biodiversity remains central in the concept and projects serve nature conservation and restoration, but they should currently benefit the environment and the society (Sarabi et al., 2019).

Another goal of NbS is increasing social resilience and the capacity of the system to adapt and accommodate to natural issues (Sarabi et al., 2019).

We can distinguish three different types of NbS (Sarabi et al., 2019):

- Type 1: NbS with minimal intervention including protection and conservation, urban planning, and monitoring strategies
- Type 2: Management approaches developing sustainable ecosystems and optimizing the generation of ecosystem services (e.g., IWRM)
- Type 3: Intensive management approaches including the creation of entirely new ecosystems

2.1.2. Examples

Linked to water management, NbS are needed to (re-)create space for water. In his article, Ruangpan (2020) exposes some of these solutions: floodplain lowering, dike relocation, groyne[4] lowering, summer bed deepening, water storage, bypassed and flood ways, high-water channels, obstacle removal, and dike strengthening, and result as reducing flooding and increasing opportunities for recreation, habitat, and biodiversity (fishes, birds, other wildlife).

There is a non-exhaustive list of strategies related to NbS: low-impact developments (LIDs), best management practices (BMPs), water-sensitive urban design (WSUD), sustainable urban drainage systems (SuDs), green infrastructure (GI), blue–green infrastructure (BGI), ecosystem-based adaptation (EbA) and ecosystem-based disaster risk reduction (Eco-DRR) (Ruangpan et al., 2020).

Regarding NbS for reducing hydro-meteorological risk, we can divide them into two categories (Ruangpan et al., 2020):

- Small-scale solutions referring to urban or local scale (green roofs, rain gardens, rainwater harvesting, dry retention ponds, permeable pavements, bio-retention, vegetated swales, open stormwater channel, etc.)
- Large-scale solutions referring to rural areas, river basins or regional scales (riparian buffer, flood storage basins, forests preservation and regeneration in flood-prone areas, river restoration, wetlands and mountain forestation, etc.)

All these solutions are designed to modify the land cover and to manage important amount of surface water runoff during extreme events (Solheim et al., 2020).

2.1.3. Differences with "Grey solutions"

In water management, we can distinguish so called "grey infrastructure" and "blue/green infrastructure" solutions. The first one in also called "traditional infrastructure" and refers to man-made and built infrastructures such as dams, floodwalls, pipes, gutters, retention basins, etc., aiming most of the time to tackle one issue at a time (European Commission, 2013; European Environment Agency, 2017; US EPA, 2022). Blue (e.g., water) and green (e.g., land)

[4] "*A groyne is a stiff hydraulic structure erected from the coast (in the case of oceans) or the bank (in the case of rivers) to disperse wave energy or to preserve the banks from eroding by trapping sediments*." (*Groynes*, 2022)

infrastructure refers to natural systems such as forest, floodplains, wetlands, etc., and aims to mimics these ecosystem's functioning (European Environment Agency, 2017; US EPA, 2022).

The European Commission (2013) defines green infrastructure as "[…] *a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation*.". Exactly as mentioned in the nature-based solutions' definition, these infrastructures provide a lot of ecological, economic and social benefits and co-benefits. It relies on the principle that protecting and restoring natural processes will benefit to ecosystems as much as to human beings (European Commission, 2013).

The main differences between blue/green infrastructure such as NbS and traditional/grey infrastructure is, on one hand, that blue/green infrastructure aims at fulfilling different objectives at the same time when grey solutions follow single purposes (European Commission, 2013). And on the other hand, blue/green solutions include ecosystems protection and preservation when we know that grey solutions can harm these same ecosystems (Archambeau et al., 2021).

Even though green solutions might seem better than the grey ones, in stormwater management, for example to avoid damage from extreme floods, an effective combination of NbS and traditional infrastructure (Sarabi et al., 2019) such as "green-grey integration" can be the best option and avoid reluctance of implementation.

2.2. COMMUNICATION, EDUCATION AND PUBLIC AWARENESS (CEPA)

Humans have a great influence on nature, and some biodiversity-rich countries don't have sufficient forces promoting biodiversity to influence major policy decision in favour of effective conservation policies. This can be explained by reasons such as the lack of political will, inadequate funding, absence of policies, and mismanagement of available resources (Hesselink et al., n.d.).

There are different types of problems. These that can be solved with communication as sole instrument (voluntary changes, attitudes, practices), these that are related to communication that will be a supporting instrument and these with no relation with communication at all.

In this chapter, I will explain what CEPA is and assess its purposes and means. The whole chapter is based on the manual "*Communication, Education and Public Awareness (CEPA): A toolkit for National Focal Points and NBSAP coordinators*" from the Secretariat of the Convention on Biological Diversity and IUCN.

2.2.1. Overview

CEPA has a systematic approach that tries to understand the stakeholders and beneficiaries' interests and is adapted to the local context, culture, and traditions.

- Communication is based on dialog between sectors and stakeholders to increase understanding and support planning and acting for the environment.
- Education means developing understanding and creating concern for the environment as well as will to act.
- Public awareness is key to develop understanding and concern, help people to get the issue and make them conscious of it.

Communicating and educating lead to increase understanding and, as a complement, participation allows knowledge sharing and increases empowerment by informing, consulting, consensus building, partnerships.

The Convention on Biological Diversity promotes understanding and develops education and awareness programs. It is not just about making scientific information available to the public. CEPA has different goals and tools (Hesselink et al., n.d.):

- Attracting, motivating, and mobilising individual and collective action for biodiversity
- It has a range of social instruments such as information exchange, participatory dialogue, education, and social marketing
- Identifying common interests amongst stakeholders to conserve and use biodiversity sustainability
- Providing means to develop networks, partnerships, and support knowledge management
- Providing ways to gain dialogue and cooperation of different groups and stakeholders
- It has learning and research actions
- Providing tools to develop capacity to support

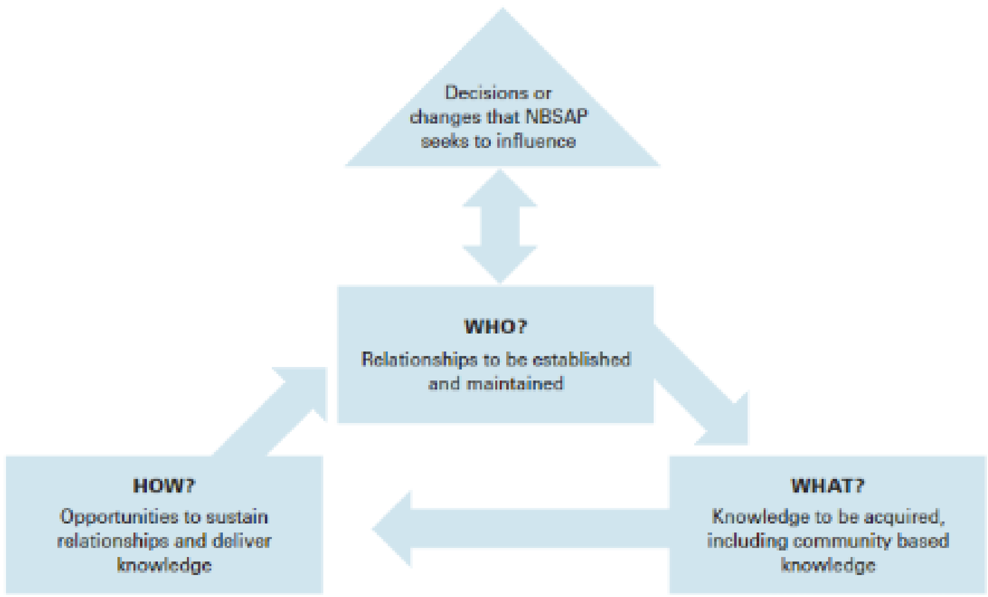
CEPA has different roles such as (Hesselink et al., n.d.): facilitating participation (offering opportunities for input and soliciting it, giving voice to smaller groups, enhancing participation in planning environmental programs, supporting stakeholders to engage decision-making), fostering policy change and acceptance, making information understandable and meaningful (explaining and conveying information), supporting project management (understanding audience concerns to better target messages, motivating beneficiaries, improving efficiency by informing both internally and externally), positioning and branding an organisation/project.

Internally, communication focuses on orienting staff to the vision and externally, it is about convincing the public that the organisation has an important role in society. To convince stakeholders, we need to identify emotional or practical reasons for their actions and translate scientific facts into attractive concepts and message, relevant to them and connected with their emotions. A common mistake is trying to make public think as we do by trying to educate them instead of listening and considering their point of view, which can help to understand their perception of the issue. It is all about perception.

"*People tend to listen what they know or believe*" (Hesselink et al., n.d.). They are not going to try to understand environmental issues if they don't have any interest for the environment, that's why we need to associate scientific messages and public's interests.

Networking and participation are keys. Community participation is encouraged as a learning and educating process in which communities can identify their vision and needs and develop plans to answer them. They're becoming actors in biodiversity conservation. About network, it is important to establish and maintain relationships between stakeholders, groups, or individual by increasing their level of interest in the topic. Different tools can help, such as edutainment, education in school, materials, community activities.

CEPA uses multi-stakeholder processes "[…] *to bring these with an interest in the issue together and engage the different perspectives from science, community, farmer, environmentalist, economic, policy and political in dialogs*" (Hesselink et al., n.d.). There are different ways to inform, and it shows that the more interactive methods lead to higher retention. A large suite of measures exists to communicate, educate, and concern. Interactive tools and games are a way.



Networks provide for a mutually beneficial relationship that significantly adds to the value the various actors.

Figure 12: Relationship valorising all actors (Hesselink et al., n.d.)

CEPA can also be used to strengthen capacities of the stakeholders. We are not talking about training, courses or guidelines. These new "know-hows" take place at three levels: systemic, organisational, and individual level (developing new knowledge, attitudes, skills, and professional behaviour).

In the CEPA guide, some elements that encourage effective learning are highlighted (Knowles M., 1950; Lewin K., 1951; Freire P., n. d.; quoted in Hesselink et al., n. d.):

- *"People believe more in knowledge that they have discovered themselves than in knowledge presented by others;*
- *Learning is more effective when it is active rather than a passive process;*
- *People remember 20% of what they hear, 40 % what they hear and see; 80% what they discover themselves.*
- *Acceptance of new ways of reasoning about acting, attitudes and behavioural patterns cannot be brought about by a piecemeal approach – one's whole cognitive, affective, behavioural system has to change;*
- *It takes more than information to change our theories of why and what we do, attitudes and behavioural patterns;*
- *It takes more first hand experience to generate valid knowledge;*
- *Behaviour changes will be temporary unless the reasons for and attitudes underlying them are changed;*
- *For changes in behaviour patterns, attitudes and action theories to be permanent, both the person and the social environment have to change;*
- *The more supportive, accepting and caring the social environment, the freer a person is to experiment with new behaviours, attitudes and theories;*
- *It is easier to change a person's theories, attitudes and behavioural patterns when he or she accepts membership in a new group. The discussion and agreement that takes place within a group provides a personal commitment and encouragement for change that is not present when only one person is being changed;*
- *New groups with new role definitions and expectations for appropriate behaviour are helpful in educational efforts. A person becomes socialized by internalizing the normative culture of the groups to which s/he belongs. As the person gains membership in a new group, new normative culture is accepted and internalized."*

• Lecture = 5% • Reading = 10% • Audiovisual = 20% • Demonstration = 30%	• Discussion Group = 50% • Practice by doing = 75% • Teach others/immediate use of learning = 90%

Figure 13: Percentage of what people remember depending on the teaching technique (Hesselink et al., n.d.)

Before even thinking about developing a communication plan, it is important to identify the target groups, meaning the people targeted by the message. These are homogenous groups of people whose cooperation is needed to solve the problem. It concerns stakeholders but not all of them, it can be people having a behaviour at the opposite that what is needed, people affected by "wrong behaviours", people having formal responsibility, or influencers (media, celebrities, etc.). It is first needed to determine the useful information (existing data, interviews, surveys, etc.) to determine target groups. After that, it is important to determine the problems and the expected effect of communication (or "communication target").

The communication target must be specified within the local context and current situation. Three categories of targets exist:

- Providing knowledge (ex. Explaining that floodwalls can do harm than good during floods and that it harms biodiversity)
- Changing attitudes (ex. Making people consider that grey solutions are not the only solution against flood problems)
- Changing behaviour (ex. Making people stop implementing flood protection measures without thinking about the impact on biodiversity)

When target groups and communication are identified, it is time to choose the means. These must be link to the target group and have a strong impact. It can be interpersonal means (dialogues, conferences, tours, meetings, workshops, etc.) or mass media (newspapers, brochures, television, website, etc.). Both have advantages and disadvantages, but the chosen means must help achieve the communication target, reach the target group and strengthen the message. Of course, the question of the cost must be considered as well.

In the case of SABICAS, a website has been created (www.sabicas.no), the project's partners have been publishing on their own website, articles have been published, the project and its expected results have been presented during conferences, and workshops have been and are currently set up. The project is also shared on social media such as Twitter or LinkedIn (cfr. Appendix n°1).

2.3. Stakeholders

Projects using NbS projects require a sustainable and integrated management of water and land. Such approaches require collaboration between multidisciplinary scientists and multisectoral stakeholders to create a system based on the understanding and identification of shared values (Siew et al., 2016).

"*'Stakeholders'' are defined as these who are either (1) involved in the decision-making process, (2) affected by the decisions made, or (3) not involved in the decision-making process but important for a successful implementation of decisions made"* (Grimble and Wellard 1997, Reed et al., 2009; quoted in Hasselink et al., n. d.).

NbS have the potential to bring stakeholders together and to initiate social innovations. They are also supposed to provide health and well-being benefits, create job benefits, etc. NbS include multiple actors at different levels (Sarabi et al., 2019):

- Micro-level actors (citizens, landowners, business owners, citizen groups, NGOs): key actors for uptake and implementation, diverse category, often primary beneficiaries, can be end-users with little decision-making power (top-down) or initiators of innovations (bottom-up)
- Meso-level actors (city level): monitoring supervisory, supportive roles, providing required institutional context and land and financial support, benefits from the image of the city
- Macro-level actors (regional, national, and international levels): contextual knowledge and experience to management actions, provide incentives to accelerate transition toward NbS
- Transboundary actors: knowledge brokers, diffuse knowledge among stakeholders and facilitate mainstreaming the concept

As part of NbS projects, scientists could have to collaborate with key informants such as:

- Professionals experienced in urban design, architecture or landscape architecture, in management of urban watersheds (Pavan, 2015)
- Policy makers (Pavan, 2015)
- Private and public landowners (e. g. farmers) (Pavan, 2015)
- Community groups (Pavan, 2015)
- Authorities and administrations (Solheim et al., 2020)
- Politicians (Solheim et al., 2020)
- Contractors in buildings, construction industry (Solheim et al., 2020)
- Etc.

Stakeholders are vital people or organisations for the success of a project. Among them, we find the primary stakeholders (needed for permission, approval and financial support, or who are directly affected by the project), the secondary stakeholders (indirectly affected) and the tertiary stakeholders (not affected/involved but who can influence opinions) (Hesselink et al., n.d.). Engaging various stakeholders, it is sometimes effective to combine formal and informal communication (Hesselink et al., n.d.).

In SABICAS, two workshops with stakeholders have been organized. The first one took place on November 16th (2021) and concerned the Haldenvassdraget. The second happened on November 24th (2021) about the Gausa river and brought together the following stakeholders (Oppsummering av arbeidsmøte i Gausavassdraget 24.11.21):

- Follebu Bruk AS (company, manufacture of grain mill products)

- Forum for Nature and Outdoor Recreation (FNF) Inland Norway
- Fåberg Farmers' and Smallholders' Association
- Gausdal Municipality
- Innlandet County Municipality
- Lillehammer Municipality
- Lågen Fiskeelv (fishing community)
- Norwegian Nature Conservation Association Inland Norway
- NVE Region East (Norwegian Water Resources and Energy Directorate)
- County Governor of Inland Norway
- Sør-Gudbrandsdalen Forest Owner Area
- Watercourse Association for Mjøsa with inlet rivers /Water area Mjøsa
- Viken County Municipality

Of course, public-oriented communication is key to develop people's understanding and concern, and interest in the issues make them conscious of it. As a complement, participation allows knowledge sharing and increases empowerment by informing, consulting, building consensus and partnerships (Hesselink et al., n.d.). Public participation is crucial, and it needs to be clear at what level the public will be engaged, because changes may happen more easily if the situation is well understood. It is often faster when people take responsibility for their decisions and creativity can come from sharing different knowledge (Hesselink et al., n.d.).

2.4. BARRIERS (FOCUS ON COMMUNICATION-RELATED ISSUES)

This sub-chapter focuses on the barriers that could prevent the implementation of a project such as SABICAS. In the first place, I will a list of the barriers related to NbS project in general and then I will describe in detail the barriers that could be encountered within the framework of SABICAS.

I have classified all the identified barriers in a table. The classification includes five different categories that are:

- Public awareness
- Costs
- Habits and perceptions
- Administration and policies
- Knowledge gaps

Table 1: Résumé of the communication-related barriers that could prevent the implementation of NbS

Type	*Barriers*

Public unawareness	- Lack of awareness or denial of climate change risks - Lack of awareness of the impact of land use changes to flood magnitude - Lack of awareness about biodiversity issues and its impacts on society - Lack of awareness of NbS and their benefits - Lack of awareness regarding the problems caused by floods - Scepticism, uncertainties - Perception and acceptance - Lack of communication and integration in the process
Costs	- Costs and priorities - Income losses - Lack of time - Lack of financial incentives
Perception and habits	- Values - Place attachment - Nostalgia and resistance to change - Social vulnerability - Protection of the current land use - "Good sides" of climate changes - Utilitarian vision of the landscape - Growth obsession barrier[5]
Administration and policies	- Lack of political will and long-term commitment - Lack of sense of urgency among policy makers - Lack of supportive policy and legal framework - Path dependency[6] - Inadequate regulation - Institutional fragmentation - Mechanism of compensation - Facility to modify the watercourse - Maladaptation
Knowledge gaps	- Lack of understanding of NbS - Interdisciplinary topics - Lack of skilled knowledge brokers and training programs - Challenge for effectiveness evaluation

[5] Barrier related to the paradigm of growth and the will to develop continuously
[6] Tendance to make decisions based on habits instead of current circumstances

2.4.1. Lack of awareness

The first category of barriers concerns the lack of public awareness. This lack of awareness can cover many different matters, such as biodiversity issues, flood issues, climate change risks, land use impacts, and NbS benefits.

First of all, there is a clearly a lack of understanding about what NbS are and their effectiveness. There is also a lack of information and evidence, the body of knowledge has remained mainly academic with limited diffusion and this has a negative effect on the level of acceptance from the public (Sarabi et al., 2019). NbS are not well-known by the public and it remains a difficult concept to imagine for a non-specialist audience. Therefore, it is also really complicated to imagine the benefits that it could provide, and people become sceptical (Solheim et al., 2020). The mix of all these uncertainties leads to distrust, which could end up as opposition at some point during the implementation process (Hesselink et al., n.d.; Kabisch et al., 2016; Pavan, 2015; Pischke et al., 2017; Ruangpan et al., 2020; Sarabi et al., 2019, 2020; Solheim et al., 2020). Also, the lack of understanding of the hydrological cycle and its functions is a barrier and implies a lack of openness to new alternative solutions and idea (Pavan, 2015). On the other hand, is important not to over-sell it as a miracle solution because sometimes grey or hybrid solutions may be right depending on the situation (Solheim et al., 2020).

