bioeconomy development

Sustainability Screening – Biofuel Region, SE

March 2024

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EXECUTIVE SUMMARY

This report has been produced as part of the SCALE-UP project funded by the Horizon Europe research and innovation programme. The aim of this project is to support the development of small-scale bioeconomy solutions in rural areas across Europe. The aim of this study is to raise awareness of the ecological limits in the northern part of Sweden, based on three resources: water, soil and biodiversity. The report provides an overview of water resources management, land and soil resources management, and biodiversity management profiles in Sweden, focusing on Biofuel Region, the Swedish partner in the SCALE-UP project. BioFuel region corresponds to the four most northern counties in Sweden, Norrbotten, Västerbotten, Västernorrland and Jämtland

Water: Northern Sweden boasts stable water conditions, with approximately 40 rivers and creeks forming part of its hydrology. Governance is overseen by five water districts, each managed by a County Administrative Board, responsible for implementing the EU Water Framework Directive. The region is significant for hydropower production, with 80% of Sweden's hydropower generated here. However, re-examination of hydropower installations is underway due to EU regulations and concerns about energy security.

Soil: Sweden's land area comprises mainly forest land, with 68% covered by forests. The Forestry Act regulates forest management, emphasizing sustainability and biodiversity conservation. Forest land is predominantly owned by individual owners, private companies, and the state. The forest industry plays a vital role in Sweden's economy, ranking as the second-largest exporter of pulp, paper, and sawn wood products.

Biodiversity: Sweden's biodiversity is shaped by its post-ice age colonization, resulting in relatively few endemic species. Implementation of EU Nature Directives is managed by various sector authorities, ensuring the conservation of habitats and species. Recent government initiatives focus on reviewing forest policies to balance environmental and production goals while promoting sustainable forestry practices.

Finally, this large territory is fully aware and affected by the impacts of climate change, primarily with rising temperatures causing forest fires and insect attacks in summer and making the period of frozen soils shorter in winter, limiting the harvest season. It is extremely important to continue with a comprehensive approach to natural resource management, balancing economic interests with environmental sustainability and biodiversity conservation including water, soil and biodiversity.

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Abbreviations

CEC	**Cation Exchange Capacity**
DOC	**Dissolved Organic Carbon**
EQS	**Environmental Quality Standards**
EEA	**European Environment Agency**
EU	**European Union**
MW	**Megawatts**
RBD	**River Basin District**
RBMP	**River Basin Management Plan**
SEK	**Swedish Krona**
SFA	**Swedish Forest Agency**
SOC	**Soil Organic Carbon**
SOM	**Soil Organic Matter**
TWh	**Terawatts per hour**
WEI+	**Water Exploitation Index plus**
WFD	**Water Framework Directive**
WISE	**Water Information System for Europe**

1 Resource management profiles (by BFR)

1.1 Water resources management profile

The hydrology in northern Sweden is connected to the catchment areas of approximately 40 rivers and creeks. In total Sweden has approximately 120 main catchment areas (see **Error! Reference source n ot found.**). Northern Sweden has relatively stable water conditions with good availability and relatively small variations. The catchment areas located in the BioFuel Region (i.e. the area contemplated in the SCALE-UP project and in this study) are the ones labelled 1-42, 114 and 116 in **Error! Reference source not found.** (with the latter two flowing into Norway).

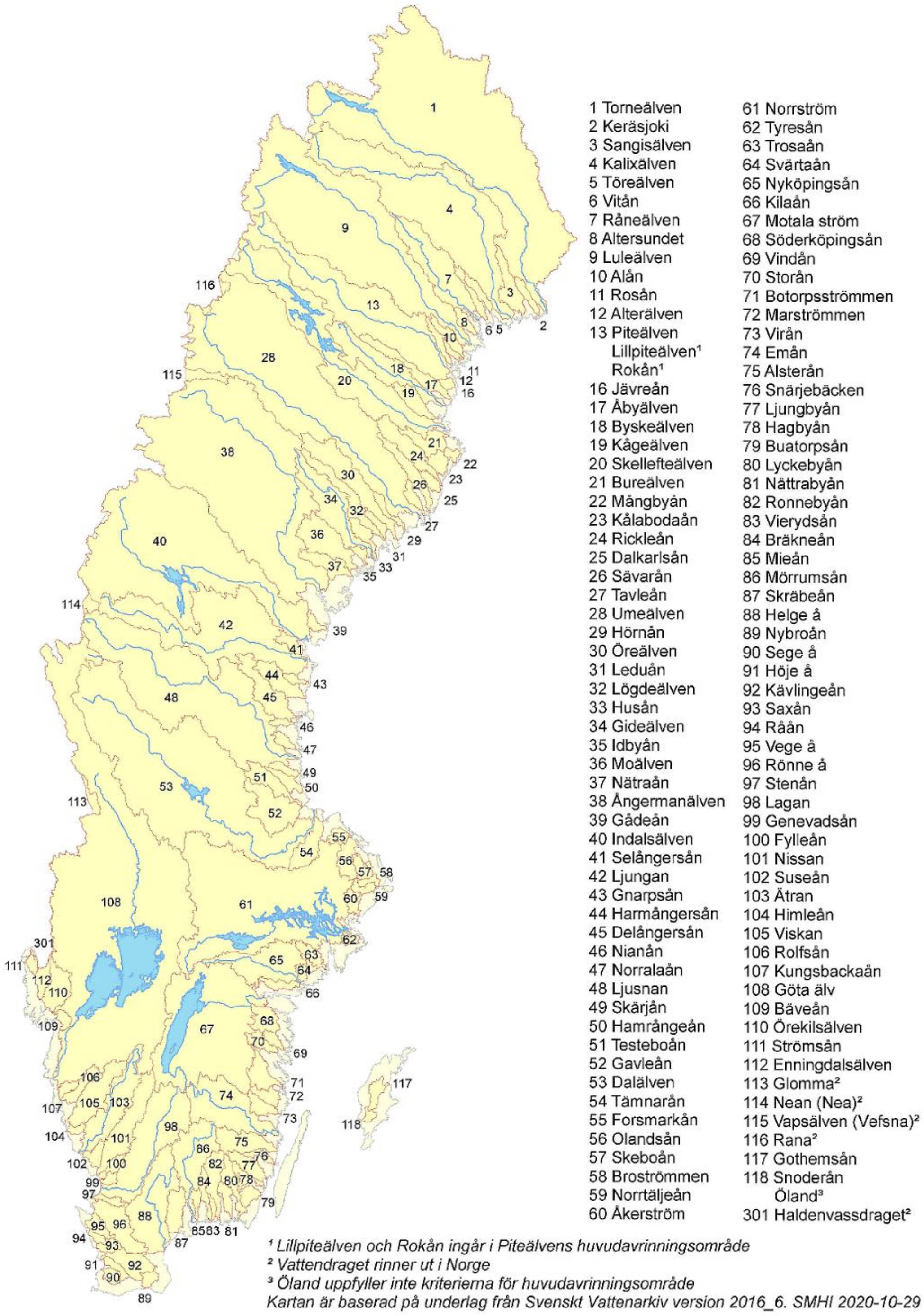

Figure 1 Catchment areas in Sweden. Source: SMHI, 2022.

Governance and regulations

In Sweden, the water authorities' mission is to implement the EU Water Framework Directive. Sweden is divided into five different water districts, based on the borders of the major sea basins and catchment areas, which means that the 21 counties and 290 muni-cipalities can be a part of more than one district.

In each water district one of the county administrative boards is appointed by the government to act as water district authority:

- The County Administrative Board of Norrbotten is the Water Authority of the Bothnian Bay Water District
- The County Administrative Board of Västernorrland is the Water Authority of the Bothnian Sea Water District
- The County Administrative Board of Västmanland is the Water Authority of the North Baltic Sea Water District
- The County Administrative Board of Kalmar is the Water Authority of the South Baltic Sea Water District
- The County Administrative Board of Västra Götaland is the Water Authority in the Skagerrak and Kattegat Water District.

Each water district authority has an office which prepares cases for the water delegation, coordinates the county administrative boards producing documentation, and collaborates with affected parties at all levels from local to international level. The five water authorities must manage the quality of the water environment. This means, among other things, that Swedish water authorities:

- Produce and revise the management plan and programme of measures for each RBD
- Decide on environmental quality standards (EQS)
- Coordinate water management work within the districts
- Collaborate nationally, regionally and locally with interested parties in water management
- Submit information to the Maritime and Water Authority for further reporting to the European Commission

The role of hydropower and energy security

There are roughly 2,000 hydropower plants in Sweden, with a total installed output of approximately 16,300 Megawatts (MW). During a year with normal water inflow the hydropower produces around 65 TWh. That is approximately 30 percent more than the electricity consumption of the entire Swedish industry per year. Sweden has four so called “National Rivers “that are protected from further expansion of hydropower. All of them are situated in the area of BioFuel Region. Two of them are not affected by hydropower (Torne River and Kalix River), while the other two are (Vindel River and Pite River). The power plants located in the BioFuel Region account for 80 percent of hydropower production in Sweden.