Secondly, people are not systematically aware of the environmental issues that these solutions are trying to tackle. In this situation (the delta of the Gausa), the aims are to reduce the magnitude of floods and to protect and restore biodiversity. On one hand, not everybody realises that biodiversity in this very place is threatened and neither that it could have impacts on society (Pavan, 2015). On the other hand, some people remain uninformed about all the damage caused by floods. It even happens that citizens impacted by stormwater runoff don't really see the point in water management (Eckman et al., 2011). It is easy to understand that if there is no consciousness of the problems, neither will be a will to implement solutions. A quote in the article of Eckman et al. (2011) is a prefect resume of this problem: "*You don't know the importance of stormwater management, until it happens to you*".

In addition, if people are generally reasonably well informed about climate change, there remains some uncertainties regarding the related risks that can border on denial. Following the same idea, not everyone is informed that the flood phenomenon is changing because of the climate change. This is particularly true in this case, because people have been living with yearly flood events since they were born and have experienced some bigger events during their life. It then becomes normal, and most people have not been in the area long enough to notice that the floods have been changing. Following the same idea, they could hardly have noticed that the magnitude of the floods has been increasing by the modification done to the river channel because it has been done too long ago.

All these issues are related to a lack of communication or a miscommunication (and integration) with the public and stakeholders. By miscommunication, it is meant that scientists and stakeholders do not necessarily use the same language because they have been trained in a scientific paradigm and using an incomprehensible vocabulary can hinder communication or provoke disinterest from the target audience (Kabisch et al., 2016; Pavan, 2015; Pischke et al., 2017; Ruangpan et al., 2020).

The lack of awareness causes negative perception and mistrust among the locals and the lack of support from local business can also be problematic (Sarabi et al., 2020). The lack of public support, going beyond unwillingness to participate can be problematic. Furthermore, "*underappreciation of environmental benefits, fear of heightened costs for the implementation and maintenance of green spaces and distrust in the publicly announced costs and benefits, or the fear of rising housing prices*" (Schmalzbauer, 2018) can result in resistance from the public and lead to vandalism.

2.4.2. Costs

If flooding problems cost money and time, putting mitigation measure in place does have a cost too. In many cases, money is an obstacle for people to be willing to implement new types of solution (Pischke et al., 2017; Sarabi et al., 2020; Solheim et al., 2020). Plus, as mentioned before, landowners get compensation to repair damage caused by the flood that they may not necessarily get to implement preventive measures (Gundersen et al., 2016). Moreover, implementation represents a cost, but some solutions need to be maintained as well which is also a cost (Pavan, 2015).

It should be noted that it is probably not often a matter of motivation. If, as a specialist, it makes sense to implement certain measures rather than others, people such as farmers or landowners can have other priorities as to where their money or time should go (Eckman et al., 2011). It is important to know that some NbS aim to give more space to the river, which means that another land use type will lose that space and loosing land for a farmer is obviously no good news (Sarabi et al., 2019, 2020).

Economic issues affect a project. Not only because of arable land loss but also, for example, income from after flood-transport and deposition of eroded sand and gravels. Gravel extraction is an additional income for some landowners (Solheim et al., 2020).

Finally, the lack of financial incentives, combined with risk aversion, means that people fear the failure of NbS and associated financial losses (Sarabi et al., 2020; Solheim et al., 2020). Many citizens and entrepreneurs are not ready to be financially involved in NbS and are reluctant to collaborate in its development because they don't know what is in it for them. This is a consequence of the lack of information about NbS benefits and successes (Sarabi et al., 2020).

2.4.3. Perception and habits

Habits and perception play a great role in the acceptance of new solutions (Kabisch et al., 2016; Pavan, 2015; Ruangpan et al., 2020; Schmalzbauer A., 2018). In his article, Gundersen (2016) writes: "*The fact that former ways of rural life are perceived as threatened, combined with resistance against the ongoing rationalization and restructuring of the entire agricultural sector, has created social forces that seem to work against adaptation. Reducing the vulnerability of local communities such as Gausdal to climate change effects would require degrees of openness and reflexivity in responses to new challenges that are scarce today.*"

For example, project implementation in an already-build environment can be challenging because it can be difficult for citizens to imagine more flowing surface water in the urban environment, water can even be perceived as a danger in some case (Pavan, 2015).

In an article, Gundersen et al. (2016) talks about "social vulnerability" to flood (as a climate change effect). According to him, this concept represents "[…] *the exposure and sensitivity of a social actor or group to adverse events or processes that cause changes in a socio-ecological system.*" (Gundersen et al., 2016). This idea of vulnerability is directly related to the adaptive capacity and resilience, meaning the capacity to respond to these events and cope or adapt (Gundersen et al., 2016). These concepts are influenced by historical land use development and practice, and by current management and guideline policies (Gundersen et al., 2016).

In the area of interest, agriculture and forestry are important sources of income and, consequently, people could tend to protect the present uses of the landscape (Gundersen et al., 2016). That kind of resistance to change can be linked to the concept of place attachment (Gundersen et al., 2016; Sarabi et al., 2020; Solheim et al., 2020). We will see later that it can also be a driver to the implementation of a project but attachment to a place could threaten adaptation because it contributes to a romanticized past. In Gausdal, for example, people feel really connected to the place they're living in and are paying attention to what is happening in the neighbourhood. There is an identity-making process linked to the place and they've developed contextual knowledge connected to this (Gundersen et al., 2016). Social bonds and networks are important for them, and they sometimes were "happy" about the floods because they got to see more people working together like in the "good old days" when more workers were practicing traditional farming methods. It reinforces social networks (= "*activities and processes that support and build collaboration between people*" (Gundersen et al., 2016)) by accomplishing (repairing) things together in a way and this contributes to their well-being. (Gundersen et al., 2016).

Acceptance depends also a lot on perception and values, on people's background and interests. Norwegians do value nature because of outdoor recreation such as sport, fishing, and hunting (Ruangpan et al., 2020), but in a lot of cases ecological and functional value of the landscape come after economic, recreational, cultural, historical, and aesthetical values

(Pavan, 2015). Lots of actors have utilitarian vision of landscape and consider that natural resources should be 100 % utilized to secure livelihoods (Gundersen et al., 2016).

Climate change impacts are also perceived differently for various reasons. Huge impacts on climate are predicted in Norway such as a warmer climate but people seem to welcome it sometimes (better summer season, less snow in the valley and more in the mountains, improved condition for agriculture and forestry) but farm production is threatened by floods for example. Opinions are divergent, the risk can be precepted as acceptable, tolerable, or intolerable (Gundersen et al., 2016).

Kabisch et al. (2016) mentions the "*growth obsession barrier*", a mindset that pushes people to "build" more and more. Following this concept, people could have the feeling that "removing" an existing solution or giving more space to nature instead is a backstep.

Perception is key for NbS adoption and effectiveness, a lack of confidence in public preferences and socio-political structures (Ruangpan et al., 2020) and uncertainty can limit the adoption of NbS.

2.4.4. Administration and policies

NbS are effective at larger scales meaning that it needs to become a mainstream solution, but several barriers (technical and practical) are preventing the proliferation of NbS, mostly policy barriers or context-and place-specific barriers (Solheim et al., 2020):

- Lack of political will and long-term commitment: There are misalignments with short-term political plans and long-term goals (Solheim et al., 2020) set by NbS projects. For example, it is important to know about potential changes within the administration (elections) because regional and local politics can affect the decision-making process, and sceptical stakeholders are sceptical voters (Schmalzbauer A., 2018; Solheim et al., 2020).
- Lack of sense of urgency among policy makers: Administrative procedures are really time consuming, and it affects the acceptance procedure of projects (Solheim et al., 2020).
- Lack of supportive policy and legal framework: Frameworks are not designed at local context and are irrelevant in some situations. For example, a small retention dam was supposed to be restored to mitigate floods, but it felt under the regulations dam classification for hydraulic power, involving excessive costs for maintenance that couldn't be afforded by the landowner (Ruangpan et al., 2020; Sarabi et al., 2020; Solheim et al., 2020). This lack of workable framework that prevent stakeholders' groups to work together, and it implies challenges regarding local participation in the process (Sarabi et al., 2019).
- Path dependency: Decisions are based on the memory of decision-makers from past experiences that often leads to resistance to change. To make a link with the

paradigm of growth, urban stakeholders are used to use grey infrastructure for addressing challenges (Sarabi et al., 2019; Solheim et al., 2020) and changing their mindset can be difficult.

- Inadequate regulation: Regulations regarding NbS are scattered, made for grey infrastructures, and when it exists there sometimes is a lack of law enforcement that can uptake of solutions (Sarabi et al., 2019).
- Institutional fragmentation: Different departments use different visions, framework and procedures, languages, and responsibilities that limit the opportunities for incorporating novelty in planning and management processes (Sarabi et al., 2019). It is also difficult to see who is responsible for what. This concept is also called silo mentality (Sarabi et al., 2019, 2020).
- Mechanism of compensation: There can be economic compensation for direct losses, but without any requirements for improvement (Solheim et al., 2020).
- Ease of modifying the watercourse: Since the recent floods, it has been easier to obtain authorization from the environmental authorities to alter the river channel (Gundersen et al., 2016).
- Maladaptation: Many maladaptive practices have been observed, like draining the water away from properties as fast as possible instead of allowing it to flood without causing damage like in the past (Archambeau et al., 2021; Gundersen et al., 2016).
- Property ownership complexities: This regards a legal dimension as well as the attitude of individual owners that will think about financial benefits before sustainability goals (Sarabi et al., 2020).

2.4.5. Knowledge gaps

The concept of NbS is new and there is a lack of understanding regarding what it is and what it can bring in comparison to traditional approaches (Sarabi et al., 2019). There is a real challenge for the evaluation of the efficiency of NbS because it is related to local contexts and that it is relatively new (Schmalzbauer, 2018). The evidence regarding synergies between NbS for climate change mitigation or adaptation and biodiversity, human health, and social and economic aspects remains uncomplete (Kabisch et al., 2016).

This lack of knowledge about NbS as effective mitigation measures and the potential co-benefits reaches every stakeholder (authorities, landowners, politicians, contractors in the building, construction industry, public) (Solheim et al., 2020). Understanding and acceptance are closely linked, and we could help make people better understand the importance of watercourse renewal if we could evaluate opportunities and constraints for its implementation (Pavan, 2015).

In consequences, we observe a lack of skilled knowledge brokers and training programs that could facilitate networking and connecting stakeholders with scientists (Sarabi et al., 2020).

It is obvious that there can't be a good communication about something that lack a knowledge pool.

Within the area of interest (Gausdal, Lillehammer), little evidence of adaptation is observed and some constraints to the development of resilience have been identified (Gundersen et al., 2016):

- Traditions
- Interests and concerns (conflicts between stakeholders)
- Benefits from climate change (and floods)
- Habits (flooding events)
- Current strategies
- Maladaptive practices (insurance)/maladaptation (modification of the main river by public subsidies)
- *"Scale mismatch between single stakeholders' strategies and community-level strategies to manage flooding from the river Gausa"* (Gundersen et al., 2016)
- Uncertainties (climate change link with floods)

2.5. Drivers (focus on communication-related enablers)

If a lot of constraints appear when talking about the implementation of an NbS project, there are also some enablers that can facilitate acceptance among people and stakeholders. Most of the time, it is related to utilisation and feelings linked to the area in question.

There is a non-exhaustive list of drivers intervening in the acceptance process of a NbS project spread out in three different classes:

Table 2: Résumé of the drivers that could enable the implementation of NbS

Class	*Drivers*
Landscape uses and values	- Traditions - Recreational uses - Aesthetic - Tourism - Place attachment - Social capacities such as sense of responsibility and ownership
Information and involvement	- Stakeholders' information and participation - Public awareness - Understanding
Proof	- Extreme events

2.5.1. Landscape uses and values

The enablers from the first class are related to the uses that people can/could do of the landscape and how and why they value this one.

Not all stakeholders necessarily agree on water management as being important. Economic, recreational, cultural, historical, and educational values as well as aesthetic value can override ecological and functional value (Pavan, 2015).

For the instance, recreation and sport are a big part of leisure in Norway, including hunting and fishing that is part of identity and traditions. Around the Gausa river, the main income sources are dairy, timber, meat production, forest product and wood processing, as well as tourism (Gundersen et al., 2016). NbS provide multiples benefits for the society by reducing flood risks (storing and infiltrating rainfall, reducing erosion and particulate transport, recharging groundwater discharge, reducing pollution from surface water, increasing nutrient retention and removal, delaying and reducing surface run-off, maintaining soil moisture, and enhancing vegetation growth) but also additional benefits through recreational areas and aesthetic value encouraging tourism and preventing damages costs (Ruangpan et al., 2020).

Recreational use, nature and scenery can be key to water acceptance in the landscape. Stakeholders may accept things such as riparian buffers and understand their functions and values and may accept visual appearance of water, if it represents an important function for them (Pavan, 2015).

It also happens that the motivation of individuals depends on cultural values such as identity, place attachment or social networks. Aesthetics preferences are bounded with acceptance and perception, and there is a gap between the social process of landscape perception and the concept of ecology (Gundersen et al., 2016).

Social capacities such as sense of ownership and responsibility contributes to better response to environmental stressors or environmental changes and help to avoid conflict between stakeholders by constructing a shared vision of the situation (Buchecker et al., 2013).

2.5.2. Information and involvement

As mentioned before, understanding and acceptance are closely linked. The more people are aware of issues and solutions, the more they can develop understanding of the situation and create interest for the environment (Hesselink et al., n.d.).

Even if it can be challenging, stakeholders need to be involved for their knowledge to be useful and to integrate their interests and perspectives (Siew et al., 2016). According to Solheim et al. (2020): "[…] e*nthusiasm, sense of ownership and knowledge, can be improved through close stakeholder involvement from the early stage, through co-creation and co-design, often* *also co-defining and agreeing on the problems to solve."*. It also happens that citizens are sometimes keen to be involved in processes or at least informed (Eckman et al., 2011).

Better delivery of social, economic, and environmental benefits of NbS are observed when the public's interests are included in the process. User groups and stakeholders need to be consulted and involved in the planning, implementation, and monitoring processes (Schmalzbauer, 2018) to build connection and sense of community ownership activating participation.

In short, involving stakeholders and local population, and providing environmental education and capacity by informing the public about current issues and benefits of NbS is effective for raising awareness and increasing community support (Wamsler et al., 2020).

2.5.3. Proof

The last category is called proof because, in some cases, extreme weather events that cause dramatic damages or prove effectiveness of alternatives infrastructures may help stakeholders to accept these alternatives (Pavan, 2015).

2.6. Strategies

This sub-chapter is an overview of communication-related strategies which aim to overcome issues related to stakeholders and public engagement.

Strategies have been classified in different categories but all of them are intrinsically linked to each other, which means that they must be combined in order to work efficiently. Using one of them alone will probably have little or no effect on the acceptance of a project.

Table 3: Résumé of the communication-related strategies helping to overcome barriers preventing NbS implementation

Class	*Strategies*
Research	- Filling knowledge gaps - Contextualized approaches - Getting to know local context and using local knowledge - Finding stakeholders' interests and values - Social learning and social capacity building

Communication and participation	- Sharing experience and knowledge - Public information and education to increase awareness and understanding - Promoting NbS - Using a clear language - Spending time and resources on knowledge communication - Involving citizens and community groups - Cooperation with stakeholders and local partners - Developing a shared vision with stakeholders and associating capacities
Others	- Combining NbS and grey solutions - Economic instruments - Political and financial supports - Avoid overselling

2.6.1. Research

As mentioned before, current approaches tend to over-generalise the management strategies instead of focusing on local context. There is a need to turn to a more sustainable management and a more holistic approach to socio-ecological values within the catchment area (Gundersen et al., 2016).

First, in 2020, 80 % of the articles regarding NbS were about urban flooding. Knowing that there are still big knowledge gaps regarding NbS efficacy, it is essential to fill the gap in the research on small-scale and large-scale NbS, especially, for example, when it to comes issues around landslides that are more complex to understand (Ruangpan et al., 2020).

Then it has to be remembered that no single NbS can solve all problems and every project need to be designed to address challenges in its context and respective community. The effectiveness, benefits and acceptance of NbS depend on the implementation purpose, local context and culture (Ruangpan et al., 2020). Therefore, getting to know the local context is important. Considering that involving local population tends to decrease resistance and provides information on local environment and problems, including representatives from very different organisations and sectors (governmental, NGO, private sector, local people) sounds like an interesting strategy to increase the legitimacy of the processes (Siew et al., 2016). This is also an occasion to benefit from local knowledge on the natural dynamics of the river system (Gundersen et al., 2016).

Understanding stakeholders' interests and concerns allows the identification of common interests regarding the conservation of biodiversity and a better association between messages and public's interests (Hesselink et al., n.d.). Stakeholders together can identify different barriers in function of their level as well as they are key to see some enablers appearing (Sarabi et al., 2019).

Finally, social learning and social capacity building have become popular with the implementation of the WFD and its obligation of actively involving stakeholders (Buchecker et al., 2013). Social learning is defined as learning processes and changes in individuals and systems and well as knowledge gained by observing and interacting with others in a group (Pahl-Wostl, 2006). Practice such as co-researching that enhance social learning create shared understanding of management and common purpose (Buchecker et al., 2013; Collins & Ison, 2010). Different social capacities contribute to the building of acceptance: knowledge capacities (understanding), motivational capacities (sense of responsibility) and network capacities (trust) (Buchecker et al., 2013). This is particularly important in restoration/conservation projects that involve changes in management paradigms (let surface water flow instead of controlling it) such as NbS because it involves changes in the roles of stakeholders (Pahl-Wostl, 2006). NbS projects necessitate that architects, engineers, and ecologists must work together even if they don't necessarily share a common language. This is when social learning is important in order to overcome fragmentation and silo mentality (Pahl-Wostl, 2006; Solheim et al., 2020).

2.6.2. Communication and participation

The increase in people's understanding about issues, alternative solution and implementation details is a driver for project implementation by lowering scepticism (Solheim et al., 2020). Enhancing people's awareness can be achieved in different ways but this is all about informing and involving local people and stakeholders.

We tend to think that communication is information transmission, but a good communication/education is a two-way approach, interactive and participatory, aiming to create shared meaning amongst different perceptions of a problem and the likely solution by using dialog (Hesselink et al., n.d.). In this way people feel respected, share their knowledge and learn at the same time. Some implementations fail because of local opposition. It is then important to try to understand why locals are protesting. It could just be that communication has not been done and it would have been easier if people had been consulted before. It is always more costly to repair damage after. To facilitate the implementation of projects, there is a need of identifying best practice within the community and facilitating knowledge exchange between stakeholders (Hesselink et al., n.d.).

Why is it important to invest in communication? There is a link between information and satisfaction. Residents having other etiquettes can become ambassadors for your cause if you can influence their perception (Hesselink et al., n.d.). Since the most important barrier seems to be perception and understanding, it is important to educate and communicate (Pavan, 2015) and that is why it is crucial to spend enough time and resources on explaining (issues, NbS, benefits, etc.) (Solheim et al., 2020). Challenges and solutions need to be promoted to the public and stakeholders. Communication could be an eye-opener that allows people with different backgrounds to approach the same subject (Wamsler et al., 2020).

To communicate efficiently, using a clear language that can be understood by all disciplines, stakeholders, policy makers and publics involved to facilitate communication. That could help understanding the meaning of the projects and its values, finding opportunities, and overcoming the barriers to implementing measures (Pavan, 2015).

Not only do people need to be informed but also to be involved in processes. Co-creation, co-design and close dialogue with stakeholders is important to avoid scepticism (Solheim et al., 2020).

As mentioned before, more benefits are obtained from NbS when the public's interest has been taken into account. Different actions are possible for public participation: maximizing the flow of targeted information to stakeholder groups and organizing consultations; workshops and opportunities for feedback; communicating the multi-functionality of NBS to increase awareness and support; inviting volunteers to take part in implementation, monitoring and maintenance activities. (Schmalzbauer, 2018) The interest will depend on socio-economic and cultural background as much as experience (Schmalzbauer, 2018) but operating with local stakeholders allows the development of a shared vision and provides opportunities for learning and enhancing ecosystem stewardship even though it can be challenging.