In January 2019, the Swedish government tasked the Swedish Agency for Marine and Water Management, the Energy Agency and Svenska Kraftnät (the country’s electricity network operator) with the task of producing a proposal to re-examine hydropower in the country. The plan was submitted to the government in October 2019. In the summer of 2020, the government announced its decision. According to provisions in the regulation on water activities, work on re-examination began in February 2022 and is expected to last for 20 years. The need for the re-examination arose from the fact that hydropower was expanded long before the entry into the EU and the laws concerning water in the EU affects the hydropower installations. The government has announced in autumn 2022 that they want to pause the work. This is due to, among other things, the war in Ukraine and the discussion about security of supply. The extra time is primarily needed to analyse how much the re-examinations/reconsiderations may risk affecting the capacity of the electricity system to ensure energy security.

Soil moisture on productive forest land

The hydrologic influence on soil moisture classes shows that only 5.5 percent of the productive forest land in the BioFuel Region area (Norrland) is classified as dry (Table 1), the corresponding number for Sweden in total is 6.22 percent.

Table 1 - Percentage distribution and areas of different soil moisture classes on productive forest land in Sweden.

Code Designation*	Norrland		Svealand		Götaland		Hela landet	
	(%)	(Milj. ha)	(%)	(Milj. ha)	(%)	(Milj. ha)	(%)	(Milj. ha)
Dry Soil	5.50	0.68	6.88	0.36	7.37	0.36	6.22	1.41
Mesic soil	59.58	7.43	59.27	3.10	57.66	2.84	59.09	13.37
Mesic-moist soil	33.14	4.13	32.58	1.70	31.96	1.58	32.75	7.41
Moist soil	1.74	0.22	1.27	0.066	2.85	0.14	1.87	0.42
Wet soil	0.04	0.005	0.01	0.001	0.17	0.008	0.06	0.014
Total	100	12.47	100	5.23	100	4.93	100	22.63

Source: Data from the Swedish Forest Soil Inventory 1993-2002. (Norrland= Northern Sweden) The soil moisture class reflects the average conditions during the growing season.

**** Code Designation Description***

Dry soil: The groundwater level is estimated to be deeper than 2m below the soil surface.
Mesic soil: The groundwater level is estimated to be at 1-2 m depth.
Mesic-moist soil: The groundwater level is estimated to be at less than 1 m depth.
Moist soil: The groundwater level is estimated to be at less than 1 m depth. It is usually visible in hollows within the sample plot.
Wet soil: Groundwater forms permanent pools of water at the soil surface.

1.2 Land and soil resources management profile

Sweden's land area is 410,000 square kilometres or 41 million hectares. Of that area, 68 percent is forest land and 7 percent agricultural land. The built-up and landscaped (bebygd och anlagd mark) land does not make up more than 3 percent of Sweden's total land area. Open marshes and other open land with and without vegetation and glaciers account for 22 percent.

Of Sweden's total forest land area, almost 69% is made up of moraine and in Norrland (Northern Sweden) the share is 75% (see Table 2).

Table 2 - Percentage distribution and areas of different land uses in Sweden.

	Norrland		Svealand		Götaland		Whole country	
	(%)	(Milj. ha)	(%)	(Milj. ha)	(%)	(Milj. ha)	(%)	(Milj. ha)
Productive forest land	**75.42**	12.47	84.11	5.23	82.72	4.94	78.82	22.64
Pasture land	0.09	0.015	1.16	0.072	6.12	0.37	1.58	0.45
Mires	20.76	3.43	11.06	0.69	4.88	0.29	15.36	4.41
Rock	1.81	0.30	3.51	0.22	6.28	0.37	3.10	0.89
Subalpine woodland	1.75	0.29	0.14	0.009	0	0	1.04	0.30
Other climate impediment	0.17	0.029	0.03	0.002	0	0	0.11	0.030
Total	100	16.53	100	6.22	100	5.97	100	28.72

Source: Data from the Swedish Forest Soil Inventory 1993-2002.

National regulation concerning forest land

The Forestry Act expresses the demands society has on you as a forest owner. The law states that the forest is a renewable resource that must be managed so that it sustainably provides a good return. At the same time, you must take into account the cultural environment, reindeer husbandry and other interests. In short the legislation regulates:

- Establishing new forest: New forest must be established after felling.
- Notification of felling: Regeneration felling of at least 0.5 hectares must be notified to the Swedish Forest Agency no later than six weeks in advance.

- Natural and cultural environment conservation: Forest biodiversity must be preserved. It is therefore important to take this into account in all forestry operations. At the same time, other interests, such as the cultural environment and outdoor recreation, must be considered.
- Reindeer husbandry: If you have land where reindeer husbandry may be conducted, you must take reindeer husbandry into account
- Mountainous forest: In montane forests, you must apply for a permit to harvest for regeneration.
- Measures against insects: Insect pests reproduce in unbarked fresh coniferous wood. Insect damage must be prevented by taking care of the amount of damaged spruce and pine forest that exceeds 5 cubic metres of forest within one hectare

Ownership of forest land

The largest area of productive forest land in 2020 was owned by the group of individual owners consisting of natural persons, estates and unlisted companies. These own just under half (48 percent) of the area declared as productive forest land. The second-largest share (25 percent) is owned by private limited companies, followed by state owned companies (12 percent) and the state (8 percent). Other private owners and other public owners hold the remaining 6 and 1 per cent productive forest land, respectively. The development of these shares during the period 1999 to 2020 was relatively stable, with only slight changes. In 2020, almost half of the productive forest land in Sweden was owned by 310,749 private persons (SFA, n.d.)

The economic importance of the forest industry

Sweden is the world's fourth largest combined exporter of pulp, paper and sawn wood products (2022). The export value in 2022 was 186 billion SEK (2021: 157 billion). About 82 percent of the production of Sweden's forestry sector is exported. Investments in the sector in 2022 amounted to SEK 15.8 billion (2021: SEK 12.1 billion) (Skogs Industrierna, 2024).

Pulp, paper and sawn timber comes second place when comparing important export goods for Sweden, 186 billion SEK. In the following table from Statistics Sweden, the timber part is missing.

Sweden's 10 most important export goods in 2022, Source: SCB, 2023.

Export goods	**Billion SEK**
Vehicles	243
Mineral oils	160
Medical and pharmaceutical products	139
Nonelectric machines and devices	109
Paper, pulp and goods made of paper	103
Electric Machines and devices	93
Iron and Steel	93
Machines for specific industries	74
Telecom, radio, television sets	73
Power-generating machines	63

1.3 Biodiversity management profile

Late colonization after the ice age has resulted in very few endemic species being found in Sweden compared to older geographical regions (SLU, 2020).

Implementation of the EU Nature Directives in Sweden

It is primarily the responsibility of the relevant sector authorities to ensure that the provisions of the EU Birds and Habitats Directives are transposed into Swedish legislation. The authorities concerned, primarily the Swedish Environmental Protection Agency, the Swedish Forest Agency, the Swedish Board of Agriculture and the Swedish Board of Fisheries, must therefore ensure the appropriate formulation, implementation and enforcement of regulations within their area of responsibility. Primarily, this refers to the relevant provisions of the Species Protection Ordinance and the Hunting Ordinance, where the articles of the Directives have been incorporated.

Currently, some such implementing regulations are found in the statute books of the authorities mentioned. The provisions of Swedish legislation that derive from the EU Nature Directives and that this handbook deals with concern a variety of societal activities. This means that it is not only the most directly responsible sector authorities and authorities such as the county administrative boards and the environmental courts that must be aware of- and apply the provisions. The country's municipalities are responsible for several issues relating to protected species. One example is planning matters, which can have a direct impact on the interests safeguarded by the Species Protection Ordinance and the Hunting Ordinance.

It is therefore important for the municipalities to know the purpose and content of the ordinances. In connection with Sweden's membership of the EU, species protection was clarified in Swedish legislation. The Habitats Directive's species protection was the guiding principle when it was introduced in the Species Protection Ordinance. As a result, birds were subject to the same regulations as the species listed in Annex 4 of the Habitats Directive. Both the Habitats and Birds Directives are minimum directives, which means that the individual Member States can introduce more far-reaching provisions, such as in the Species Protection Regulation, where the protection of birds is slightly strengthened compared to the Birds Directive (Naturvårdsverket, 2009).