Communication and involvement can happen through different processes and tools but It is important to involve the right stakeholders at the right time during the process (Hesselink et al., n.d.). For example, including relevant stakeholders such as landowners, political levers and administration, at an early stage is key to co-defining problems (Solheim et al., 2020). On another hand, it is not recommended to inform all stakeholders at the same time and using the same approach (Hesselink et al., n.d.).

Among communication tools and techniques, we can find:

- <u>Information + socialization:</u> Social meetings and events encouraging involvement (Hesselink et al., n.d.). Discussing water management during public meetings is a way of motivating local actors, although that kind of gathering is becoming less common, preventing transmission of knowledge between inhabitants (Gundersen et al., 2016).
- <u>Partnership among stakeholders</u>: Partnerships allow cooperation between stakeholders that can add different skills, means and ideas (Hesselink et al., n.d.).
- <u>Knowledge sharing mechanisms and technologies</u>: Sharing understanding of NbS and its benefits by using place-based approaches to engage local actors (Sarabi et al., 2019) facilitates social learning. Sharing ideas is important because it is an iterative process which can also include citizens.

- Education and training: Providing environmental education and widening knowledge by informing the public about issues and benefits decrease uncertainties regarding the functionality of NbS and increases community support (Schmalzbauer, 2018). This can be at school or through informal education (newspaper, tv, radio, internet, etc.) (Hesselink et al., n.d.).
- Living Labs: Creating areas for environmental education and filling up the knowledge gap concerning performance and impact of implemented NbS (Sarabi et al., 2019). There is a need of associating capacities that can be reached by applied learning or living lab methodology (Wamsler et al., 2020). Providing an opportunity for people to see installed infrastructures could improve local knowledge and encourage adoption of practices (Eckman et al., 2011; *SABICAS*, n.d.).
- Workshops: Where stakeholders can share ideas and concerns and deliberate about land use objectives, landowner responsibilities, etc. (Hesselink et al., n.d.; *SABICAS*, n.d.)
- Tools and material: standard media formats such as websites (Eckman et al., 2011), platforms including data collection, web access to laboratory networks and open education resources (Maletić et al., 2020), artistic projects increasing visibility (Hesselink et al., n.d.; Pavan, 2015).
- Targeted stakeholder collaboration: meaning targeted involvement of the private sector, academia and/or other local authorities based on solid knowledge. It is needed to fill gaps in knowledge to increase awareness about NbS (Hesselink et al., n.d.; Wamsler et al., 2020).
- Strategic citizen involvement: the aim is to increase public awareness and avoid objection and protest (for example from conservative groups) that can be a major obstacle. This can be achieved through different techniques such as informal workshops, continuous dialogue, creating residents/organisations/work groups, etc. The involvement of citizens has been proven to be effective for raising awareness and increasing public support. This can be used in combination with other stakeholders' involvement activities (Eckman et al., 2011; Hesselink et al., n.d.; Wamsler et al., 2020).
- Collaborative monitoring: Effective monitoring and valuation systems for implementation processes and benefits. Experimentation provides opportunities for stakeholders from different levels to meet and interact, and facilitates innovation diffusion (Sarabi et al., 2019).
- NbS ambassadors: Knowledge valorisation and sharing, exploiting knowledge we currently have (Kabisch et al., 2016).
- Community-integrated design projects, participatory design (Pavan, 2015)
- Co-researching approaches: Integrated Catchment Management (Collins & Ison, 2010)

2.6.3. OTHERS

The last category includes solutions that are not directly related to communication but that can help overcoming some of the mentioned barriers:

- Avoid overselling: It is important not to over-sell it as a miracle solution because sometimes grey or hybrid solutions may be right depending on the situation (Solheim et al., 2020).
- Investigate rules and regulations (Sarabi et al., 2019)
- Economic instruments: Price instruments, quantity instruments, fiscal instruments (Sarabi et al., 2019)
- Plans, acts and legislations: It can facilitate mainstreaming the concept (Sarabi et al., 2019)
- Combining NbS with grey solutions: According to Sarabi (2019): "*Providing protection in face of extreme floods, or water cleaning functions in urban areas with high density cannot be accomplished solely through NBS implementation in most cases. Effective combination of NBS and gray infrastructure, or green-gray integration, can also facilitate breaking the path dependency toward gray infrastructure in communities while retaining functional gray infrastructure*"
- Appropriate planning and design: Paying attention to organisational and aesthetical aspects for acceptance from the public (Sarabi et al., 2019)
- Outsourcing: Information and advices are supporting stakeholders in their implementation of NbS (Wamsler et al., 2020)
- Concealed science-policy integration: Policies mainstreaming NbS into planning regulations and guidance (Wamsler et al., 2020)
- Political and financial support (Sarabi et al., 2019; Schmalzbauer, 2018)

3. METHODOLOGY

In this chapter, I will describe how I produced a map for the purpose of communication. I will explain my thought pattern and methods I used to create the map.

The process behind this master thesis is summarised below, and will be explained in more details subsequently:

1. Getting to know the project and what my contribution will be
2. Beginning with the visualization and quantification of land use changes of the area of interest
3. Literature review about NbS, stakeholders, barriers and drivers to NbS project implementation
4. Getting to know what has been done so far regarding the stakeholders within the project
5. Informing myself about the best ways of communicating with stakeholders and the public
6. Completing the interactive map project
7. Evaluation of the project
8. Identifying possible improvements

3.1. PRE-CONCEPTION PHASE

Firstly, I got to discover SABICAS project by reading the final proposal and discussing with different researchers working on the project. Towards writing an article, I have been asked to create a visual design of the delta between the Gausa river and the Gudbrandsdalslågen and quantify land use changes in that area based on image analysis.

When talking about the project, I was surprised by the fact that some people would be against these kinds of projects, and it piqued my interest. After that, I decided that I wanted to learn more about barriers that obstruct the implementation of projects, especially projects involving nature-based solutions. I first asked researchers working on the work package focus on stakeholders for more information about the situation and stakeholders, etc. and then tried to find as much existing literature as I could about that topic.

As mentioned in the previous chapters, I found out that a lot of barriers can prevent protective/restorative measures from being implemented and that it stems, most of the time, from a lack of awareness or knowledge. I also realized that, even though it is developing with the Water Framework Directive, there is a real lack of communication or a miscommunication between the academic community and the "rest of the world" (meaning non-academic stakeholders and public).

I wanted to create a tool that would provide a bridge between people and scientists. With this in mind, I looked for some ways of communicating efficiently with the audience. Then, after reaching agreement with my supervisors, I decided to use the content I had to produce for the article and to develop it as an interactive map that could be used to communicate with the stakeholders and the public.

At first, I considered doing a poster map, but it didn't fit the target audience nor the communication target, that is why I opted for an interactive map instead. I defined my goals following the CEPA method.

3.2. CONCEPTION METHOD

3.2.1. INTERACTIVE MAP'S PROJECT

The program I used to create the project is QGIS, a free professional GIS application. QGIS is a user-friendly Open-Source Geographic Information System (GIS) licensed under the GNU General Public License. It is a volunteer driven official project of the Open Source Geospatial Foundation (OSGeo) (*Discover QGIS*, n.d.).

To be able to show the land use changes that happen through time, I had to create a different map for every selected year (1947, 1959, 2010, 2019), then I combined everything by using QGIS2WEB, a QGIS plugin that generates web maps from QGIS project, either as OpenLayers, Leaflet, or Mapbox GL JS, including as many aspects of the project as possible (layers, styles (including categorized and extent) (*Discover QGIS*, n.d.).

Benjamin Kupilas (Researcher Scientist, PhD at NIVA) recommended that I also design poster maps of the different chosen time so that they can be used in presentations.

In order to explain the method used to design the maps, I will proceed step by step:

1. Collecting aerial photographs from the different times of interest (1947, 1959, 2010, 2019). The years were chosen according to available date and relevant changes in the landscape. All areal pictures were collected from the website norgeibilder.no.
    - <u>1947</u>: The oldest areal image of the delta of the Gausa available with sufficient quality to make a land use classification is from 1947. It is also a relevant time because the Gausa river had not yet been modified for timber transport at that time.
    - <u>1959</u>: That time was relevant because it allows us to see the landscape after the channelizing of the river for timber transport.
    - <u>2010:</u> I opted for 2010 because the picture had a high quality and it was the closest date from 2012, year when the first riparian zone classification of Corine Land Cover was available. I was then able to use it as a base.

- 2019: I opted for 2019 because the picture had a high quality and it was the closest date from 2018, year when the second riparian zone classification of Corine Land Cover was available. I was then able to use it as a base.

For each picture, I had to merge the different images of the mosaic and then crop them to keep the area of interest only. The selected pictures have been taken during the summer to get the most accurate comparison possible.

2. Defining the limits of the area of interest. The area of interest was a section of the Gausa river of about 2 km long.
3. Defining the rules for the land use classification.
    - Blue = Areas where water flows or can flow (e. g. areas where sediment banks are observable)
    - Red = Urban (roads and paths non-included)
    - Dark green = Forest and woodland (a single tree is not considered as forest/woodland)
    - Light green = Grassland
    - Yellow = Cropland
    - Brown = Open space with no or little vegetation (non-including areas where water can flow)
4. Classifying the land use for 1947 by creating a vector layer in QGIS using the picture of 1959 as base for visual image analysis. The base picture is black and white, so I was not able to perform an (semi-)automatic classification. I had to draw every polygon and chose its land use class manually. It must be noted that this was only possible because the area of interest is really restricted.
5. Classifying the land use for 1959 by creating a vector layer in QGIS using the picture of 1959 as base for visual image analysis. Again, the base picture as black and white so the procedure adopted for 1947 was used.
6. Combining the Corine Land Cover classification 2012 and Land cover classification for riparian zone 2012 in one vector layer. I used a combination of these two layers because CLC was not precise enough compared to the classification I've made myself and RZ classification does not cover the whole delimited area.
7. Modifying the CLC classification from 2012 to correspond to the land use of 2010 within the area of interest and simplifying the classification to correspond to the manual land use classification made for the previous date. The area has been delimited by another vector layer indicating that the zone classification matches with the land use of 2010 and not 2012. The changes have been drawn manually after visual image analysis to be the most accurate possible. I simplified the classification as much as possible in order to get a map which is comprehendible for people from every background.
8. Combining the Corine Land Cover classification 2018 and Land cover classification for riparian zone 2018 in one vector layer. I used a combination of these two layers

because CLC was not precise enough compared to the classification I've made myself and RZ classification does not cover the whole delimited area.

9. Modifying CLC classification of 2018 to correspond to the land use of 2019 within the area of interest and simplifying the classification to correspond to the manual land use classification made for the previous date. The area has been delimited by another vector layer indicating that the zone classification matches with the land use of 2019 and not 2018. The changes have been drawn manually after visual image analysis to be the most accurate possible. I simplified the classification as much as possible in order to get an understandable map for people from every background.
10. Selecting and collecting relevant data such as river network, flood and landslide zones, etc. All the details about the data used will be covered in the next sub-chapter.
11. Implementing data in the QGIS project.
12. Modifying the final layers' rendering to make it understandable and pleasant to the eyes.

3.2.2. Side project

To quantify and allow visualisation of the changes within the watercourse, I made a separate project.

I first isolated the features representing water and compared them by calculating their area and their width. I calculated the width with the help of a line type vector layer. I manually drew the lines for the period of 1947, 1959, and 2018, then calculated the length of each line.

I used a distance of 100 m between every measurement line. The distance has been calculated with the QGIS plugin Qchainage.

After that, I exported and compared the data in Excel and calculated the changes in meters. I also calculated the differences of land use for the riparian zones of the area of interest only.

3.3. Used data

3.3.1. Aerial pictures

- Areal picture 1947 (Norge i bilder)
  Project: Nittedal-Vinstra 1947
  Raster data, mosaic, TIF files.

  This layer only covers the area of interest.

Table 4: Information regarding the aerial picture from 1947

Image date	*1947-06-12*	Record method	*Analogt kamera*
Published date	*2021-04-26*	Original- image format	*Tiled TIFF*
Project start	*2020*	Orientation- method	*AT*
Owner	*Geovekst*	Standard deviation	*0.7*

Type	*Ortofoto*	Coordsys.	*UTM32 EUREF89*
Resolution	*0.1 (m)*	Aerial company	*Widerøes flyveselskap*
Coverage number	*WF-0224*	Producer	*COWI AS*
Image category	*Pankromatisk*	Product- specification	*OrtofotoRapport WF-0224 Nittedal-Vinstra 1947...*
Color depth	*8 bit/px*		

For information, a part of the area of interest was not covered by this project, the blank has been filled in with the project of 1959. This very area include part of the Gausa river, this part has therefore not been taken in account for the quantification of land use changes (cfr. Appendix n°3).

- Areal picture 1959 (Norge i bilder)
  Project: Sør-Gudbrandsdalen 1959
  Raster data, mosaic, TIF files.

  This layer only covers the area of interest.

Table 5: Information regarding the aerial picture from 1959

Image date	*1959-06-25*	Record method	*Analogt kamera*
Published date	*2021-02-16*	Original- image format	*Tiled TIFF*
Project start	*2020*	Orientation- method	*AT*
Owner	*Geovekst*	Standard deviation	*0.7*
Type	*Ortofoto*	Coordsys.	*UTM32 EUREF89*
Resolution	*0.2 (m)*	Aerial company	*Widerøes flyveselskap AS*
Coverage number	*WF-2105*	Producer	*COWI AS*
Image category	*Pankromatisk*	Product- specification	*OrtofotoRapport WF-2105 Sør-Gudbransdal 1959....*
Color depth	*8 bit/px*		

For information, a part of the area of interest was not covered by this project, the blank has been filled in with the images of another the project Gjøvik - Otta - Hjerkinn - Grotli 1958. This area does not include part of the Gausa river nor its related riparian zone (cfr. Appendix n°4).

- Areal picture 2010 (Norge i bilder)
  Project: Lillehammer 2010
  Raster data, mosaic, TIF files.

  This layer only covers the area of interest.

Table 6: Information regarding the aerial picture from 2010

Image date	*2010-09-06 2010-09-04 2010-08-30 2010-07-25 2010-07-24 2010-07-07 2010-07-02*	Record method	*Digital sensor*

Published date	*2016-04-15*	Original- image format	*TIFF*
Project start	*2010*	Orientation- method	*GNSS/INS med AAT*
Owner	*Geovekst*	Standard deviation	
Type	*Ortofoto 20*	Coordsys.	*UTM32 EUREF89*
Resolution	*0.2 (m)*	Aerial company	*Terratec AS*
Coverage number	*TT-13895*	Producer	*Terratec AS*
Image category	*Farge*	Product- specification	*Ortofotorapport Lillehammer 2011_GSD20.pdf*

- Areal picture 2019 (Norge i bilder)
  Project: Lillehammer-regionen 2019
  Raster data, mosaic, TIF files.

  This layer only covers the area of interest.

Table 7: Information regarding the aerial picture from 2019

Image date	*2019-06-28* *2019-06-27*	Record method	*Digital sensor*
Published date	*2020-03-07*	Original- image format	*TIFF*
Project start	*2019*	Orientation- method	*GNSS/INS med AT*
Owner	*GEOVEKST*	Standard deviation	
Type	*Ortofoto 10*	Coordsys.	*UTM32 EUREF89*
Resolution	*0.1 (m)*	Aerial company	*TerraTec AS*
Coverage number	*TT-14437*	Producer	*Rambøll Norge AS*
Image category	*Farge*	Product- specification	*Rapport for ortofoto Lillehammer-regionen 201...*

3.3.2. Land use classification layers

- Land use classification 1947
  Vector data, type polygons, SHP files.
  ⇨ Image visual analysis + manual classification by polygons

  This layer only covers the area of interest.

- Land use classification 1959
  Vector data, type polygons, SHP files.
  ⇨ Image visual analysis + manual classification by polygons

  This layer only covers the area of interest.

- Land use classification 2010 and 2012 (Copernicus Land Monitoring Service)
  Vector data, type polygons, SHP files.

⇨ Corine Land Cover (CLC) 2012, Version 2020_20u1. This layer covers the five municipalities concerned by the Gausa catchment.
⇨ Riparian Zones 2012 status. This layer covers the whole Glomma catchment.

For the map of 2010, these two land classifications have been modified by myself to correspond to the land use of 2010. The modified area has been clipped to correspond to the area of interest.

- Land use classification 2018 and 2019 (Copernicus Land Monitoring Service)
  Vector data, type polygons, SHP files.
  ⇨ Corine Land Cover (CLC) 2018, Version 2020_20u1. This layer covers the five municipalities concerned by the Gausa catchment.
  ⇨ Riparian Zones status 2018. This layer covers the whole Glomma catchment.

For the map of 2019, these two land classifications have been modified by myself to correspond to the land use of 2019. The modified area has been clipped to correspond to the area of interest.

- Riparian zones delineation (Delineation of Riparian Zones — Copernicus Land Monitoring Service)
  Vector data, type polygons, SHP files.
  ⇨ Drza = delineation of actual riparian zones
  ⇨ Drzp = delineation of potential riparian zones
  ⇨ A third delineation exists (drzo = delineation of observable riparian zones) but I removed this one to avoid overloading the layer.

  These layers cover the whole County of Innlandet.

- River network of the County of Innlandet (NVE data nedlast).
  Vector data, type lines, SHP file.
- Innlandet municipalities (Administrative enheter kommuner - Kartkatalogen (geonorge.no))
  The data set shows the division of municipalities in Innlandet County with the most accurate boundaries that have been digitally registered and collected in one data set.
- Gausa catchment (NEVINA (nve.no))
  Vector data, type polygon, SHP file.
- Floods folder
  ⇨ Flood barriers. Vector data, type lines, SHP file. Handmade, based on Valley of Gudbrandsdalen, Norway - PHUSICOS R&D project to reduce risk in mountain landscapes.
  This layer represents the existing grey barrier existing in the zone of interest and the one that should have been implemented in the PHUSICOS project.
  ⇨ River network. Vector data, type lines, SHP file. (NVE data nedlast)

This layer represents the river network of the County of Innlandet, classified by importance.

⇨ Flood_event_area. Vector data, type polygons, SHP file. (NVE data nedlast)
  This layer represents areas where historical flood events happened.

⇨ Flood zones (return periods: 10 years, 20 years, 50 years, 100 years, 200 years, 500 years, 1000 years). Vector data, type polygons, SHP files. Spread of a flood for a given recurrence interval. (NVE data nedlast)

⇨ Catchment areas. Vector data, type polygons, SHP file. Main catchment area and other catchment areas where the river has an outlet into the sea. (NVE data nedlast)

- Landslides folder (NVE data nedlast)
  - ⇨ Landslides_dangerzone (100, 1000, 5000 years). Vector data, type polygons, SHP files.
  - ⇨ Dangerzones dimensioning point. Vector data, type points, SHP file.
  - ⇨ Landslide_Danger Zone Analysis Area. Vector data, type polygons, SHP file.
- Actual land use. Vector data, type polygons, SHP file. (FKB-AR5 - Kartkatalogen (geonorge.no))

The AR5 classification system is a tool for systematic mapping and classification of land resources with emphasis on the production basis for agriculture and forestry. The abbreviation AR5 stands for area resource map in scale 1:5 000. The map is part of the Common Map Database (FKB) which contains detailed map data for Norway and is managed by the Geovekst collaboration. It is a surface-covering data set that is suitable for analysis purposes and map production (NIBIO, n.d.).

4. RESULTS

4.1. PRESENTATION OF THE MAP'S PROJECT

The final result of the mapping project is a QGIS project including different layers with different information that will serve as base for a future interactive map. I will here explain the different layers below.

4.1.1. LAYERS USED FOR THE COMMUNICATION MAP'S PROJECT

The following layers are supposed to be used as part of the communication map project. Ideally, the user should be able to visualise the following layers:

- 1947 (land use + background picture)
- 1959 (land use + background picture)
- 2010 (land use + background picture)
- 2019 (land use + background picture)
- Floods (flood events areas, barriers)
- River evolution (1947 + 1959 + 2012 + 2018)
- Riparian zones (actual + potential)
- River network
- Google Satellite

The extend of the map would be limited to the one you can see on the figure n°14 and, except for the Google Satellite used as background image, none of these layers could not be displayed at the same time.

Comparative layers

The groups 1947, 1959, 2010 and 2019 are build the same way. A first layer is an aerial view of the delta between the Gausa and the Gudbrandsdalslågen, and the second one is a land use classification.

Thanks to the riparian zones' classification from the Copernicus project, the last two maps benefit from the representation of the wetlands and roads (included in "Urban"). Unfortunately, I was not able to identify wetland zones nor every part of every road on the pictures from 1947 and 1959.

The rendering might differ a little bit because of the colours of the image in the background.

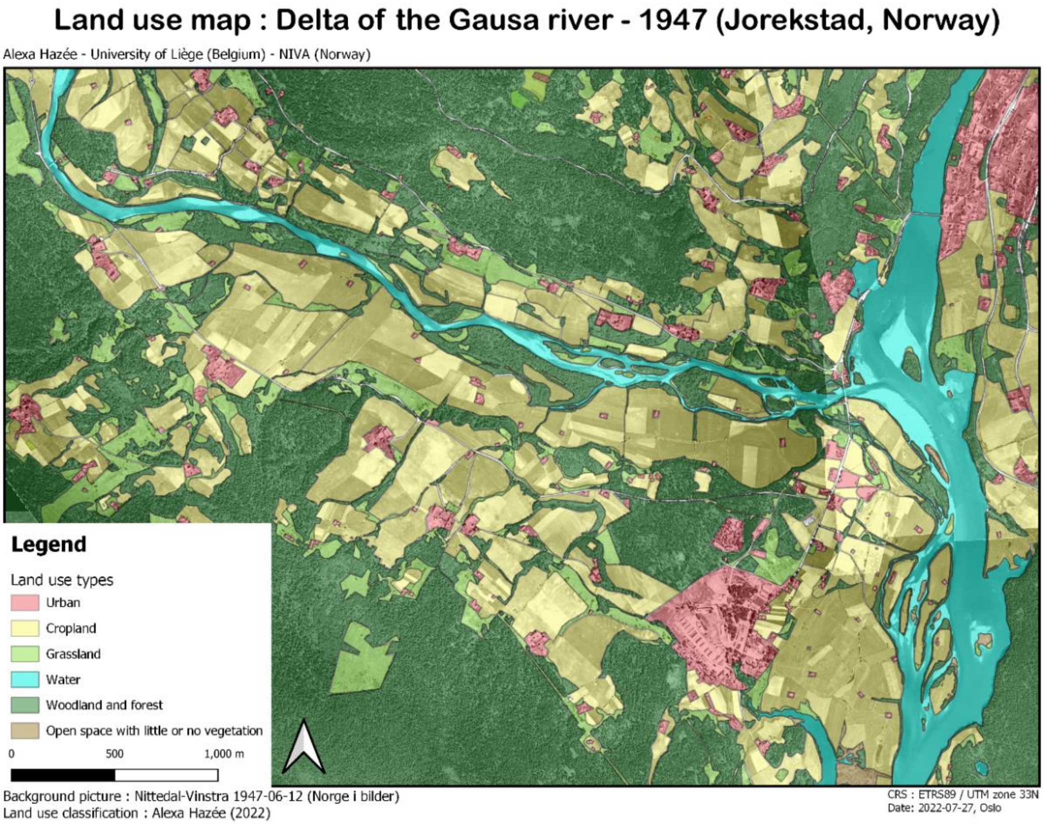


Figure 14: Land use map of the delta of the Gausa based on a picture from 1947

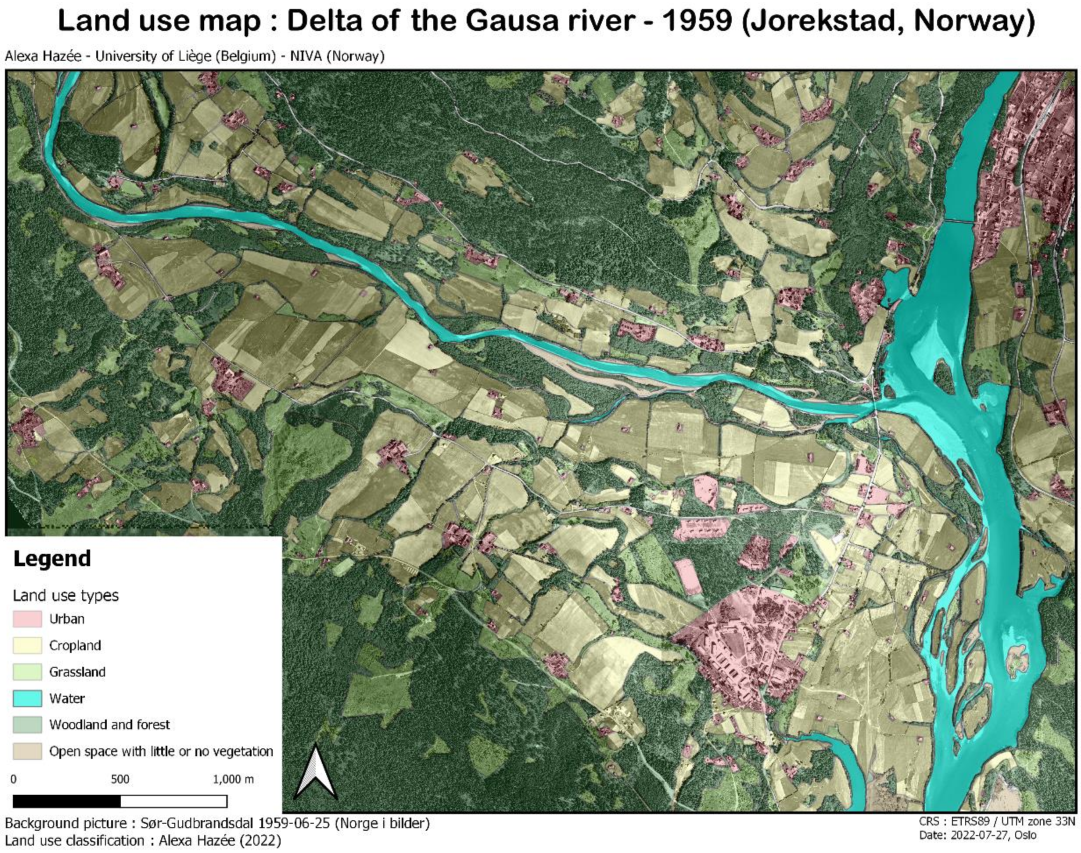


Figure 15: Land use map of the delta of the Gausa based on a picture from 1959

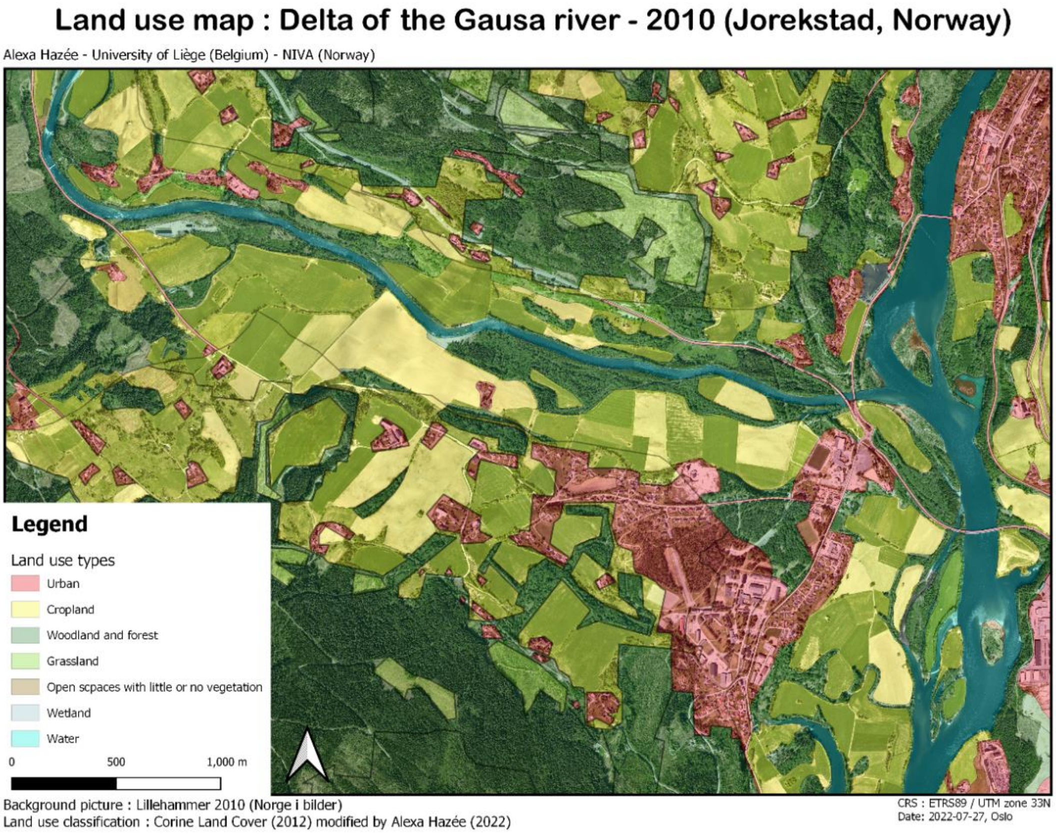


Figure 16: Land use map of the delta of the Gausa based on a picture from 2010

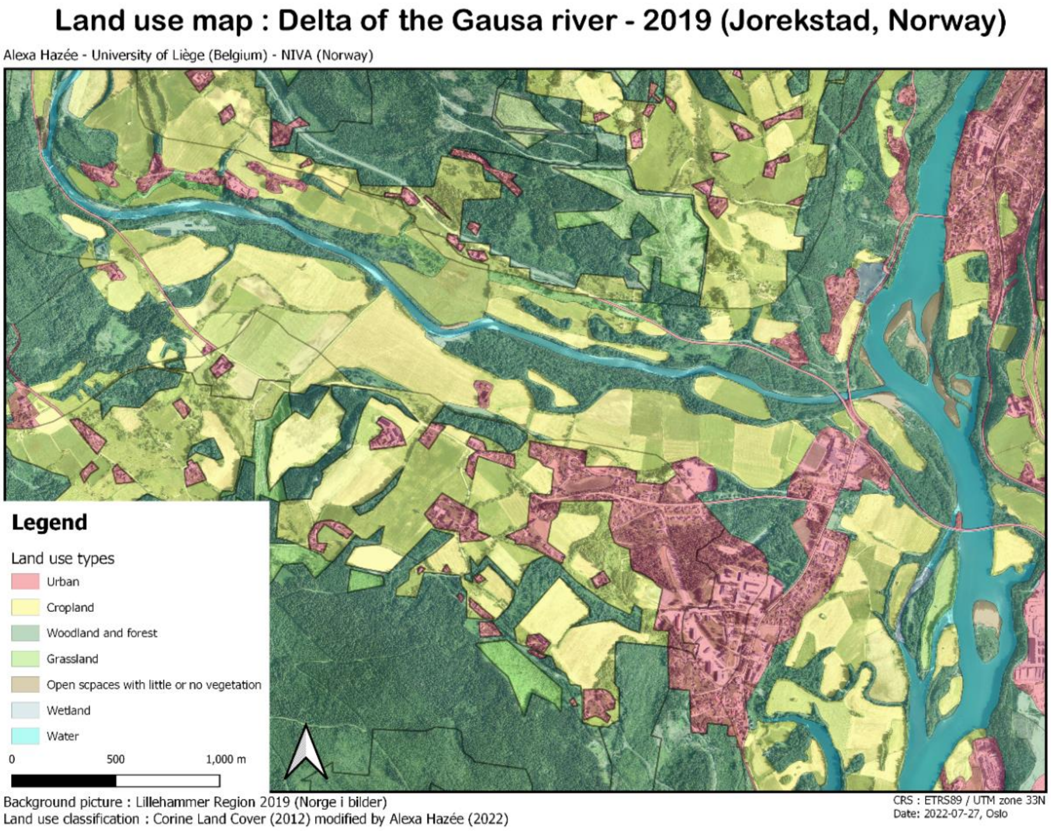


Figure 17: Land use map of the delta of the Gausa based on a picture from 2019

The maps above have been developed to give the possibility to see the four periods at the same time.

Riparian zones

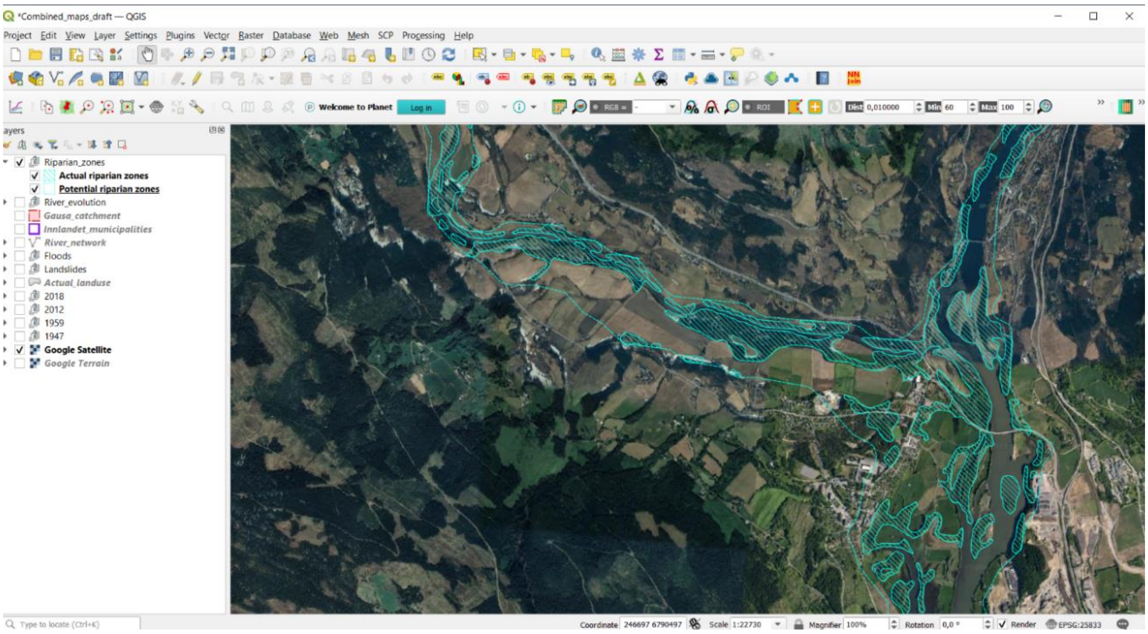


Figure 18: Screenshot of the QGIS project with riparian zones layers active

These layers represent the delineation for actual (hatched) and potential riparian zones (dotted lines). This groups should be accompanied by a definition of what is a riparian zone, its utility, biodiversity, etc.

Floods

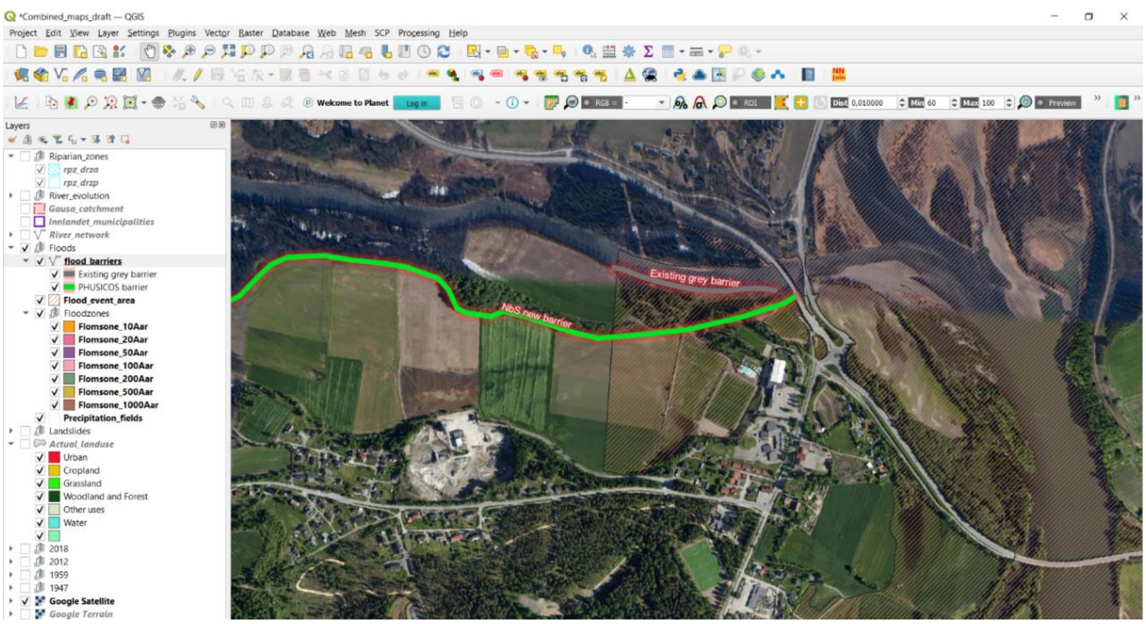


Figure 19: Screenshot of the QGIS project with previously flooded zones and flood barriers layers active

This group of layers represents flooding areas (not visible in the map extend), catchment areas (not visible in the map extend), areas where historical flood have happened and the location of the actual grey barrier against floods (grey) and the location of the barrier pictured as part of the PHUSICOS project (green).

Regarding the flood zones, the municipality of Lillehammer has some data about rainfall, but the dataset is old and over a short time period, so the developed Intensity-Duration-Frequency curves (IDF) are not accurate for actual flood events (Lillehammer kommune, 2022). Therefore, the area of interest is not yet listed in the flood zones.

River network

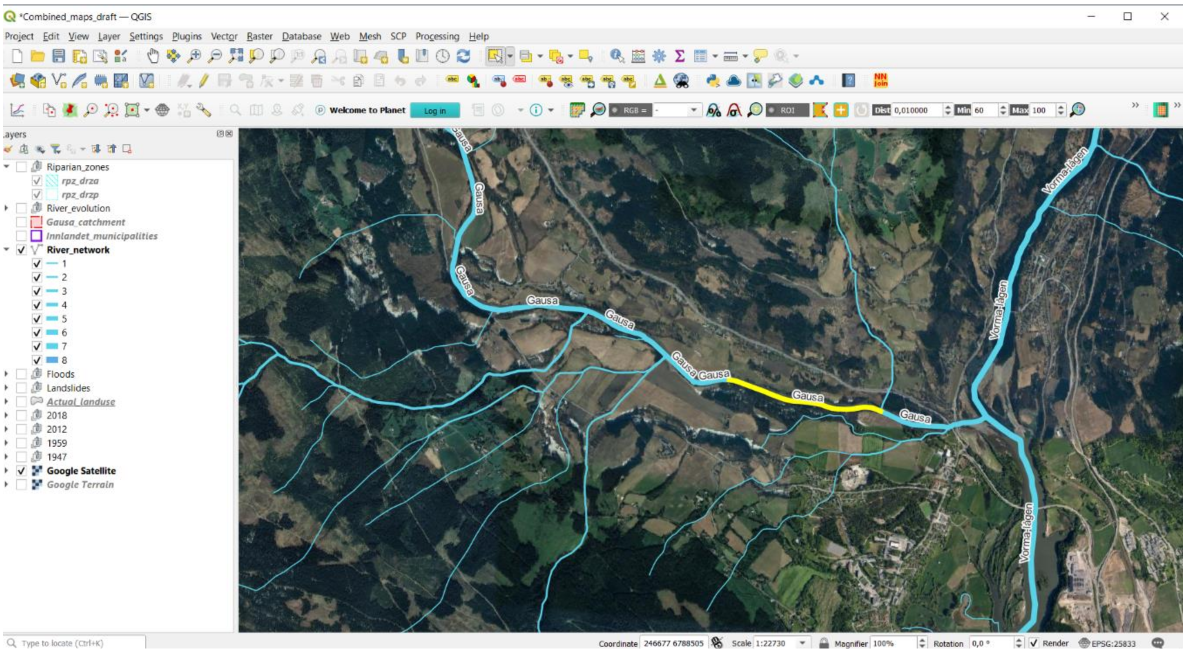


Figure 20: Screenshot of the QGIS project with river network layer active

This layer is representing the whole river network of the Innlandet county, classified by order of importance and playing with the size of the lines. It is interesting because most of land use classification do not take small tributaries in account.