New investigation announced by the Swedish government.

On the 7th of February the Swedish government announced a new investigation called “A robust forest policy that sees the forest as a resource"

A special investigator will carry out a review of the national forest policy given the development since the forest policy reform in 1993, including policy development within the EU, as well as consider measures for long-term sustainable and competitive forestry that strengthens economic freedom and the willingness to invest.

The task also includes making proposals for effective, simple and well-functioning supervision of forestry and a more effective way to work with the national environmental goals that concerns the forest. The aim is to develop a future expedient forest policy that promotes long-term sustainable competitive forestry, increased forest growth and long-term increased access to sustainable forest biomass in order to fully contribute to climate change and jobs and growth throughout the country. The equal forest policy goals - the environmental goal and the production goal – remains (Regeringskansliet, 2024).

Biodiversity on forest land

To measure forest biodiversity on an area of 28 million hectares is difficult and is therefore often done by measuring important structures for biodiversity such as the amount of dead wood and, old trees, amount of broadleaves and snags. In 1993 the Swedish Forestry Act was revised, and two targets were incorporated: a production target and an environmental target. The intention, according to the preparatory work, was that these two goals would be equal. In order to follow up on the revised law the National Forest Survey now has 30 years of data to analyse and it is clear that all the above-mentioned important structures have increased, as have the areas of formally and voluntary protected forest land. *(Skogsdata 2014 with theme on (Biological diversity, Skogsdata 2019 with theme on from 2014, Forest structures, Skogsdata 2020 with theme on from 2019, Dead wood, Skogsdata 2022 on the theme from 2020, The formally protected forest from 2022)*

2 Methodology for the appraisal of available capacity of the regional ecosystem (by Ecologic Institute)

The text in this chapter is strongly based on the description of the methodology for the BE-Rural Sustainability Screening presented in Anzaldúa et al. (2022), with only minor adaptations that resulted from the implementation of the approach in SCALE-UP.

2.1 Water data and indicators

To run the sustainability screening of surface and groundwater bodies potentially relevant to the BioFuel Region in Sweden, the authors of this report have reviewed the data reported in the 2nd River Basin Management Plans (RMBPs) of the Bothnian Sea and the Bothnian Bay River Basin Districts published in 2016 (data from the 3rd reporting cycle was not yet available on the WISE Database at the time of the analysis). The benefits of tapping on this reporting process is that it includes well-defined indicators like the status of water bodies in each RBD as well as data on significant pressures and impacts on them. Further, these data are official, largely available, accessible, and updated periodically (every six years). Authorities in charge of developing a regional bioeconomy strategy would generally be expected to have good access to the entity in charge of developing the River Basin Management Plan (i.e. the River Basin Authority), and so could theoretically consult it if necessary.

2.1.1 Description of the data / definition of the indicators employed

Data reviewed for this part of the screening included the reported ecological and chemical status of rivers and lakes as well as the quantitative and chemical status of groundwater bodies in the two RBDs that roughly coincide territorially with the BioFuel Region. These data give indications on water quality in the two river basins according to the five status classes defined in the WFD. These are: high (generally understood as undisturbed), good (with slight disturbance), moderate (with moderate disturbance), poor (with major alterations), and bad (with severe alterations) (EC, 2003). Further, data on significant pressures and significant impacts on the water bodies in the river basin districts are used to indicate the burden of specific pressure and impact types on water ecosystems in the regions based on the number and percentage of water bodies subject to them. Significant pressures are defined as the pressures that underpin an impact which in turn may be causing the water body to fail to reach at least the good status class (EEA, 2018).

All data described above were accessed on 05.06.2023 from the WISE WFD data viewer (Tableau dashboard) hosted on the European Environment Agency's (EEA) website[1].

Table 3 - Indicators used for the water component of the sustainability screening

Category	Indicator Family	Indicator	Spatial level	Unit of measure	Comments/Reference
Water	Water quality	Status of water bodies according to the EU Water Framework Directive	River Basin District	Number of water bodies in high, good, moderate, poor, bad or unknown status	WISE WFD Data Viewer[2] Disaggregated data for ecological and chemical status of surface water bodies; quantitative and chemical status of groundwater bodies, per River Basin District

[1] https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd
[2] WISE WFD Data Viewer (https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd)

	Burden on water bodies	Significant pressures on water bodies	River Basin District	No. and % of water bodies under significant pressures per pressure type	WISE WFD Data Viewer
	Burden on water bodies	Significant impacts on water bodies	River Basin District	No. and % of water bodies under significant impacts per impact type	WISE WFD Data Viewer

Source: Anzaldúa et al., 2022.

To determine which status class a certain water body falls into, WFD assessments evaluate the *ecological* and *chemical* status of surface waters (i.e. rivers and lakes) and the *quantitative* and *chemical* status of groundwater bodies. Ecological status refers to *“an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters”.* It covers assessments of biological (e.g. presence and diversity of flora and fauna), physico-chemical (e.g. temperature and oxygen content) and hydromorphological criteria (e.g. river continuity) (EC, 2003; BMUB/UBA, 2016). The chemical status of a surface water body is determined by comparing its level of concentration of pollutants against pre-determined Environmental Quality Standards (EQS) established in the WFD (concretely in Annex IX and Article 16(7)) and in other relevant Community legislation. These standards are set for specific water pollutants and their acceptable concentration levels.

In the case of groundwater bodies, chemical status is determined on the basis of a set of conditions laid out in Annex V of the WFD which cover pollutant concentrations and saline discharges. Additionally, the water body’s quantitative status is included in the WFD assessments, defined as “*an expression of the degree to which a body of groundwater is affected by direct and indirect abstractions”*. This gives indication on groundwater volume, a relevant parameter to evaluate hydrological regime (BMUB/UBA, 2016).

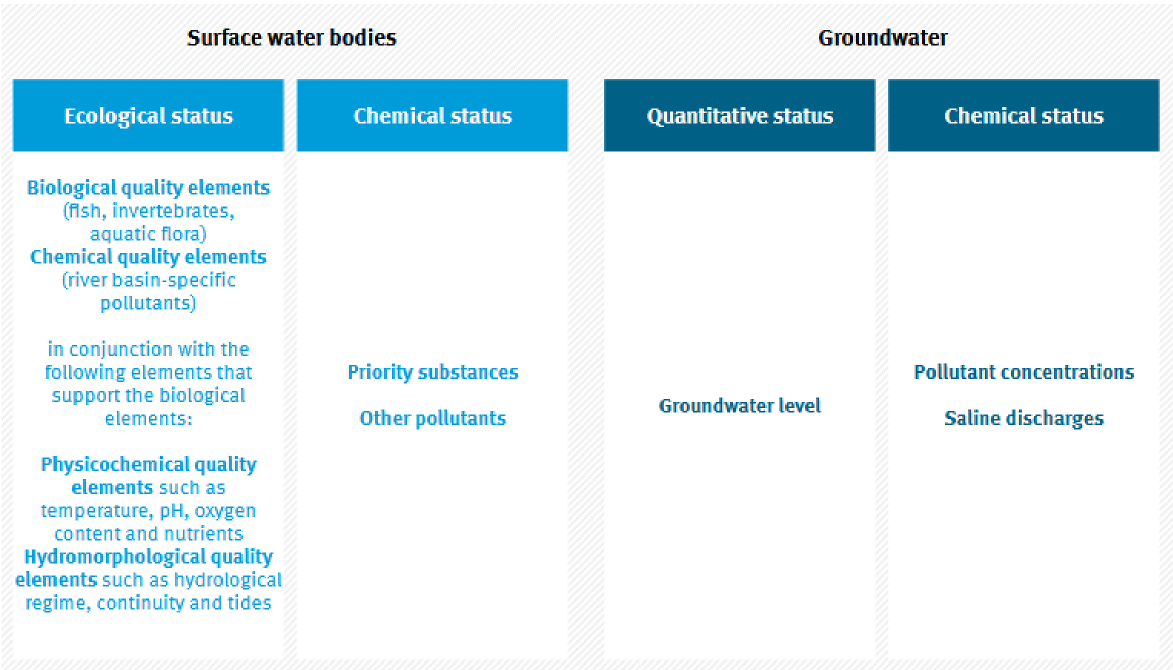

Figure 2 - Overview of surface water body and groundwater status assessment criteria, as per the Water Framework Directive. Source: BMUB/UBA, 2016.

In the case of surface water bodies, the WFD objective is not only that they reach good status, but that quality does not deteriorate in the future (EC, 2003), which is relevant in the context of the development of bioeconomy value chains.