River evolution

The “river network” group is the only group for which users would have the possibility of choosing whether layers are displayed or not in order to be able to compare between the different time periods.

There are four layers, one for each different time period: 1947, 1959, 2010, 2019.

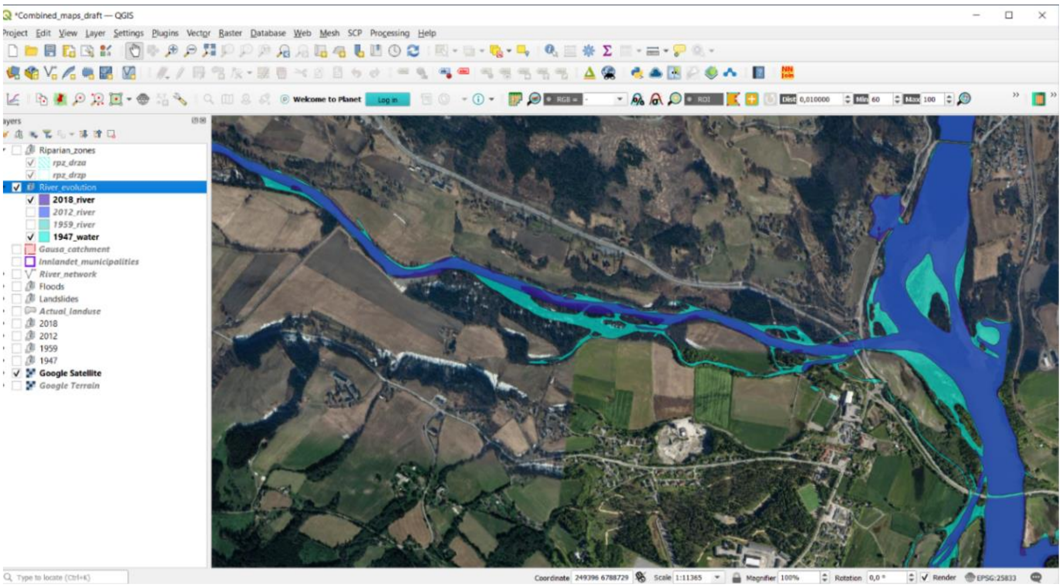


Figure 21: Screenshot of the QGIS project with river evolution layers active

4.1.2. LAYERS USED FOR OTHER PURPOSES

The following layers contains interesting information for the project, but they are not meant to be presented to the public, at least not in the framework of this particular project. These layers mostly cover a wider area such as the Gausa catchment, the Glomma catchment or the county of Innlandet.

Land use in the municipalities concerned by the Gausa catchment for 2012 and 2018

Since I used these data as a base to quantify the land use in 2010 and 2019, I decided to leave them in the project to make an additional map, outside the area of interest. These groups are composed of the riparian zone classification and the CLC classification both from the Copernicus project. I also clipped the CLC layer so that the riparian zone can fit in the map.

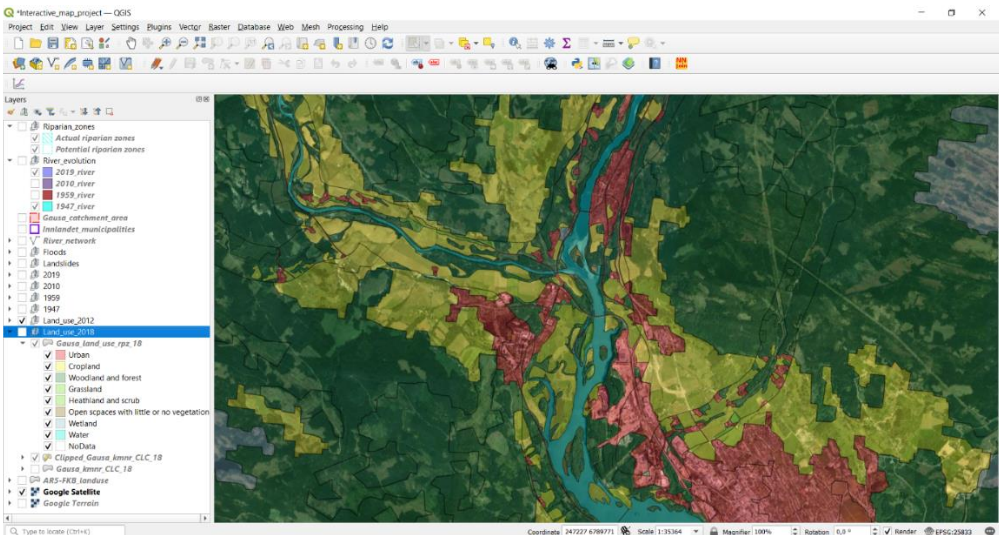


Figure 22: Screenshot of the QGIS project with land use from 2012 layers active

Land use classification FKB-AR5

The FKB-AR5 land use layer is the most recent and precise land use classification that I have been able to find. I simplified the classes for them to fit to the previous classifications, but classes can of course be revised easily.

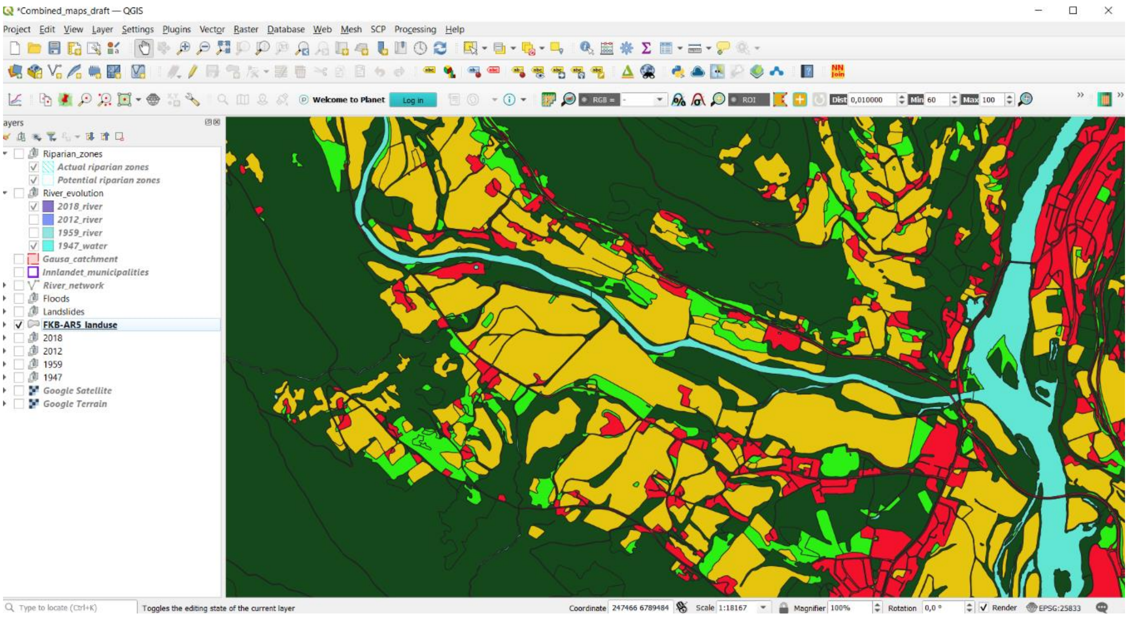


Figure 23: Screenshot of the QGIS project with FKB-AR5 land use classification layer active

Flood zones and catchment areas

These two layers represent respectively flood zones and catchment areas in the County of Innlandet.

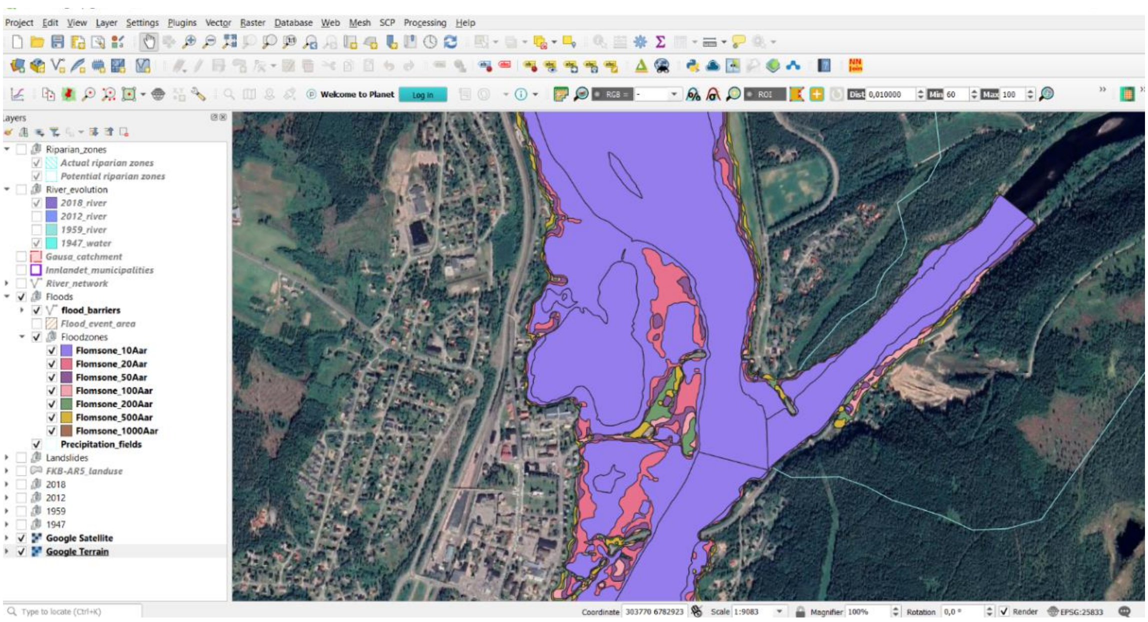


Figure 24: Screenshot of the QGIS project with flood zones layers active

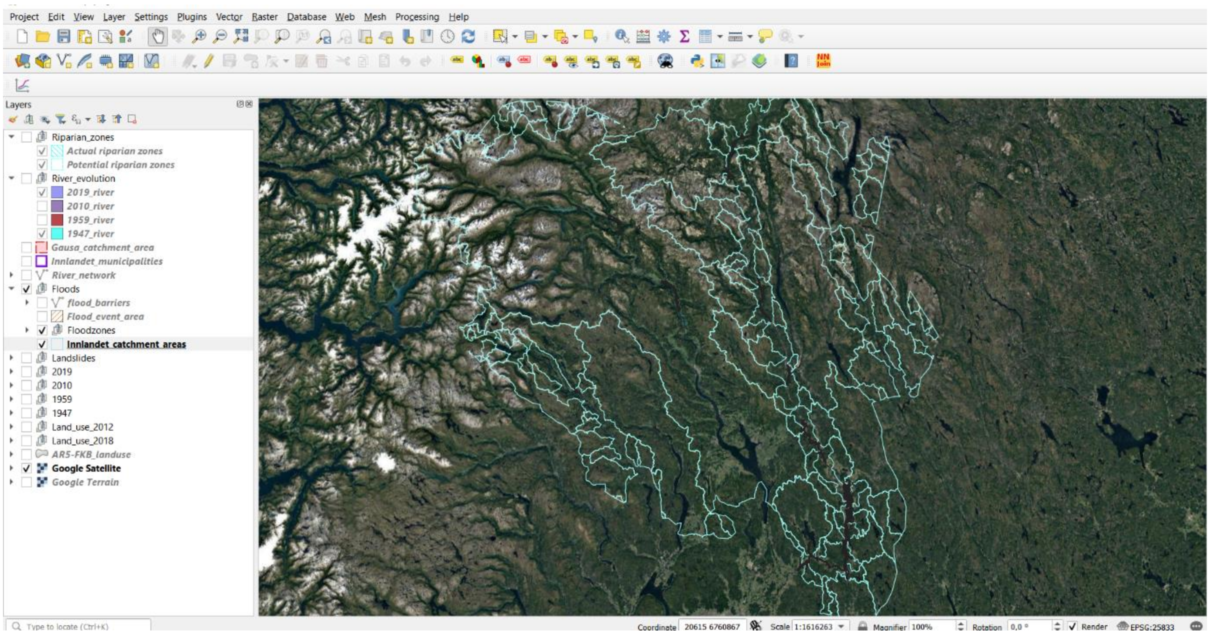


Figure 25: Screenshot of the QGIS project with Innlandet_catchment_areas layer active

Gausa catchment and Innlandet municipalities

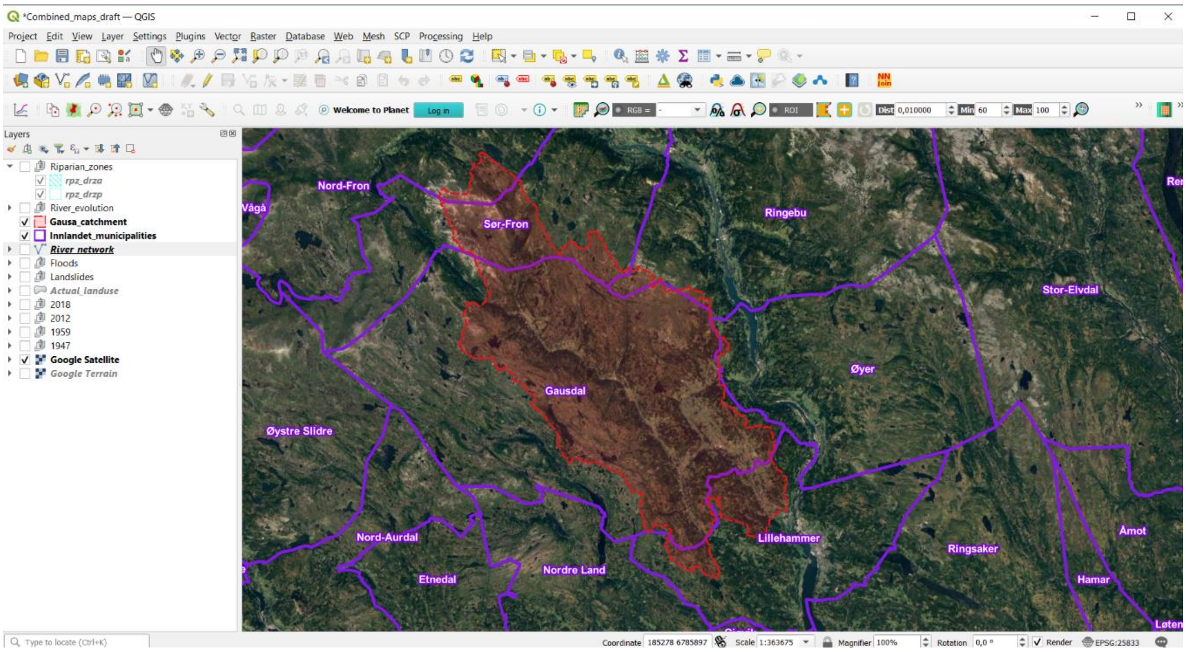


Figure 26: Screenshot of the QGIS project with Innlandet's municipalities and Gausa catchment layers active

4.2. TARGET

The targets of this tool can be multiple: stakeholders, project partners, broader audience.

Due to a lack of reliable information about the stakeholders and to enable the project to serve as many purposes as possible, no precise targeted public has been focused on. This is also the reasons why the project does not include information about biodiversity or recreational activities for example. The SABICAS project is still in its early stages at the time of writing, and we don't know precisely what the concerns of the local population are regarding the implementation of alternative measures.

For the map to be an efficient communication tool, it will be important that people who will use it define clearly the targeted audience with respect to of their interests and their opinion about floods and NbS implementation. As new data are gathered, different targets may appear.

When carrying out this project, my goal was to reach local people, people that live around the Gausa and who, for a reason or another, would be against the project. Also, the project is aiming to gain the support of "positive" people, meaning people that are attached to their living place and would like its natural ecosystems to be healthy because they care about it. In this way, a dialogue could be open between groups with different opinions, and it could turn in favour of the NbS.

Since the target audience are people living around the Gausa, the map has to be translated into Norwegian, but it is important to write it in English as well for scientists to be able to use it to communicate and in case a broader audience interested in the project.

4.3. Purpose

In the first place, the map is meant to be used as a communication tool between researchers and stakeholders and/or the public. The main purpose is showing the changes that have been made to the Gausa river through time.

In the beginning, the mapping project is supposed to lead to an interactive map of the area of interest using a time frame to compare the changes that happened to the river through the years. The final user should be able to browse the map and when clicking on a place, get information such as endangered species, recreational places, fish species, etc. via a pop-up windows. The final user is also supposed to be able to display layers with implemented or to be implemented flood mitigations both NbS and traditional. The map will also give information about the floods (frequencies, impacted areas, etc.).

Considering the QGIS project as it is now (2022), it could easily be transformed into an interactive map and published on the website by someone with computer sciences knowledges.

The main purpose of this project is informing, not convincing. By showing that changes happened to the watercourse, I want to make people conscious that the river has not always been the way it is now and that, yes, ecosystems are threatened. It is all about raising awareness. If the information contained in the map are of interest for them, they may be more favourable to the implementation of NbS, but it is not the first objective.

For instance, the project contains only one layer about NbS (e.g. flood barriers layer) presenting an existing flood wall and a NbS proposed as part of the PHUSICOS project ('Valley of Gudbrandsdalen, Norway', n.d.). My intention was to represent NbS and its expected impacts, for example, by showing the previously flooded zone and how the runoff would spread in the landscape if such solutions were in place. Indeed, presenting an example and its benefits is relevant within the framework of a project like SABICAS. As discussed before however, this is not the main nor the only information that the map should present, because it is crucial to avoid overselling these solutions.

As I learnt from reading about CEPA, people remember better what they see and what they discover themselves, which is why I wanted to create visual content that people could explore by changing layers, reading pop up information, etc. and discover how the river was in the past. The aim of this project is to get people learning more actively instead of simply listening to someone explaining things.

On the other hand, after getting feedback about the project, it turns out that project partners could also use it to share and present information such as collected data with each other.

4.4. CONTRIBUTION TO SABICAS

As mentioned before, my task in the SABICAS project was quantifying the changes that have happened to the Gausa river in the area of interest and to make them visible. I used data from 1947, 1959 and 2018 to achieve the quantification.

The results obtained results were as follows:

Table 8: Quantification of the change in width of the Gausa over a segment of about 2 km just before the confluence between 1947, 1959 and 2018

id	width_1947 (m)	width_1959 (m)	width_2018 (m)	changes_47_59 (m)	changes_59_18 (m)	changes_47_18 (m)
1	52	52	45	0	-7	-7
2	24	24	28	0	4	4
3	28	28	57	0	29	29
4	42	39	41	-3	2	-1
5	58	33	32	-25	-1	-26
6	93	43	38	-50	-5	-55
7	107	44	40	-63	-4	-67
8	105	42	40	-63	-2	-65
9	134	49	28	-85	-21	-106
10	143	52	34	-91	-18	-109
11	138	52	41	-86	-11	-97
12	91	47	41	-44	-6	-50
13	165	52	43	-113	-9	-122
14	249	34	32	-215	-2	-217
15	221	33	30	-188	-3	-191
16	217	42	39	-175	-3	-178
17	221	49	34	-172	-15	-187
18	207	50	29	-157	-21	-178
19	166	53	30	-113	-23	-136
20	91	48	32	-43	-16	-59

Between 1947 and 2018, considering the cross-sections from number 1 to 20 on the next figure, the river has lost on average 90,9 m of its width. A margin of error of a few meters must be considered as the measurement tracings were made manually.

The main changes happened between 1947 and 1959, with an average width loss of 84,3 m mostly because of the channelising work. On average, the river has lost 6,6 m of its width between 1959 and 2018.

The distance between every measurement of the width is 100 meters with a margin error of 1 meter.

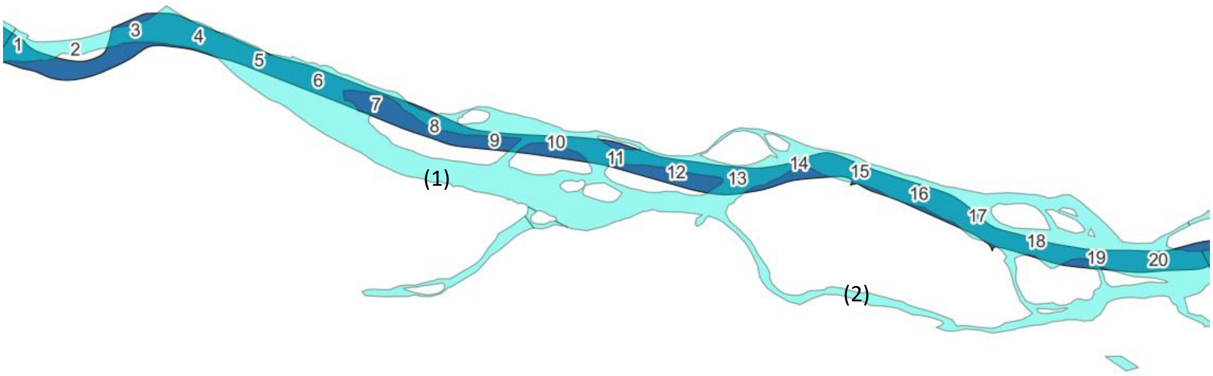


Figure 27: Representation of the change in width of the Gausa over a segment of about 2 km just before the confluence between 1947 and 2018

In addition to the reduction of the width, three side channels have been filled in, two disappeared in the early 50s to the benefit of the timber transport, and the last one to the benefit of the road infrastructure development notably for the Lillehammer 1994 Winter Olympics. These side channels were approximately (1) 650 m, (2) 850 m, and (3) 880 m long. The first two ones are visible on the figure above and the last one can be observed on the figure below.

All the existing islands that were in this segment of the water course were removed when the channelling was performed.

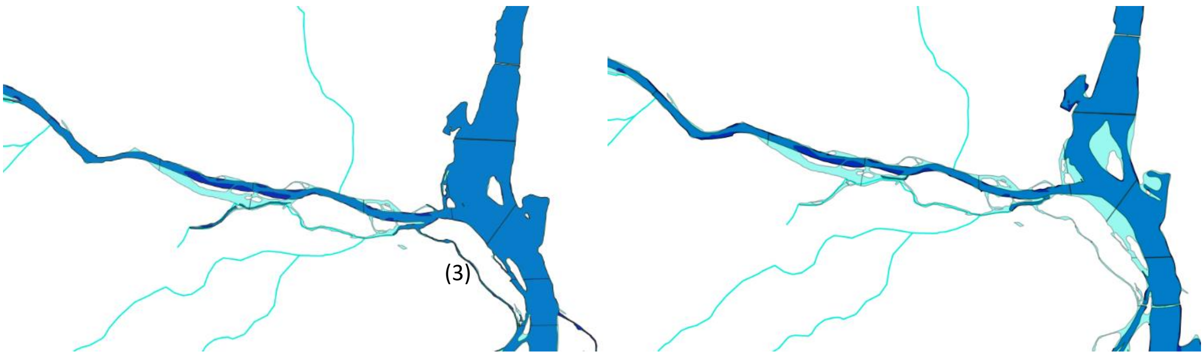


Figure 28: Representations of the changes in the shape of the river Gausa at its confluence with Gudbrandalslagen between 1947 (light blue) and 1959 (dark blue) on the left and 2019 on the right (dark blue)

I also compared the evolution of land use in the potential riparian zones (5 ha) and came to these conclusions:

- Urbanisation has increased a lot between 1947 and today. The built surface has almost doubled over the past 60 years and represents around 10 % of the landscape in the area.
- The proportion of woodland in the landscape has increased between 1959 and 2012, but this is not surprising when we know that forests are managed. They were covering around 20 % of the riparian area until 1595 and 30 % from 2012.
- Croplands were, and remain, very important in the area. They represent around 40 % of the land use. However, the type of crops might have changed with need over time.
- There is a decrease in extent of grasslands between 1959 and 2012. This type of land use dropped from 5 % to 1 %, but this may be explained by the fact that it was difficult to distinguish actual grassland and grass for production when classifying.
- A slight increase in the area of soil with no or little vegetation is observed between 1947 and 1959 because of the channelizing work. This has decreased again by 2012. This type of land use remains small (less than 1 %).

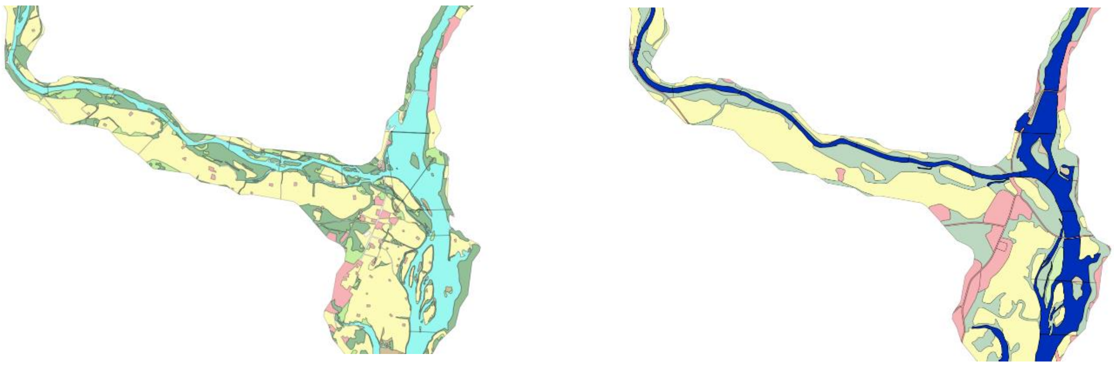


Figure 29: Used area for quantification, delineation representing potential riparian zones (1947 on the left, 2019 on the right)

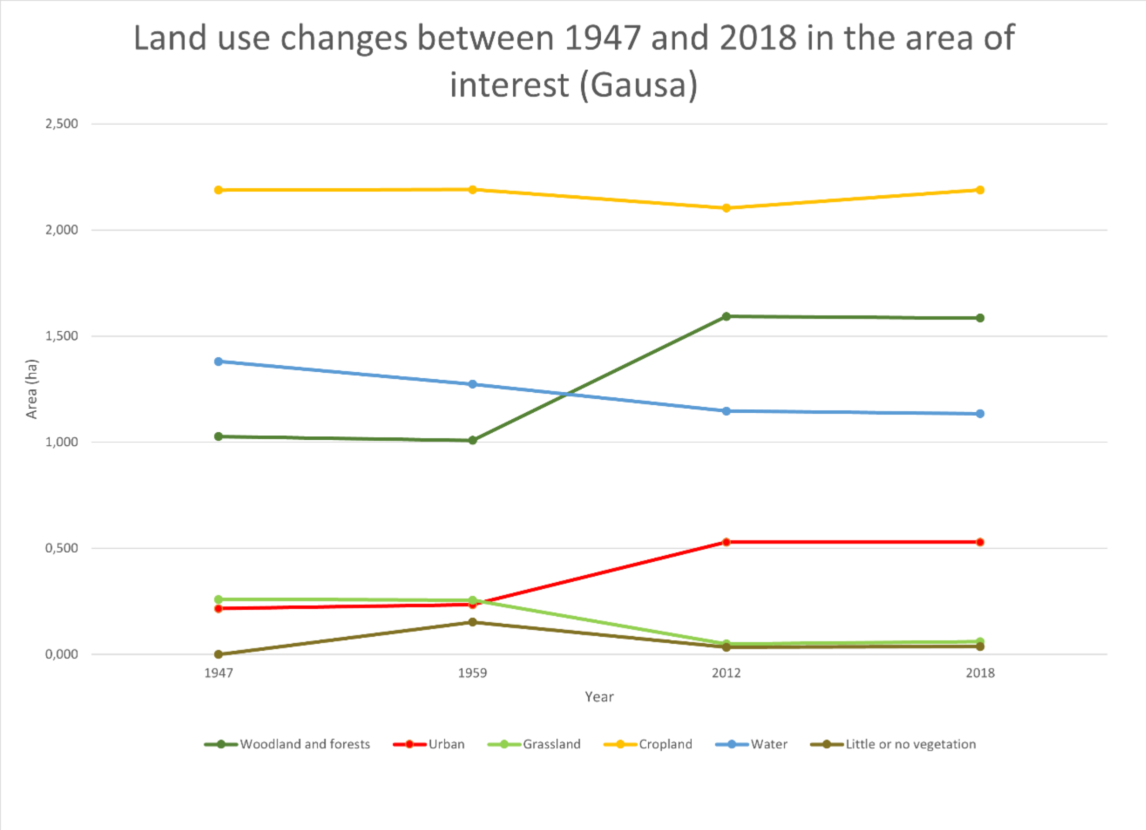


Figure 30: Graph showing the changes in land use between 1947 and 2018 in the area of interest (Gausa)

All the calculations are in the excel sheets in the appendix n° 2.

4.5. Further usages

This project can be used to communicate:

- Through the SABICAS website for a broader audience
- During workshops, meetings and interviews with stakeholders
- During meetings and conferences with other scientists and/or partners
- As a peer reviewed scientific publication

For example, as part of SABICAS, they have been using a map to get people's opinion on where they think problems are and where NbS measures should or shouldn't be, and why. The mapping project could be used during interviews and/or people could directly write comments on the map in a specially designed layer. It is important for people to feel valuable when participating to a project of this kind and having the possibility to share their local knowledge directly through this type of tool is something that could make them feel respected.

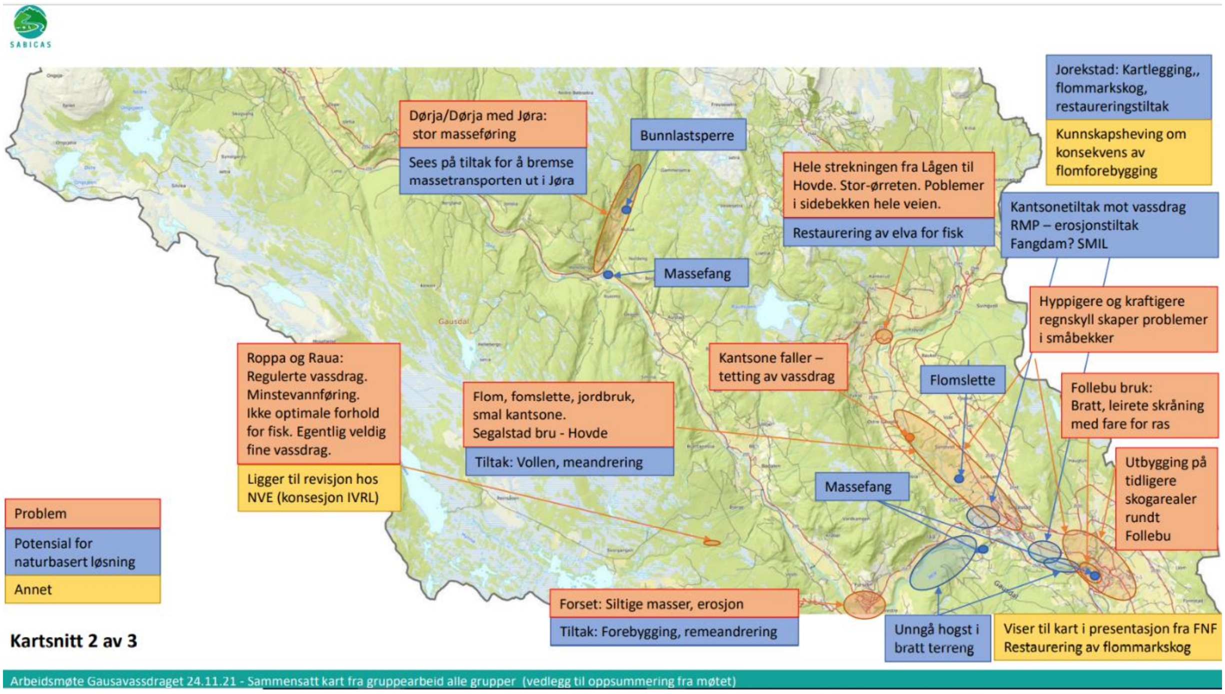


Figure 31: Example of information received during Gausa workshop with stakeholders (sabicas.no)

The strength of this project is that it can be shaped according to the target(s) or the purpose(s) of its users. Relevant information can be added in line with the message to be conveyed or in accordance with the targeted-public's interests.

Pischke et al. (2017) has also highlighted that communication between scientists can be complicated, especially for transdisciplinary topics such as environmental issues, and this project can help with the sharing of data and information between researchers working on the SABICAS project.

Although I focused on the area of the delta, I still implemented information/data/layers to cover the whole Gausa catchment, because I wanted the project to help fulfil other aims of SABICAS. For example, many layers concern the entire municipalities through which the Gausa river flows and they can be used to locate sampling sites carried out as part of the project.

To ensure that users (researchers) can use the QGIS project easily, I created a guide connecting layers and information into the folder containing the data files. I also explained where to find the data in case of users need more information about it. This can be found in appendix n°5.

4.6. Improvements

The first improvement I would do is simple. When I carried out the first land use classification by using the picture from 1947, I drew polygons and then modified it by drawing rings[7] and

[7] In QGIS, a ring corresponds to a "hole" in a polygon. This one can be empty of filled.

adding other polygons inside of the rings. In the end, and because QGIS does not allow when features touch one another, there are spaces remaining between the inner and outer polygons. What I would do if I had the occasion of doing it again is drawing a big polygon of the whole area of interest and then adding filled rings and/or modify this large polygon. The final rendering of the map would be much nicer, and it would be the same as the riparian zones' classification of Copernicus. I could have done that if I have had more time, but the manual classification was time consuming, and I preferred going on than doing it all over again because it was not that important for the comprehension of the information.

Secondly, because the project is still in its beginning, I don't have all the information I would have liked regarding stakeholders, NbS, impacts, etc. I don't know their opinion on NbS and, consequently, I couldn't define a precise target audience. Therefore, I do not have data about which impacts would NbS have in that very area, and I was then not able to translate it in the mapping project. As mentioned before, it will be important to define the target audience and its interest/concerns to select relevant data to be presented on the map to make a good communication tool of it.

My idea was that the project would produce an interactive map with a time frame like the one we can observe in Google Earth Engine. In the end, I only have the QGIS project because the options I had to create this type of web map were limited and that I don't have the necessary computer sciences' knowledge to create such a map by myself. It would be ideal if someone could take the project and add it to the SABICAS website with a possibility for the researchers to add interesting data when they get new ones. For example, I would have liked to put relevant information about animal and plant species that are or were present, about recreational areas (swimming, fishing, etc.) and about NbS solutions and their effects on the landscape. I choose not to add these data in the map even when I was able to find them because it was too much information, and it was cluttering the map and reducing its clarity. But it would be great if people with a good knowledge of the stakeholders/public's interest could add relevant data such as fish species, fishing spots, etc., or any type of things that would be preserved by implementing NbS in the landscape for example.

The way I envisaged it is that people would explore the map and clicking on parts of it. At this moment, a pop-up window would appear and give species present in the area with pictures. Then users could click on one of the species to read information or they could be directly redirected to a webpage giving information about these species. Of course, for people to be able to understand it, the map should be in English and in Norwegian.

Ultimately, the goal is to show people what the effect of implementing NbS would be on floods and landslides, so it would be ideal to illustrate proposed measures on the map and, as above, let the user access pictures and information about its expected effects.

4.7. Difficulties

The first difficulty I encountered was that official documents, some scientific articles, or other types of documents were often written in Norwegian. I tried to translate some of them when they were short, but it is really complicated to find relevant information when you do not speak the language and I probably missed relevant information because I was not able to understand it. At the same time, it was really time consuming to translate it. Similarly, most of the website/data bases are in Norwegian and it was difficult to know where to find the relevant data and information in the first place. Fortunately, my colleagues were always willing to help when they were able to.

Secondly, I arrived at the beginning of the project and the quantity of information regarding the stakeholders was very limited. Relevant literature has been selected and two workshops (one about Gausa) had been organised, but we don't really know stakeholders needs and motivations yet. Again, the documents were written in Norwegian, and I haven't had the opportunity to attend to an interview or a workshop during my internship. For these reasons, I could not precisely focus on a defined target among the stakeholders. However, I was able to discuss it with other researchers which allowed me to understand the situation a little bit better. I don't really know if it is really a problem now because I like the fact that the project can be adapted to any kind of purposes, but it is not what I imagined at the start.

Thirdly, the aerial pictures from 1947 and 1959 are in black and white and it was not possible to perform any type of automatic classification with QGIS. I had to draw every polygon manually and it took a very long time.

Furthermore, I wanted to create an interactive map by using QGIS2WEB but every time I have been trying to generate the preview, QGIS collapsed, and every time I exported it, I ended up on a blank webpage (see figure hereunder); or with QGIS2THREEJS but the rendering didn't fit at all what I was expecting the map to be. As I don't have any background in computer sciences, I don't have the capacity to develop a web map myself.

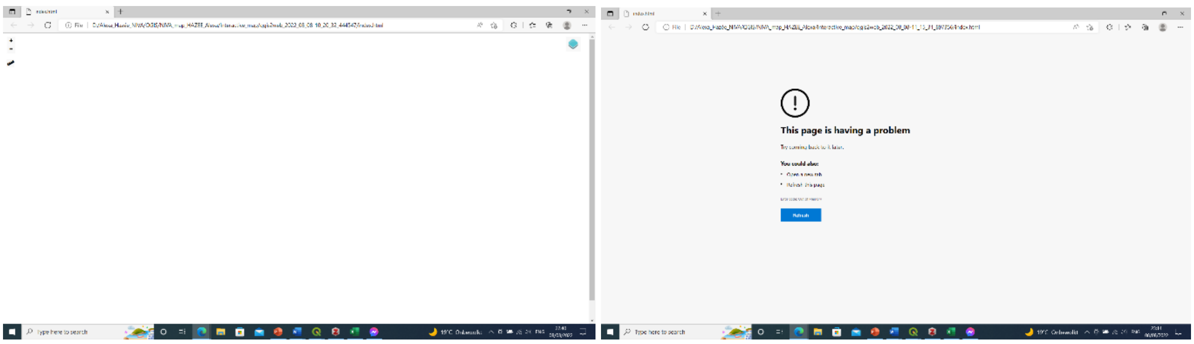


Figure 32: Screenshots of the results obtained when exporting the project via QGIS2WEB

DISCUSSION

Floodplain ecosystems are subject to a lot of pressures. Climate change, urbanisation, invasive species, flow modifications, floods and even flood mitigation measures are threatening habitats and biodiversity.