2.1.2 Methodology applied

The authors of this report have followed the approach described in Anzaldúa et al. (2022) to valorise the data from the WFD reporting described in the previous sub-section that allows for an appraisal that is non-resource intensive (based on reliable, publicly available and accessible data) yet capable of providing a rough overview of the state of the BioFuel Region's waters. This is in line with the rationale of this sustainability screening, which aims to enable stakeholders with limited financial resources and/or expertise in the field to consider ecological limits in a structured manner when exploring bioeconomy activities. The preferred option for this part of the assessment would have been to supplement the WFD data with a water quantity balance indicator like the Water Exploitation Index plus (WEI+) developed by the EEA and its partners. That indicator compares the total fresh water used in a country per year against the renewable freshwater resources (groundwater and surface water) it has available in the same period. This could have strengthened the water quantity element in the screening. However, the calculation of the WEI+ at regional level is currently not conducted or foreseen by its developers, and it would entail a disproportionately large effort that falls beyond the scope of this task in SCALE-UP. For these reasons, the reported data from the WFD process has been employed exclusively within the following methodology.

The overall apportionment of rivers, lakes and groundwater bodies in the BioFuel Region according to their WFD status classification can be used to set the baseline for the sustainability screening. It provides initial insight on the situation in the demarcation as regards "ensuring access to good quality water in sufficient quantity", "ensuring the good status of all water bodies", "promoting the sustainable use of water based on the long-term protection of available water resources" and "ensuring a balance between abstraction and recharge of groundwater, with the aim of achieving good status of groundwater bodies", all explicit aims of the WFD that are aligned with the consideration of ecological limits. Further, the data on significant impacts and pressures affecting the water bodies in the river basins are useful as they can point towards specific problems (e.g. nutrient pollution) and the types of activities that may be causing them (e.g. discharge of untreated wastewater, agriculture).

As a first step, the approach used for this element of the screening entails calculating what proportion of the total number of surface water bodies located in the RBD is reported as failing to achieve Good Ecological Status/Good Chemical Status or for which conditions are unknown. Similarly for groundwater bodies, the proportion is calculated of those who are reported as failing to achieve Good Chemical Status/Good Quantitative Status or for which conditions are unknown. The resulting ratios are then compared to the respective EU proportions, which are used as (arbitrary) thresholds. According to the latest assessment published by the EEA in 2018, "around 40% of surface waters (rivers, lakes and transitional and coastal waters) are in good ecological status or potential, and only 38% are in good chemical status" (EEA, 2018). Accordingly, "good chemical status has been achieved for 74% of the groundwater area, while 89% of the area achieved good quantitative status" (EEA, 2018). Using these markers, the following step is to rank the current conditions of the BioFuel Region using an ordinal risk rating (high, moderate, low) based on the distance of the result of each indicator to the EU level results. On this basis, the thresholds and ordinal ranking convention suggested by the authors of this report are as shown in Table 4 and Table 5.

Table 4 - Proposed thresholds for the water section of the sustainability screening

Water body type	Status category	2018 EU-level assessment results (proportion of water bodies achieving good status)	Proposed thresholds for the sustainability screening		
			High concern	Moderate concern	Low concern

Surface water bodies	Ecological status	~40%	0-40%	41-89%	90-100%
	Chemical Status	38%	0-38%	39-89%	90-100%
Groundwater bodies	Chemical status	74%	0-74%	75-89%	90-100%
	Quantitative status	89%	0-89%	-	90-100%

Source: Anzaldúa et al., 2022.

Table 5 - Ordinal ranking convention for the water section of the sustainability screening

Ordinal ranking for water resources		Chemical status		
		High concern	Moderate concern	Low concern
Ecological or Quantitative status	High concern			
	Moderate concern			
	Low concern			

Source: Anzaldúa et al., 2022.

This initial appraisal based on the thresholds shown above is then supplemented with a review of the reported data on the types of significant pressures and impacts on surface and groundwater bodies. In this case percentage values are already given, and so this step in the screening simply entails the listing of the reported pressures and impacts and the identification of those which are more frequently reported. From here, the screening team can seek potential correlations between the most reported pressure types and the most reported impact types (e.g. diffuse sources causing nutrient pollution).

The final step in the approach is to draft a note describing the share of water bodies failing to reach good status and formulating preliminary statements on the types of bioeconomy activities that could be considered, those that should be considered with reserve, and those that should be avoided. These initial statements are used to frame the discussion of the group of stakeholders involved in the development of the bioeconomy value chains in focus in the SCALE-UP project.

2.1.3 Data uncertainties

The data resulting from the assessments reported in the WISE Database are subject to the limitations of the scientific and methodological approaches used by their authors. It thus must be considered that the official assessments are based on estimates, include assumptions, and will therefore carry a margin of error.

An important limitation bound to the implementation of the sustainability screening is that the WFD data used refer to the RBDs of the Bothnian Bay and the Bothnian Sea, whose territorial boundaries do not coincide entirely with those of the BioFuel Region. A future iteration of this exercise by the local stakeholders could increase the resolution of the screening of water resources by tapping on additional information sources, like higher resolution data for the specific territorial demarcation of the BioFuel Region, if they become available.

Lastly, another issue to consider is the data currently available on WISE is from 2016, while more updated assessments are already available at the time of writing of this document. These come as part of the 3rd cycle of river basin management planning (2022-2027), but are not yet reflected on the WISE Database hosted by the EEA. Here as well, such sources could be considered by the stakeholders performing the sustainability screening to avoid overlooking any relevant recent developments.

2.1.4 Methodological uncertainties

The proposed methodology for the water section used in this application of the sustainability screening is straight-forward and accessible, yet it must be used with care and, where possible, should incorporate higher resolution data evaluated by thematic experts. As previously mentioned, the thresholds set in this case have been the proportions, at EU-level, of water bodies that fail to achieve good status or for which conditions have been reported as unknown. This has been a pragmatic, yet easy to challenge way of defining a benchmark for the BioFuel Region. Conditions and context in other European RBDs may be significantly distinct to those in Northern Sweden, and thus a more appropriate reference point could be defined in those cases. For this, the authors envision the contributions and guidance from the team of local and foreign experts as briefly described in Section 3.2 of Anzaldúa et al., 2022. Optimally, these thematic experts should know the regional context well and thus be in a good position to guide the setting of such thresholds. Beyond this, the simplicity of the necessary calculations and the fact that the data on significant pressures and impacts are used without further computation and compared in relative terms within the RBD limit the possibility of additional accuracy or uncertainty issues emerging.

2.2 Soil data and indicators

2.2.1 Description of the data / definition of the indicators employed

The selected indicators for vulnerability to soil depletion are closely interrelated and refer specifically to soil erosion **by water**. These are:

- Estimated mean soil erosion rate (in $t\ ha^{-1}\ a^{-1}$)
- Share (%) of area under severe erosion (>10 $t\ ha^{-1}\ a^{-1}$)

In broad terms, soil erosion describes the process through which land surface (soil or geological material) is worn away (e.g. through physical forces like water or wind) and transported from one point of the earth surface to be deposited somewhere else (Eurostat, 2020). The above-mentioned indicators describe particularly the amount of soil (in t) per unit of land surface (in ha) that is relocated by water per year.

Variations of these indicators can be calculated by considering different combinations of land cover classification groups, such as *all land*[3] and *agricultural land*[4]. As shown in Figure 3, at EU level in 2016, about three quarters of soil loss occurred in agricultural areas and natural grasslands, while the remaining quarter occurred in forests and semi natural areas (Eurostat, 2020). Therefore, since it is the type of land cover that is most vulnerable to erosion, the present sustainability screening will

[3] This refers to all potentially erosive-prone land (in simplified terms), specifically to CORINE Land Cover classification groups: Agricultural areas (2), forest and semi natural areas (3) excluding beaches, dunes, sand plains (3.3.1), bare rock (3.3.2), glaciers and perpetual snow (3.3.5). These, as well as other classes, are excluded because they are not subject to soil erosion.
[4] This refers only to agricultural land (agricultural cropland as well as grassland in simplified terms), specifically to CORINE Land Cover classification groups: Agricultural Areas (2) and Natural Grasslands (321)

consider in first line the above-mentioned indicators specifically for agricultural areas and natural grasslands. This scope of the indicators is also in line with the two sub-indicators for soil erosion considered by the Joint Research Centre European Soil Data Centre (JRC ESDAC). Moreover, both the *mean erosion rate for agricultural land* and the *share of agricultural area under severe erosion* are part of the EU Common Agriculture Policy (CAP) context indicator 42 (CCI42) for the period 2014-2020.