Under the framework of the SABICAS project, the catchment of the Gausa river has been chosen as study case. At the confluence with the Gudbrandsdalslågen, the river has been modified because of timber transport and floods, and the delta is now experiencing increased erosion and flood magnitude, which has an impact on the lives of local people as well as existing ecosystems.

Until now, the main solutions used to overcome these issues have been gravel removal and grey solutions such as embankment, although these threaten the wellbeing of the ecosystem. But alternative solutions that work by mimicking nature have emerged, which aim to address environmental, social and economic challenge by protecting biodiversity and providing benefits to society.

However, these new solutions are not accepted by everybody, and different barriers may prevent project implementations. These barriers can be related to a lack of awareness, perceptions and habits, knowledge gaps, administration and policies, and budget. Not in all cases, but the lack of communication between scientists and stakeholders is often part of these issues.

On the other hand, drivers have been identified to potentially enable the implementation of NbS in the landscape. These communication-related enablers can be classified into three categories: landscape uses and values, information and involvement, and proof events such as extreme floods.

This master thesis had the purpose of summarizing barriers, drivers and strategies related to NbS project implementation and developing a tool that could help building communication between researchers and stakeholders/public within the framework of a NbS project. The project has been developed by taking in account the drivers and strategies that can facilitate the communication of the message.

The result is a QGIS project which should be used as a base to develop an interactive map. The project is comprised of different layers among which four layers of the delta of the Gausa river at different times (1947, 1959, 2010 and 2019) that includes a land use classification that shows the changes in the land use between 1947 and 2019. I then used these layers to quantify the land use changes.

On the top of that, other layers provide other information such as flood zones, historical flood events, the Gausa catchment, the municipalities of Innlandet, the land use of 2012 and 2018, the river network of Innlandet, the riparian zones of the Glomma catchment, flood barriers, etc. These layers are meant to be used out of the context of my area of interest (the delta of the Gausa) and they cover at least the whole Gausa catchment.

CEPA informs us that it is important to define target groups, people we need to collaborate with in order to carry out the project and communication objective. Here, the target could be a group of stakeholders, large public, depending on the users' objectives. I haven't defined a specific group because I don't have enough information to do it as SABICAS is still at an early stage and only one workshop has been organized.

Regarding the communication target, my idea was to provide knowledge about the area of interest by creating an efficient communication tool. The CEPA manual insist on the fact that visual designs are efficient, and that people tend to remember better what they have learn by themselves and that is the objective of such a map. If information about NbS and its impacts are later implemented in the map, it could also change people attitude regarding these alternative solutions. The effect depends a lot on which kind of data will be used because it could activate different drivers such as the interest in recreation places, the information sharing, the attachment to place, etc.

This project tries to cover different strategies identified as helpful into overcoming communication-related barriers. The first ones are increasing knowledge and understanding by communicating information, then using a clear language (not too academic) because this is a map including different layers that must remain easy to understand. After that, if used in workshop or interviews, this map could help with getting to know the local context, finding stakeholders interests and concerns (as has already been done during the first workshop), developing a shared vision and filling knowledge gaps. This is a two-way sharing of knowledge between researchers and stakeholders.

In the end, this map could help to overcome barriers in the perception and habits and public awareness categories that are mentioned in point 2.4.

Indeed, this map is not going to resolve all the issues related to the implementation of NbS, and other strategies and tools must be put in place. It may not be THE solution, but I think it could be aid in to getting more public support and eventually cooperation.

As of now, the project gives information about the land use changes in the area of interest and other data must be added if we want to make this tool even more useful, and it is necessary to transform it into an interactive map to make it available to the greatest number of people and on relevant platform such as www.sabicas.no.

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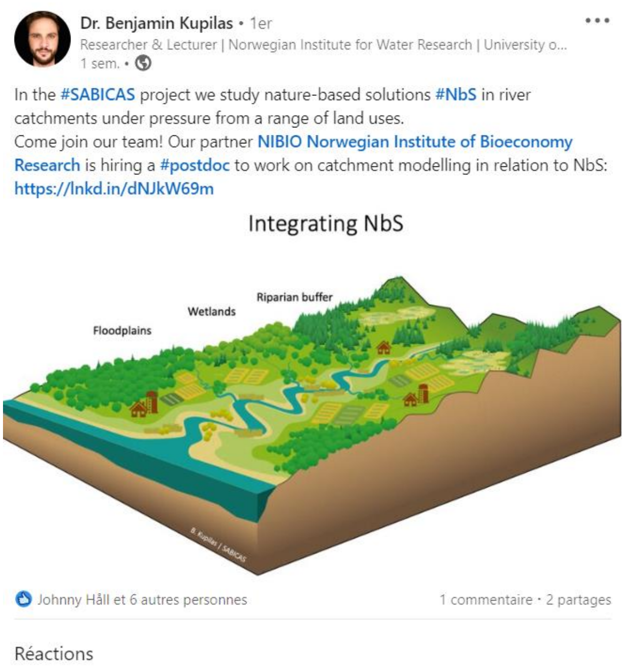
APPENDIX

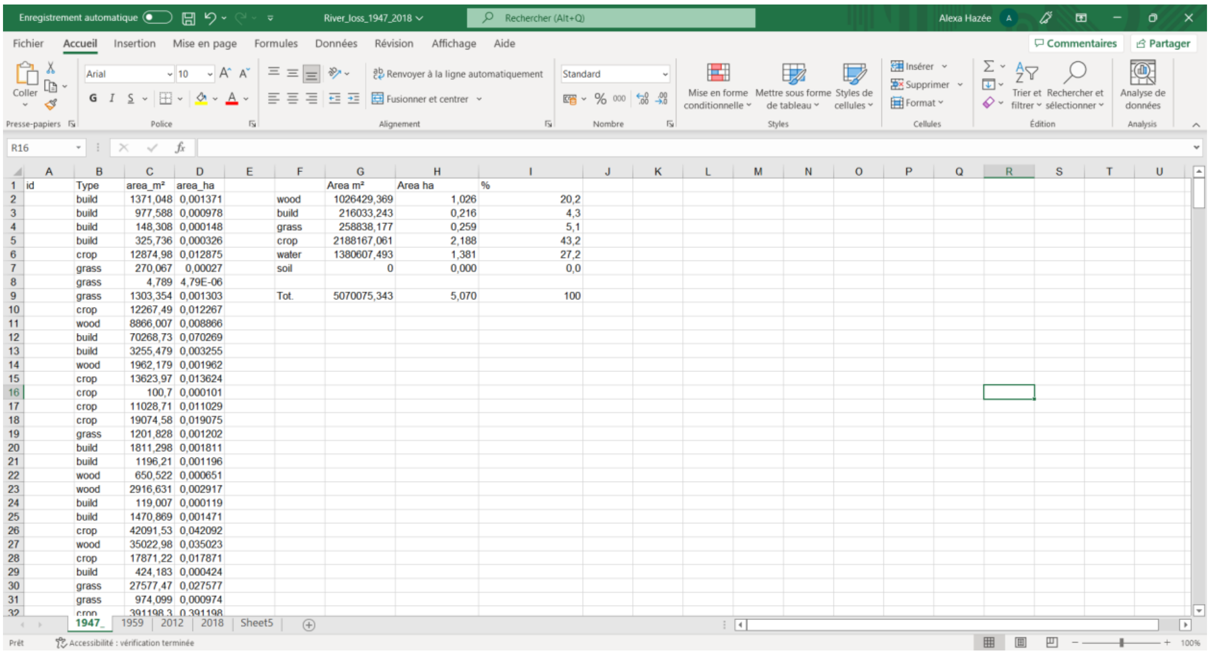
1. APPENDIX N°1: SABICAS ON SOCIAL MEDIA (TWITTER, LINKEDIN)

Source: benjamin.kupilas on Twitter: "SABICAS hosted its first national stakeholder workshop on #naturebasedsolutions. Want to connect? https://t.co/HEkyPCIJpk #SABICAS #UrbanEcology #biodiversity #Floodmitigation #urbanfarming https://t.co/sUenkkuDQX" / Twitter



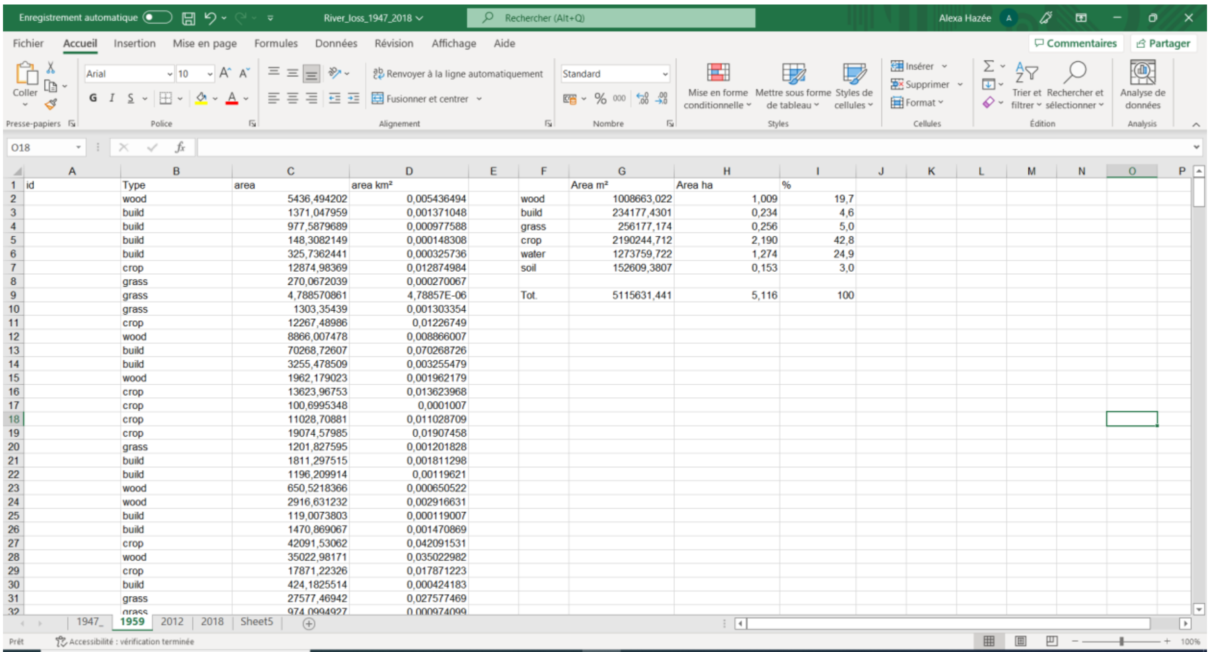
Source :
https://www.linkedin.com/feed/update/urn:li:share:6958832791501307904?utm_source=linkedin_share&utm_medium=member_desktop_share&utm_content=post

2. Appendix N°2: Excel sheets for quantification of the land use changes



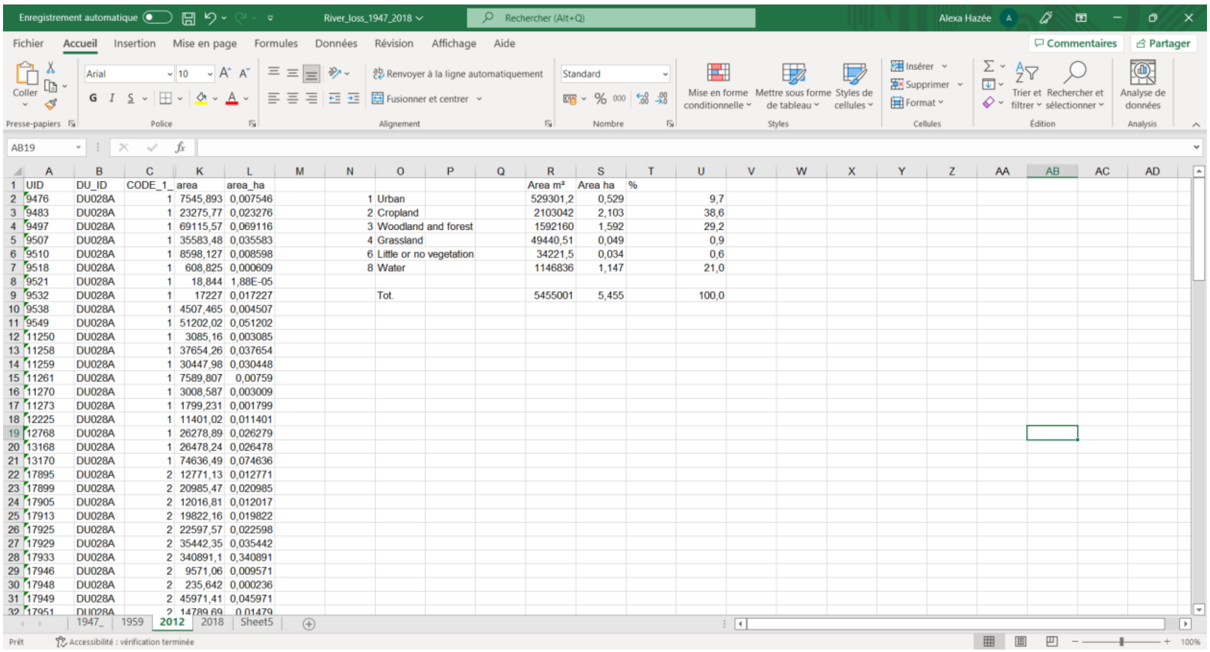
	A	B	C	D	E	F	G	H	I
1	id	Type	area_m²	area_ha			Area m²	Area ha	%
2		build	1371,048	0,001371		wood	1026429,369	1,026	20,2
3		build	977,588	0,000978		build	216033,243	0,216	4,3
4		build	148,308	0,000148		grass	258838,177	0,259	5,1
5		build	325,736	0,000326		crop	2188167,061	2,188	43,2
6		crop	12874,98	0,012875		water	1380607,493	1,381	27,2
7		grass	270,067	0,00027		soil	0	0,000	0,0
8		grass	4,789	4,79E-06					
9		grass	1303,354	0,001303		Tot.	5070075,343	5,070	100
10		crop	12267,49	0,012267					
11		wood	8866,007	0,008866					
12		build	70268,73	0,070269					
13		build	3255,479	0,003255					
14		wood	1962,179	0,001962					
15		crop	13623,97	0,013624					
16		crop	100,7	0,000101					
17		crop	11028,71	0,011029					
18		crop	19074,58	0,019075					
19		grass	1201,828	0,001202					
20		build	1811,298	0,001811					
21		build	1196,21	0,001196					
22		wood	650,522	0,000651					
23		wood	2916,631	0,002917					
24		build	119,007	0,000119					
25		build	1470,869	0,001471					
26		crop	42091,53	0,042092					
27		wood	35022,98	0,035023					
28		crop	17871,22	0,017871					
29		build	424,183	0,000424					
30		grass	27577,47	0,027577					
31		grass	974,099	0,000974					
32		crop	391198,3	0,391198					

1947_ | 1959 | 2012 | 2018 | Sheet5



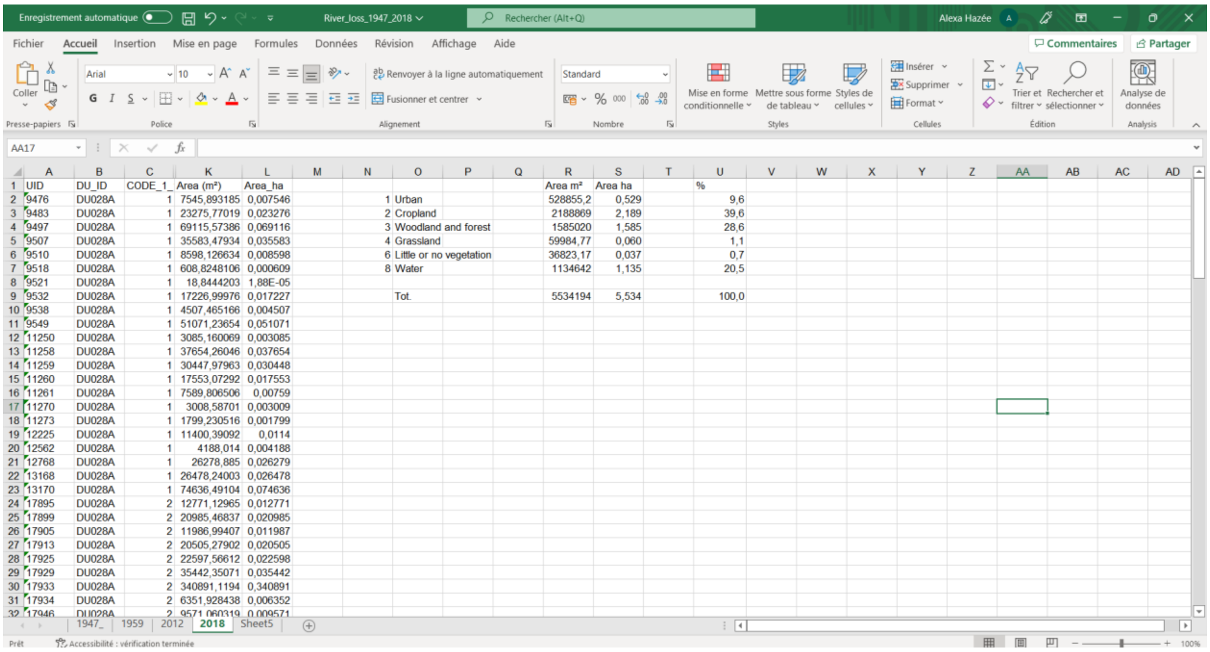
	A	B	C	D	E	F	G	H	I
1	id	Type	area	area km²			Area m²	Area ha	%
2		wood	5436,494202	0,005436494		wood	1008663,022	1,009	19,7
3		build	1371,047959	0,001371048		build	234177,4301	0,234	4,6
4		build	977,5879689	0,000977588		grass	256177,174	0,256	5,0
5		build	148,3082149	0,000148308		crop	2190244,712	2,190	42,8
6		build	325,7362441	0,000325736		water	1273759,722	1,274	24,9
7		crop	12874,98369	0,012874984		soil	152609,3807	0,153	3,0
8		grass	270,0672039	0,000270067					
9		grass	4,788570861	4,78857E-06		Tot.	5115631,441	5,116	100
10		grass	1303,35439	0,001303354					
11		crop	12267,48986	0,01226749					
12		wood	8866,007478	0,008866007					
13		build	70268,72607	0,070268726					
14		build	3255,478509	0,003255479					
15		wood	1962,179023	0,001962179					
16		crop	13623,96753	0,013623968					
17		crop	100,6995348	0,0001007					
18		crop	11028,70881	0,011028709					
19		crop	19074,57985	0,01907458					
20		grass	1201,827595	0,001201828					
21		build	1811,297515	0,001811298					
22		build	1196,209914	0,00119621					
23		wood	650,5218366	0,000650522					
24		wood	2916,631232	0,002916631					
25		build	119,0073803	0,000119007					
26		build	1470,869067	0,001470869					
27		crop	42091,53062	0,042091531					
28		wood	35022,98171	0,035022982					
29		crop	17871,22326	0,017871223					
30		build	424,1825514	0,000424183					
31		grass	27577,46942	0,027577469					
32		grass	974,0994927	0,000974099					

1947_ | 1959 | 2012 | 2018 | Sheet5



UID	DU_ID	CODE_1_	area	area_ha
9476	DU028A	1	7545,893	0,007546
9483	DU028A	1	23275,77	0,023276
9497	DU028A	1	69115,57	0,069116
9507	DU028A	1	35583,48	0,035583
9510	DU028A	1	8598,127	0,008598
9518	DU028A	1	608,825	0,000609
9521	DU028A	1	18,844	1,88E-05
9532	DU028A	1	17227	0,017227
9538	DU028A	1	4507,465	0,004507
9549	DU028A	1	51202,02	0,051202
11250	DU028A	1	3085,16	0,003085
11258	DU028A	1	37654,26	0,037654
11259	DU028A	1	30447,98	0,030448
11261	DU028A	1	7589,807	0,00759
11270	DU028A	1	3008,587	0,003009
11273	DU028A	1	1799,231	0,001799
12225	DU028A	1	11401,02	0,011401
12768	DU028A	1	26278,89	0,026279
13168	DU028A	1	26478,24	0,026478
13170	DU028A	1	74636,49	0,074636
17895	DU028A	2	12771,13	0,012771
17899	DU028A	2	20985,47	0,020985
17905	DU028A	2	12016,81	0,012017
17913	DU028A	2	19822,16	0,019822
17925	DU028A	2	22597,57	0,022598
17929	DU028A	2	35442,35	0,035442
17933	DU028A	2	340891,1	0,340891
17946	DU028A	2	9571,06	0,009571
17948	DU028A	2	235,642	0,000236
17949	DU028A	2	45971,41	0,045971
17951	DU028A	2	14789,69	0,01479

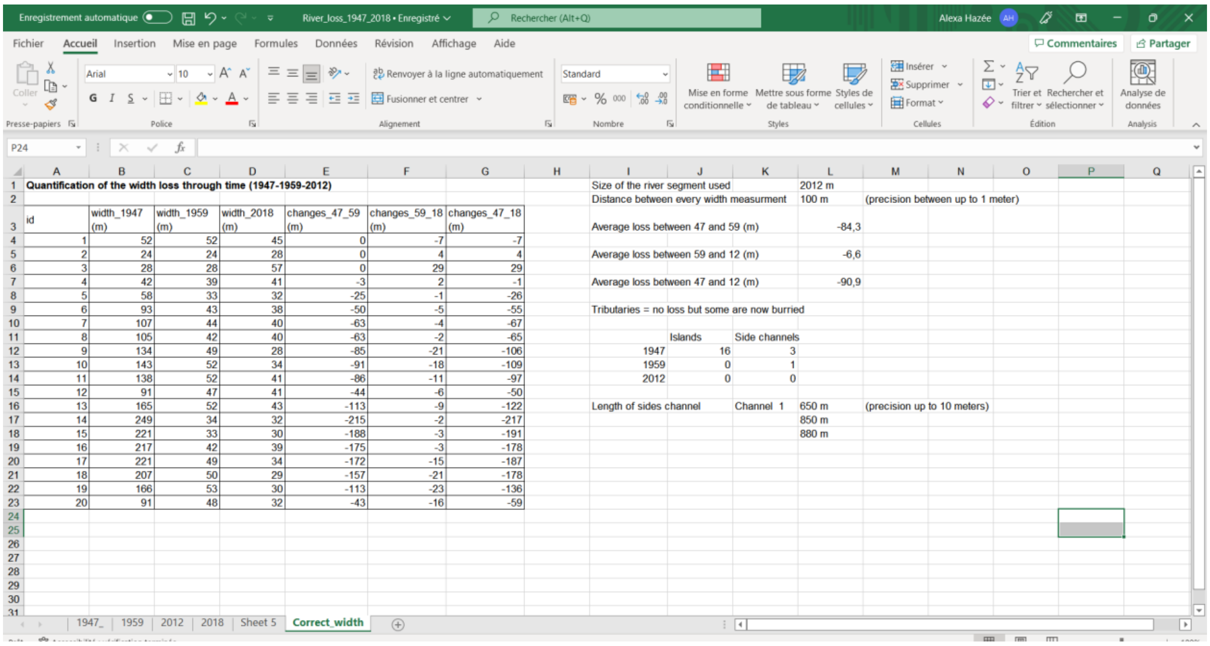
		Area m²	Area ha	%
1	Urban	529301,2	0,529	9,7
2	Cropland	2103042	2,103	38,6
3	Woodland and forest	1592160	1,592	29,2
4	Grassland	49440,51	0,049	0,9
6	Little or no vegetation	34221,5	0,034	0,6
8	Water	1146836	1,147	21,0
	Tot.	5455001	5,455	100,0



UID	DU_ID	CODE_1_	Area (m²)	Area_ha
9476	DU028A	1	7545,893185	0,007546
9483	DU028A	1	23275,77019	0,023276
9497	DU028A	1	69115,57386	0,069116
9507	DU028A	1	35583,47934	0,035583
9510	DU028A	1	8598,126634	0,008598
9518	DU028A	1	608,8248106	0,000609
9521	DU028A	1	18,8444203	1,88E-05
9532	DU028A	1	17226,99976	0,017227
9538	DU028A	1	4507,465166	0,004507
9549	DU028A	1	51071,23654	0,051071
11250	DU028A	1	3085,160069	0,003085
11258	DU028A	1	37654,26046	0,037654
11259	DU028A	1	30447,97963	0,030448
11260	DU028A	1	17553,07292	0,017553
11261	DU028A	1	7589,806506	0,00759
11270	DU028A	1	3008,58701	0,003009
11273	DU028A	1	1799,230516	0,001799
12225	DU028A	1	11400,39092	0,0114
12562	DU028A	1	4188,014	0,004188
12768	DU028A	1	26278,885	0,026279
13168	DU028A	1	26478,24003	0,026478
13170	DU028A	1	74636,49104	0,074636
17895	DU028A	2	12771,12965	0,012771
17899	DU028A	2	20985,46837	0,020985
17905	DU028A	2	11986,99407	0,011987
17913	DU028A	2	20505,27902	0,020505
17925	DU028A	2	22597,56612	0,022598
17929	DU028A	2	35442,35071	0,035442
17933	DU028A	2	340891,1194	0,340891
17934	DU028A	2	6351,928438	0,006352
17946	DU028A	2	9571,060319	0,009571

		Area m²	Area ha	%
1	Urban	528855,2	0,529	9,6
2	Cropland	2188869	2,189	39,6
3	Woodland and forest	1585020	1,585	28,6
4	Grassland	59984,77	0,060	1,1
6	Little or no vegetation	36823,17	0,037	0,7
8	Water	1134642	1,135	20,5
	Tot.	5534194	5,534	100,0

N.B.: On the different excel sheets, a difference between total areas is observed between the years. This comes from the fact that I drew the polygons for land classification myself and left spaces between them. The results are therefore not 100% precise.



Quantification of the width loss through time (1947-1959-2012)

id	width_1947 (m)	width_1959 (m)	width_2018 (m)	changes_47_59 (m)	changes_59_18 (m)	changes_47_18 (m)
1	52	52	45	0	-7	-7
2	24	24	28	0	4	4
3	28	28	57	0	29	29
4	42	39	41	-3	2	-1
5	58	33	32	-25	-1	-26
6	93	43	38	-50	-5	-55
7	107	44	40	-63	-4	-67
8	105	42	40	-63	-2	-65
9	134	49	28	-85	-21	-106
10	143	52	34	-91	-18	-109
11	138	52	41	-86	-11	-97
12	91	47	41	-44	-6	-50
13	165	52	43	-113	-9	-122
14	249	34	32	-215	-2	-217
15	221	33	30	-188	-3	-191
16	217	42	39	-175	-3	-178
17	221	49	34	-172	-15	-187
18	207	50	29	-157	-21	-178
19	166	53	30	-113	-23	-136
20	91	48	32	-43	-16	-59

Size of the river segment used: 2012 m
Distance between every width measurment: 100 m (precision between up to 1 meter)

Average loss between 47 and 59 (m): -84,3

Average loss between 59 and 12 (m): -6,6

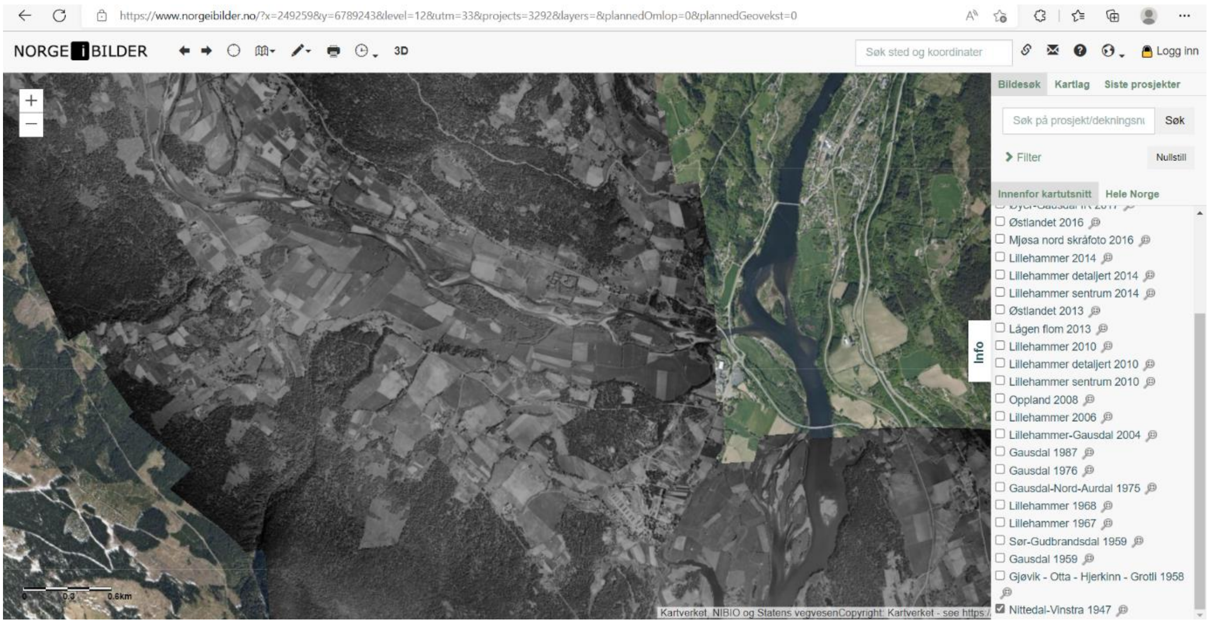
Average loss between 47 and 12 (m): -90,9

Tributaries = no loss but some are now burried

	Islands	Side channels
1947	16	3
1959	0	1
2012	0	0

Length of sides channel: Channel 1 650 m (precision up to 10 meters)
850 m
880 m

3. Appendix n°3: Nittedal-Vinstra 1947, aerial picture project

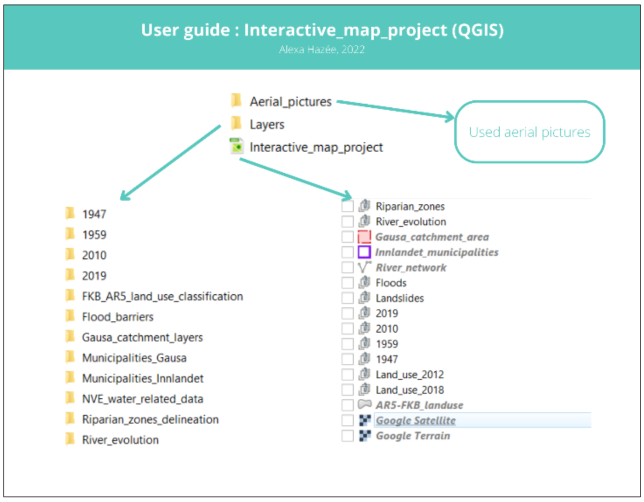


Source : Norge i bilder

4. APPENDIX N°4: SØR-GUDBRANDSDALEN 1959, AERIAL PICTURE PROJECT

Source : Norge i bilder

5. Appendix n°5: User guide



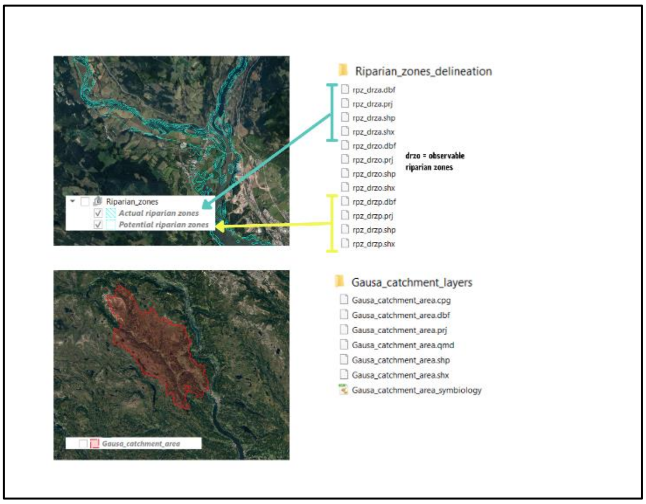
Files to be used :

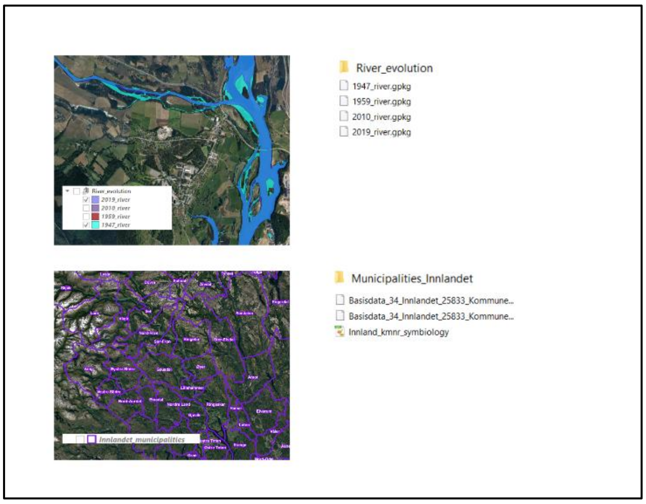
- Vector layer = .SHP/.GPKG
- Raster layer = .TIF/.GEOTIFF

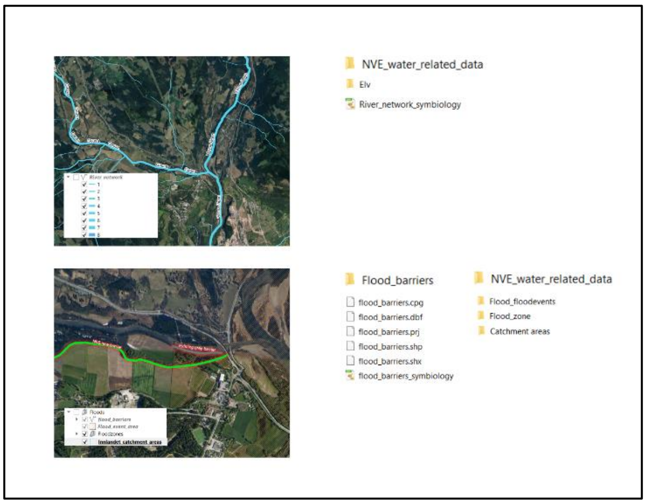
If the rendering of vector layers is not correctly displayed, you can load saved styles in "properties" of the layer(s)

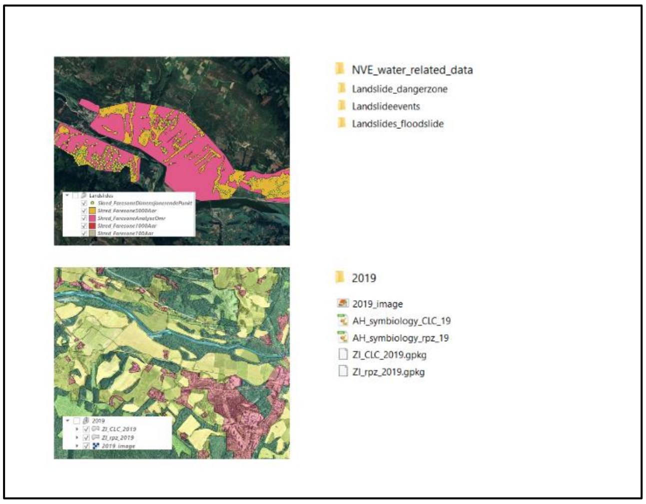
Abbreviations :

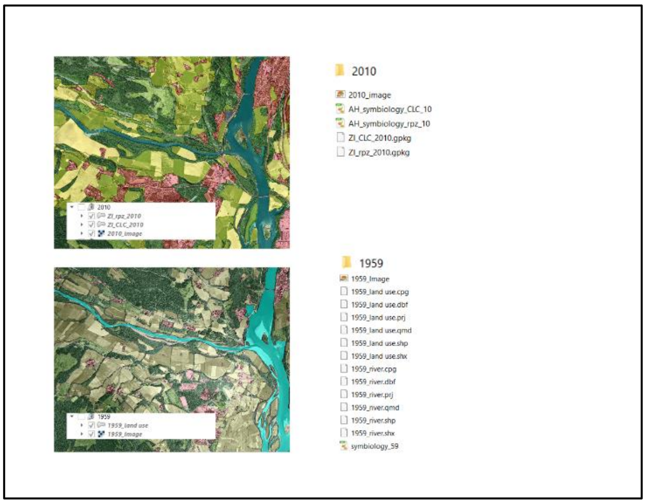
- rpz = riparian zones
- CLC = Corine Land Cover
- ZI = zone of interest
- kmnr = kommuner (municipalities)
- drz = reparian zones delineation

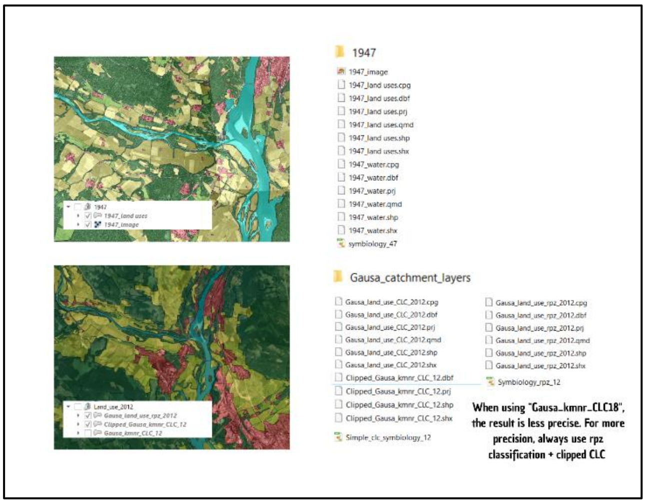


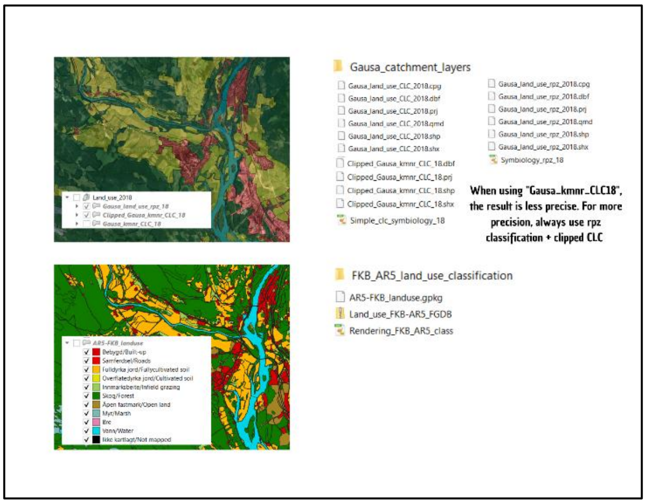












Websites where you can find data:

- www.flomhendelser.no (floods)
- www.geonorge.no (general)
- www.norgeibilder.no (pictures)
- www.biodiversity.no (species, red list species)
- www.fishbase.de (fish species)
- www.fishbrain.com (fishing areas)
- www.kartverket.no (maps)
- www.ngu.no (geology)
- www.irm.no (fish species)
- www.environment.no (environment)
- www.vann-nett.no (water-related)
- www.miljodirektoratet.no (environment)
- www.nedlasting.nve.no (water-related)
- www.nevina.nve.no (water management)
- www.land.copernicus.eu (land use)

Tips :

For every land use layer, you can choose which land use types displaying or not. For example, this allows you to see the river only.