Figure 3 Share of land cover and soil loss across the EU-27 in 2016[5]

Source: JRC, Eurostat

The data has been extracted from EUROSTAT, specifically the dataset “Estimated soil erosion by water, by erosion level, land cover and NUTS 3 regions (source: JRC) (aei_pr_soiler)”. For determining the baseline in the sustainability screening, we have selected the latest available data, i.e. for 2016.

Mean soil erosion rate, which undergirds both selected indicators, is considered useful because it provides a solid baseline to estimate the actual erosion rate in the regions (Panagos et al., 2015). This indicator is based on the latest Revised Universal Soil Loss Equation of 2015 (RUSLE2015), specifically adapted for the European context (see Panagos et al., 2015), which is a model that takes into account various aspects, including two dynamic factors, namely the cover-management[6] and policy support practices[7] (both related to human activities) (Panagos et al., 2020).

The estimated mean soil erosion rate value obtained through the RUSLE2015 model refers to water erosion only, but it is considered to be the most relevant at least in terms of policy action at EU level, due to the relative predominance of water erosion over other types of erosion. Furthermore, it offers the important advantage of providing a viable estimation for erosion vulnerability at a relatively small geographic scale, i.e. the local or regional level. This can serve as an important tool for monitoring the effect of local and regional policy support strategies of good environmental practices (Panagos et al., 2015, 2020, and Eurostat, 2020).

2.2.2 Methodology applied

The near-universal indicators available to track soil vulnerability are related to either erosion or the decline in soil organic carbon (SOC)/soil organic matter (SOM) (Karlen & Rice, 2015). However, there are major data gaps regarding to SOC/SOM and data is currently only available at national level. According to Panagos et al. (2020), soil organic carbon does not change so quickly and therefore is

[5] Excluding not erosion-prone land (e.g. beaches, dunes, etc.). Forest and natural areas exclude also natural grasslands, which are evaluated together with agricultural areas.

[6] Known as the c-factor, it has a non-arable component, which includes changes in land cover and remote sensing data on vegetation density, as well as an arable component, which includes Eurostat data on crops, cover crops, tillage and plant residues.

[7] Known as the p-factor, it reflects the effects of supporting policies in estimating the mean erosion rate by including data reported by member states on Good Agricultural Environmental Conditions (GAEC) according to the CAP, specifically contour farming, as well data from LUCAS Earth observation on stone walls and grass margins.

not so sensitive to human influence on short term. Therefore, they recommend using just a sole indicator for monitoring impact of policies: “estimated mean soil erosion rate” (by water), which they calculate using the RUSLE2015 model. For our purposes, we have complemented the *mean soil erosion rate* indicator, with the *share of agricultural area under severe erosion* in order to gain a comprehensive picture of soil erosion in a region.

Soil erosion is considered generally as a sort of proxy indicator of soil degradation, which in turn is the most relevant component of land degradation at EU level (EC, 2018). However, not all types of bio-based activities have a direct effect on erosion, but rather primary production of biomass. Nonetheless, as these are currently the most widespread bioeconomy activities in rural areas, we will consider their impact on soil degradation, and therefore on soil erosion, to be the most relevant one for this assessment.

The indicators for vulnerability to soil degradation were selected, on one hand, due to the limited number of soil indicators available at the required regional scale. On the other hand, the RUSLE2015 model used for this data also represents the current state-of-the-art methodology for calculating soil erosion. These aspects are crucial, since the choice of indicators needs to be: a) acceptable to experts, b) routinely and widely measured, and c) have a currency with the broader population to achieve global acceptance and impact (Stockmann et al., 2015). In order to carry out the screening of soil vulnerability, a number of datasets need to be accessed. As mentioned above, these data can be accessed via Eurostat.

In terms of processing the erosion data, it is important to consider that the overall erosion rate changes across geographic areas, meaning the vulnerability/risk is not necessarily evenly distributed. In cases where the mean soil erosion rate exceeds the 10 t ha^{-1} a^{-1}, erosion is considered severe and activities that can generate, or are associated with a high erosion impact should be strongly discouraged. Erosion rates between 5 and 10 t ha^{-1} a^{-1} are considered moderate, requiring some attention towards practices that have a high impact on erosion, but with less urgency. However, it is relevant to take a look not only at the mean erosion rate for the area itself, but also at its spatial distribution, which is roughly reflected on the indicator of share of (agricultural) area under severe erosion.

2.2.3 Data uncertainties

The data used is produced from an empirical computer model (RUSLE2015) and produces estimates. Hence, there are several uncertainties related to the figures if compared to data collected on the ground. However, the purpose of the model is to generate data for a large spatial scale taken into account human intervention, which is not possible to do only through empirical measurements. That being said, like every model, assumptions have to be made and there is an intrinsic level of uncertainty. Specifically related to the RUSLE methodology, Benavidez et al. (2018) critically reviewed the RUSLE methodology, upon which RUSLE2015 is based, and identified following main limitations:

- its regional applicability to regions that have different climate regimes and land cover conditions than the ones considered (in the original RUSLE for the USA, in RUSLE 2015 for Europe)
- uncertainties associated generally with soil erosion models, such as their inability to capture the complex interactions involved in soil loss, as well as the low availability of long-term reliable data and the lack of validation through observational data of soil erosion, among others.
- issues with input data and validation of results,
- its limited scope, which considers only soil loss through sheet (overland flow) and rill erosion, thus excluding other types of erosion which may be relevant in some areas, e.g. gully erosion and channel erosion, to name a few. Moreover, it also excludes wind erosion.

A further factor of uncertainty in the data is the fact that the RUSLE model is calculated using mean precipitation data over multiple years and a large territorial scale (in this case Europe). Thus, it fails to account the changes in rainfall intensity, which are highly relevant for determining water erosion accurately. This is the case not only considering the seasonality of rainfall, but also its distribution across the continent (Panagos et al., 2020). Another important uncertainty identified by Panagos et al. (2020) is the lack of georeferenced data for annual crops and soil conservation practices in the field at a continental level, which has had to be estimated from statistical data.

Nonetheless, when considered best available estimates, the mean soil erosion values generated through the application of RUSLE2015 model offer a very suitable basis for assessing vulnerability to soil loss in general terms, even if the generated absolute values are to be taken with caution (Benavidez et al., 2018).

2.2.4 Methodological uncertainties

Among the most relevant uncertainties regarding the application of the sustainability screening in terms of soil vulnerability are the selection of the threshold against which the severity of erosion is evaluated and the selection of the land cover types that will be considered.

Regarding the threshold of 10 t ha^{-1} a^{-1} for severe erosion, it is important to mention that this was obtained directly from the dataset that was used[8]. However, it is still an arbitrary value which can be adapted. For instance, some sources like Panagos et al. (2015, 2020), who were involved in the generation of the data for the JRC ESDAC, consider severe erosion to be above 11 t ha^{-1} a^{-1}. In this regard, we have also decided to stick to the lower value described in the Eurostat dataset because it is more conservative and, as such, more suitable for an initial (and indicative) sustainability screening like the one we are proposing.

The selection of land cover types presents another area for potential uncertainty. Choosing between “all lands” and “agricultural lands” can have considerable implications for interpreting the data. For example, it is possible that the mean soil erosion rate is 5 t ha^{-1} a^{-1} (moderate erosion) in one land cover type, but lower in the other. This would have an effect on the assessment, which would present any potential concerns about erosion and steps that should be taken. As such, it is important to have solid grounding for the choice of dataset. The ultimate decision whether to consider all lands (including forests) is arbitrary and lays with the group performing the sustainability screening. Particularly when that decision is based on considerations of the economic relevance of forestry related industries in the region rather than on the actual share of the area that is covered with forest (it should be high to justify their inclusion), the values of soil erosion (for all lands) shall be taken with some reservations. This is because these values tend to be lower than the value for agricultural land and can create the impression that vulnerability to erosion is lower than it actually is. However, due to the indicative (and non-exhaustive) nature of the present sustainability screening, this uncertainty is not especially relevant for cases such as the BioFuel Region, which has a high proportion of forest land and where both values (for all lands and agricultural land with natural grassland) are low (see section 4.1).

2.3 Biodiversity data and indicators

2.3.1 Description of the data / definition of the indicators employed

Unlike for water- and soil-related risks, there are no reliable indices or standardized metrics to operationalize and compare risks to biodiversity at the regional level and in an integrated manner. Biodiversity is intricate and multifaceted, spanning genetic, species, and ecosystem diversity across various regions. Attempting to consolidate this diversity into a singular index may oversimplify it, leading to the loss of crucial information (Ledger et.al 2023; Brown & Williams 2016). Instead, biodiversity risks in a given region could be uncovered by considering the status of all species known to inhabit the region under scrutiny on a one-by-one basis, without trying to synthesize their collective status in a single index. Accordingly, our methodology suggests screening for biodiversity risks of a region by taking stock of its species of flora, fauna and fungi present in the demarcation and considering their conservation status. The Red List of Threatened Species of *the International Union for Conservation of Nature* (IUCN) is a globally recognized system for classifying the conservation status of species[9]. It is structured along the following risk categories (IUCN 2001, 2003):

[8] See metadata of the used dataset at https://ec.europa.eu/eurostat/cache/metadata/en/aei_pr_soiler_esms.htm

[9] The International Union for Conservation of Nature (IUCN) is a global environmental organization that was founded on October 5, 1948. It is the world's oldest and largest global environmental network. The IUCN

(1) Critically Endangered (CR): This is the highest risk category assigned by the IUCN Red List for wild species. Species in this category are facing an extremely high risk of extinction in the wild.
(2) Endangered (EN): Species in this category are facing a high risk of extinction in the wild.
(3) Vulnerable (VU): Species in this category are facing risks of extinction in the wild.
(4) Near Threatened (NT): Species in this category are close to qualifying for, or are likely to qualify for, a threatened category soon.
(5) Least Concern (LC): Species in this category have been evaluated but do not qualify for any other category. They are widespread and abundant in the wild.
(6) Data Deficient (DD): A category applied to species when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution or population status.
(7) Not Evaluated (NE): A category applied to species that have not yet been evaluated against the criteria.

Data description

Data on the risk category of each species found in the SCALE-UP regions is accessed through the online database of the IUCN Red List website. The IUCN Red List serves as a comprehensive repository of information, offering insights into the present extinction risk faced by assessed animal, fungus, and plant species. In 2000, IUCN consolidated assessments from the 1996 IUCN Red List of Threatened Animals and The World List of Threatened Trees, integrating them into the IUCN Red List website with its interactive database, currently encompassing assessments for over 150.300 species. Since 2014, assessors of species have been mandated to furnish supporting details for all submitted assessments. Among the recorded details are the species' (1) IUCN Red List category, (2) distribution map, (3) habitat and ecology, (4) threats and (5) conservation actions. The assessment of these dimensions is elaborated below:

(1) The IUCN Red List category: The IUCN Red List categories (CR, EN, VU, NT, LC, DD, NE) are determined through the evaluation of taxa against five quantitative criteria (a-e), each grounded in biological indicators of population threat:
    a. Population Size Reduction: This criterion evaluates the past, present, or projected reduction in the size of a taxon's population. It considers the percentage reduction over a specific time frame, with different thresholds indicating different threat levels.
    b. Geographic Range Size and Fragmentation: This criterion assesses the size and fragmentation of a taxon's geographic range. Factors such as few locations, decline, or fluctuations in range size contribute to the evaluation.
    c. Small and Declining Population Size and Fragmentation: This criterion focuses on taxa with small and declining populations, considering factors like population size, fragmentation, fluctuations, or the presence of few subpopulations.
    d. Very Small Population or Very Restricted Distribution: This criterion addresses taxa with extremely small populations or limited distributions. It assesses whether the taxon is at risk due to its small population size or restricted geographic range.
    e. Quantitative Analysis of Extinction Risk: This criterion involves a quantitative analysis, such as Population Viability Analysis, to estimate the extinction risk of a taxon. It considers various factors influencing population dynamics and extinction risk.

    While listing requires meeting only one criterion, assessors are encouraged to consider multiple criteria based on available data. Quantitative thresholds of the IUCN Red List categories were developed through wide consultation and are set at levels judged to be appropriate, generating informative threat categories spanning the range of extinction probabilities. To ensure

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works to address conservation and sustainability issues by assessing the conservation status of species, promoting sustainable development practices, and providing guidance and expertise on environmental policy and action. The IUCN also plays a crucial role in influencing international environmental policies and fostering collaboration among governments, NGOs, and the private sector to promote conservation efforts worldwide (IUCN 2018).

adaptability, the system permits the incorporation of inference, suspicion, and projection when confronted with limited information.

(2) The distribution map: The IUCN Red List distribution map serves as a reference for the taxon's occurrence in form of georeferenced data and geographic maps. This data is available for 82% of the assessed species (>123.600) and is based on the species' habitat, which is linked to land cover- and elevation maps. The indicated area marks the species extent of occurrence, which is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred, or projected sites of present occurrence of a species, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of species, such as large areas of obviously unsuitable habitat. For a detailed explanation of the mapping methodology, please refer to the *Mapping Standards and Data Quality for the IUCN Red List Spatial Data* (IUCN 2021).

(3) Habitat and Ecology: The IUCN classifies the specific habitats that a species depends on for its survival. These habitats are categorized into three broad systems: terrestrial, marine, and freshwater. A species may inhabit one or more of these systems, and so the possible permutations result in seven categories of natural systems. Beyond these seven system categories, the IUCN offers a more nuanced classification system for habitats, comprising 18 different classes at level 1 (e.g., forest, wetlands, grassland, etc.), and 106 more specific classes listed at level 2 (e.g., Forest – Subtropical/tropical moist lowland, Wetlands (inland) – Permanent inland deltas; Grassland - Temperate) (IUCNa n.d.). For SCALE-UP's sustainability screening, the IUCN classification of the seven systems is sufficient to refine the search while not excluding relevant habitats. The EU Habitats Directive, in contrast, distinguishes 25 habitat types that are considered threatened and require active and recurring conservation action. The Directive demands member states to take measures to maintain or restore these natural habitats and wild species. If data on these became accessible in the future, it could be used in future iterations of the sustainability screening to supplement the results that using the IUCN classification yields.

(4) Threats: The IUCN database encompasses various general threats that can negatively impact a species. Direct threats denote immediate human activities or processes impacting, currently impacting, or potentially affecting the taxon's status, such as unsustainable fishing, logging, agriculture, and housing developments. Direct threats are synonymous with sources of stress and proximate pressures. Assessors are urged to specify the threats that prompted the taxon's listing at the most granular level feasible within this hierarchical classification of drivers. These threats could be historical, ongoing, or anticipated within a timeframe of three generations or ten years. These generalized threat categories encompass residential and commercial development, agriculture and aquaculture, energy production and mining, transportation and service corridors, biological resource use, human intrusion and disturbances, natural system modifications, invasive and other problematic species, genes and diseases, pollution, geological events, and climate change and severe weather. Beneath each general threat, more specific threats are detailed. Please refer to the IUCN Red List's website[10] for a detailed list of all threats, including explanations.

(5) Conservation Actions: The IUCN database contains conservation action needs for each species, providing detailed information on the current conservation efforts and recommended actions for protecting the taxon. It includes general conservation actions such as research & monitoring, land/water protection, management, and education. Specific conservation actions are listed under each general action, along with a description of the current conservation status and recommended actions to protect the taxon. A hierarchical structure of conservation action

[10] See here: https://www.iucnredlist.org/resources/threat-classification-scheme

categories (see the IUCN Red List's website[11]) indicates the most urgent and significant actions needed for the species, along with definitions, examples, and guidance notes on using the scheme. Assessors are encouraged to be realistic and selective in choosing the most important actions that can be achieved within the next five years, informed by the conservation actions already in place.

Note: the IUCN Red List and the EU Habitats Directive
Both, the EU's Habitats Directive and the IUCN Red List aim to preserve biodiversity, but they employ distinct methods and standards for evaluating conservation status. The Habitats Directive is centered on preserving natural habitats and wild species of flora and fauna within the EU, mandating that member states establish Special Areas of Conservation for habitats and species listed in its annexes. The Directive categorizes conservation status into three groups: favorable, unfavorable-inadequate, and unfavorable-bad. This classification system of habitats and species is based on how far they are from the defined 'favorable' conservation status, not their proximity to extinction (Sundseth 2015). Conversely, the IUCN Red List is a worldwide evaluation of the conservation status of species, categorizing them according to their extinction risk. The Red List employs a set of five rule-based criteria to assign species to a risk category (see above). However, there are inconsistencies and weak agreement between the conservation status assessments of the Habitats Directive and the IUCN Red List. These inconsistencies can be significant, and correlations can vary greatly between taxonomic groups. Specifically, the Red List assessment tends to be more pessimistic than the Directive's Annex (Moser et.al 2016). Amos (2021), on the other hand, has found strong correlations between the two classifications systems for plants, while recognizing the Red List's quicker reaction to changes in the conservation status. In summary, while both the Habitats Directive and the IUCN Red List aim to protect and conserve biodiversity, they use different methodologies and criteria to assess conservation status, leading to discrepancies in their assessments. However, they can complement each other in providing a comprehensive view of the conservation status of species and habitats at both the European and global levels (IUCN 2010).

2.3.2 Methodology applied

The methodology aims to derive a list of species which would require special consideration (e.g. close monitoring and safeguarding) in the context of implementing bioeconomy activities. To generate this list, the search function of the interactive IUCN database is used following five steps:

(1) Scope of Assessment: Selection of Europe as the scope of assessment to evaluate the conservation status of the European population rather than the global population. This approach ensures that species are identified as threatened based on their status in Europe, irrespective of their global abundance.

(2) Geographical Delineation: Utilization of the interactive map of the IUCN database to draw a polygon that exceeds the region of interest. Exceeding the regions ensures that the entire region is covered, as it is not possible to draw a polygon exactly matching the boundaries of the region. Moreover, a larger polygon also respects the uncertainty of delineating a species area of extent, since the actual area of extent is possibly more fluid than its statically indicated geolocations. Consequently, the larger polygon minimizes the risk of excluding any relevant species for which geolocations are registered just minimally outside of the regions' administrative boundaries, but which could inhabit parts of the region in the future. There is no rule of thumb for a correct distance between polygon boundary and region boundary.

[11] Ibid.

(3) Species Selection: Limiting of the search results to endangered and critically endangered species to focus on those facing the most severe risks.

(4) Habitat Selection: selection of all habitats to ensure the full coverage of habitat types present in the geographical delineation defined in step 2.

(5) Threat Selection: Selection of threats associated with the respective regional bioeconomy and/or value chain to refine the search results to species likely to be impacted by them.

By following these steps, a targeted list of species is derived, focusing on species facing significant risks within the context of the regional bioeconomy strategy or value chain being explored, aligning with the specific conservation and bioeconomic priorities of the region.

2.3.3 Data and methodological uncertainties

It is important to acknowledge certain limitations and uncertainties associated with the data and methodologies used:

(1) Inaccurate representation of relevant area: The IUCN database allows for the interactive drawing of a map for a regional assessment. However, this drawn map might not accurately represent the area directly relevant to the bioeconomy strategy or value chain being explored. Since the selected polygon is larger than the actual bioregion, the assessment risks to include species that are not relevant to the bioregion and the bioeconomic strategy of the region.
(2) Lack of local habitat differentiation: The spread of species is indicated as its extent of occurrence without differentiating between habitats at the local level. This means that certain species might solely inhabit very particular habitats within the indicated extent of occurrence. An endangered amphibious species, for instance, might have an area of extent covering an entire country. However, it will only be found in very rare habitats within this area of extent (e.g., pond with very specific qualities). Accordingly, a regional assessment as outlined here (e.g., at the municipal level) might list certain species that do not occur in the assessed regions due to a lack of suitable habitats on the local level.
(3) Potential oversights in conservation status: Using Europe as a scope of assessment might hide any problematic conservation status of a species at the global or at the local level.
(4) Outdated data: The IUCN aims to have the category of every species re-evaluated at least every ten years and aims to update the list every two years (IUCNb n.d.). Nevertheless, the data might be outdated, which could lead to inaccuracies in the assessment of biodiversity risks. For this screening carried out for Northern Sweden, 30 percent of the data was older than 5 years, the most dated ones being from 2016.
(5) Incomplete data: The data might be incomplete, which could limit the comprehensiveness of the assessment.
(6) Limited species coverage: It is estimated that the world hosts about 8,7 million species (Sweetlove, 2011). As of now, more than 150.300 species (16.120 in Europe) have been assessed for the Red List, leaving large data gaps at the global level.
(7) Taxonomic standards: The taxon being assessed must follow the taxonomic standards used for the IUCN Red List. Any deviation from these standards could lead to inaccuracies in the assessment.

The Swedish Species Information Centre at the Swedish University of Agricultural Sciences is responsible for the IUCN Red List assessments in Sweden. They do not collect data in nature, except in rare cases, instead they use what is available, e.g. from authorities' environmental monitoring programs and the like. Some examples of data sources used as basis for the Red List assessments in 2020 were:

- Environmental monitoring, e.g. test fishing, benthic fauna surveys,
- Butterfly monitoring, bird surveys
- Hunting and fishing statistics
- National Forest Inventory, e.g. proportion of dead wood and older forests
- The Swedish Board of Agriculture's figures for the area of grassland and semi-natural pastures

(measures of change in important habitats)
- Citizen Science via Artportalen
- Research on the environmental requirements and ecology of species

As previously mentioned in section 1.3 the predominant monitoring of biodiversity in forests are made based on the inventory, by the Swedish NFI, of important structures.

3 Potential ecological burden of regionally relevant bioeconomic activities

Note: the “Global Overview” sections in this chapter were produced based on a review of available and accessible scientific literature on the impacts of bioeconomy activities on water, land and soil, biodiversity, and other environmental dimensions. Quotes associating such activities (or elements thereof) with positive and negative effects on the said environmental dimensions were collected manually from the scientific studies and then fed to ChatGPT 3.5/4 for structuring and synthesis into flowing text.[12] The resulting text was then thoroughly reviewed and adjusted manually to ensure fidelity with the source documents.

3.1 Bioeconomic activity selected for the screening

The activity selected for review in this chapter is primarily forestry, in general, and the extraction of logging residues that follows clear cutting, in particular. Logging residues consist of branches and the top of the tree.

Being one of the primary wood producers in the EU, Sweden is recognized as a key contributor to the European bioeconomy, supplying significant forest biomass (Eggers et al., 2020). Nowadays, forestry plays a significant role not only in providing timber and pulpwood but also in contributing to biomass for bioenergy –including materials like branches and tops, saw dust and bark– as well as in starting to explore production of biochemicals and biopolymers. In Northern Sweden, there is a potential to increase the currently low extraction rates of logging residues. The current low extraction rates are mainly resulting from greater transport distances to end users. However, rising demand for biomass, e.g., as a renewable alternative for fossil fuels, also raises concerns regarding the environmental impact of the associated value chains and possible effects on the provision of ecosystem services.

The global overviews pinpoint some problematic issues that can arise concerning water, soil and biodiversity when extracting or processing forest biomass. Results come from academic studies carried out in several countries and include some management systems or practices that are not being used in Sweden, for example whole tree extraction and root extraction. The relevance of including them in this report is to collect reference points to provide a wider picture of the documented effects of specific activities and management practices on the three environmental dimensions considered in the sustainability screening, putting into perspective the current frameworks and practices in Northern Sweden (which are described in the sub-sections titled “The situation in Northern Sweden”).

3.2 Overview, management practices and potential burden on the resources examined

3.2.1 Potential burden on water resources

Global overview (by Ecologic Institute)

[12] Quotes fed to ChatGPT were sorted by topic and kept in quotation marks, including their correct in-text citation. Prompts and feedback were provided to the system to synthesize the information maintaining the style, using the right scientific references, and improving by avoiding repetition, not leaving any of the provided information out, and highlighting agreements, disagreements and complementarities among quotes.

Depending on the techniques employed, extraction and processing of forest biomass such as timber, and of forestry residues such as stumps, tops and branches slash, and bark can significantly impact water resources. At first instance, where no preventive measures during extraction are undertaken, water quality can be affected by soil disturbance and increased runoff, potentially carrying sediments and nutrients into water bodies. In Sweden, for this reason, the Forestry Act requires to leave zones near creaks and lakes undisturbed. Harvesting is mainly carried out in winter, when the land is frozen, to avoid compaction and damage to the soil. Approximately 50 percent of the tops and branches are used to pave the forest roads to minimize the risk for soil damage. If forest residues are harvested, approximately 30 percent is left in the forest to prevent nutrient depletion and habitat deterioration. Tree stumps consist of approximately one fifth of the tree and were previously harvested to a limited extent in Sweden. Due to both technical, economic and ecological reasons, stump extraction is not performed in Swedish forestry today.

Similarly, if the scale of manufacturing/processing operations and their wastewater management practices do not account for ecological boundaries, the processing of forest biomass into materials and products can affect water resources by abstraction and pollution pressures. This is meant to be safeguarded by the legal frameworks in place (e.g. environmental permitting procedures and environmental protection legislation).

Water Quality: Log extraction can impact water quality through increased runoff and leaching of nutrients, dissolved organic carbon (DOC), and particles that metals (Hg, Al, Pd, Cd, Zn, Fe) are attached to (Ranius et al., 2018). In particular, increased nutrient emission is observed but only after stump extraction (not practiced in Sweden see 3.1), possibly leading to eutrophication of water bodies and thereby potentially affecting aquatic life and water resources for human use. The resultant effects are variable and highly site specific (ibid.). However, it is not clear whether increased nutrient concentrations have these impacts at landscape scale (ibid.).

In acid sensitive areas, clear-cutting –as forestry management practice– and slash extraction is found to increase the risk of loss of base cations. The biomass removal can result in soil and surface water acidification as well as increased concentrations of Al (Ranius et al., 2018). As a possible solution, ash recycling may be used (Titus et al., 2021). Other practices carried out e.g. in Finland to reduce the risk of aquatic systems becoming acidified include not leaving harvested biomass adjacent to water bodies (ibid.). Similarly, the UK restricts the deposition of fresh harvest residues in trenches formed by mounding for restocking at sites with high risk of acidification of water ecosystems (ibid.).

Water Consumption: Biomass residues can be extracted not only for biofuel purposes but also to produce materials, such as biopolymers or bio-source chemicals. As such, tannins, aromatic chemicals contained in bark, can be extracted for commercial purposes. However, the conventional methods for tannin extraction require chemicals, and a significant amount of energy and water resources (Faye et al., 2021). In the referenced study, the outcomes for yield, energy, and water usage across the entire extraction process revealed that the stages of tannin extraction and tannin isolation are the most energy-intensive, accounting for 23% and 72% of the total energy consumption, respectively (ibid.).

To reduce energy and water consumption, ultrasound-assisted treatment and recycling of the extract solution can be introduced into the tannin extraction process. This method allows for the most significant energy and water reductions across the whole process –41% and 49%, respectively– while increasing the tannin yield by 13% compared to the control extraction method (ibid.).

The situation in Northern Sweden (by BFR)

Under the Swedish environmental quality objective „Only Natural Acidification“, it states: "The acidifying effects of deposition and land use should not exceed the limit of what soil and water can tolerate. The deposition of acidifying substances should also not increase the corrosion rate in soil-based technical materials, water distribution systems, archaeological artifacts, and rock carvings."

The number of acidified lakes has decreased, but in the follow-up in 2013, it was assessed that the set goals for 2020 will not be achieved with existing policy instruments. It was noted, among other things, that the acidification load from forestry is increasing as a result of increased extraction of wood fuels while ash return has not increased at a corresponding rate. A large part of the soil and surface water acidification originates from the combustion of fossil fuels and deposition of acidifying nitrogen and sulfur compounds.

However, all forest growth also contributes to soil acidification as trees, during their uptake of nutrients in the form of cations (positively charged ions), release hydrogen ions in exchange, which have an acidifying effect. If the trees are not harvested but allowed to die and decompose on site in the forest, this effect is neutralized. However, when trees are harvested, it results in soil acidification. Soil acidification caused by forest growth has increased as forest growth has increased in the country, and now with wood fuel as a new sought-after assortment, it increases further as more biomass is harvested.

The harvested biomass, in the form of branches and to some extent stumps, is also more nutrient-dense than stem wood (compare with Figure 4).

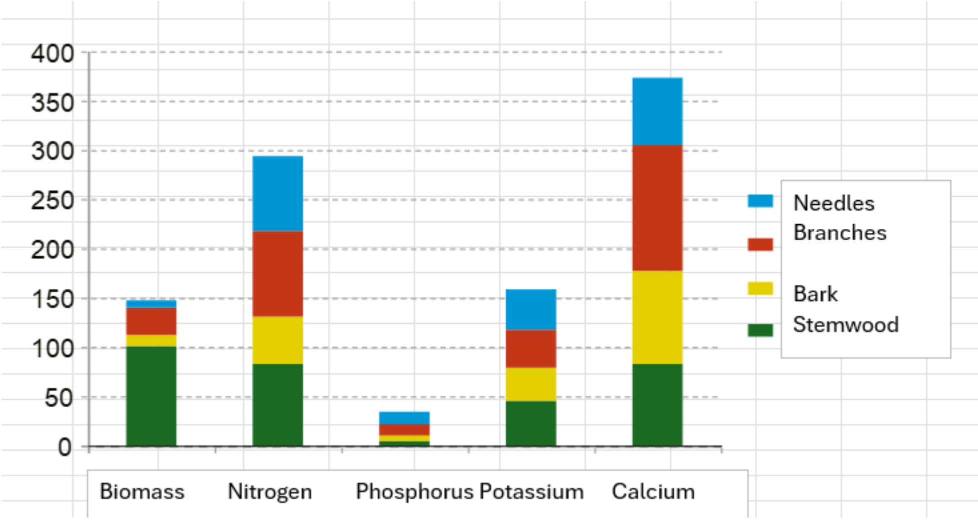

Figure 4 - Biomass (ton/ha) and nutrient (kg/ha) distribution in a 139-year-old spruce stand in Västerbotten with a standing timber volume of 278 m3sk. Source: Nykvist, N. (1974)

While the deposition of acidifying sulphur compounds has decreased significantly and recovery from acidification has been observed in soil and surface water, there is concern that increased growth and increased harvesting intensity will slow down the rate of recovery. Therefore, general advice in the Forestry Act states that the extraction of wood fuels should be compensated by returning ash to forest soil. Support for this is found in research showing that base saturation and pH decrease in forest soil after wood fuel extraction, with the greatest differences in the humus layer. The effect also manifests in soil water with higher hydrogen ion levels and lower concentrations of base cations. Ash addition has been shown to compensate for and thus counteract this. However, empirical studies showing that ash return to forest soil in moderate doses (the Forestry Board's general advice states that a maximum of 3 tons per hectare is applied per 10-year period and 6 tons per hectare per rotation) affects the quality of runoff water and thus the acidification situation in surface waters are lacking. There are therefore differing opinions on the need for ash return to counteract surface water acidification after wood fuel harvesting. Future research will have to show the way (Egnell, 2014).

3.2.2 Potential burden on soil resources

Global overview (by Ecologic Institute)

Forest biomass extraction practices that do not adequately account for environmental effects can impact soil by altering its structure, moisture retention and aeration; decreasing soil fertility by depleting nutrient capital, removing cations and gradually acidifying soil, or through soil disturbance, including erosion, soil displacement, compaction, and rutting; potentially reducing soil productivity.

Nutrient Depletion: The extraction of forestry biomass residues can lead to a decrease in soil nutrients. Specifically, whole-tree harvesting has been found to result in the export of nutrient elements at a rate 2 to 4 times greater than that of stem-only harvesting (Ranius et al., 2018) (not practiced in Sweden se 3.1). Biomass residues, when left to decompose in the forest, contribute to the cycling of nutrients, enhancing soil fertility. Their removal might therefore reduce the availability of essential nutrients like nitrogen and phosphorus, which are vital for the growth of biomass production (Ranius et al., 2018). Consequently, the nitrogen stocks are depleted at the ecosystem level. Stump harvesting in certain areas in northern Europe and America can, on the other hand has been shown to reduce emissions of carbon dioxide, nitrous oxide and methane in the short term, not affect the timber production of the next forest rotation and reduce the infection rate of root rot (Persson and Egnell, 2018).

Mitigating nutrient depletion from areas can be achieved through retaining forest biomass on grounds with restricted rooting space (such as shallow or stony soils) or on soils with diminished nutrient supply per soil unit (like sandy soils). This can be further enhanced by tailoring the rates of nutrient extraction according to the trees species present and by reducing the extraction of ground litter and forest floor materials (Titus et al., 2021). In the UK, for instance, it is recommended to postpone the removal of forest biomass until needle shedding after a drying period since needs account for half to two-thirds of the total nutrients in all the biomass (ibid.). The UK also sets a maximum retention threshold which amounts to 50-66% of total harvest residues (ibid.). Additionally, Scandinavian countries with geographical conditions akin to Sweden´s establish certain rules for retaining forest biomass. In Finland, the removal of all dead trees with a diameter exceeding 10 cm is prohibited. Meanwhile, in Norway, there are restrictions on the harvesting of both standing live and dead trees, along with a prohibition on removing dead wood lying on the ground that has been there for more than five years (ibid.). To mitigate nutrient depletion biomass harvesting guidelines, as part of broader sustainable forest management practices, should help alleviate public concerns about protecting environmental and social values, build trust in forest management and governance processes and help forest managers meet marketplace standards for sustainability (ibid.)

Soil Sensitivity and Soil Cation Exchange Capacity (CEC): CEC determines soils´ ability to retain cation nutrients (e.g., NH_4-N, K, Ca, Mg). Logging residue extraction frequently leads to the depletion of base cation stocks, which is especially evident in the reduction of base cation stocks at an ecosystem scale, the decrease of exchangeable base cation content in soils, and the diminished levels of base cations in runoff water (Ranius et al., 2018). Overall, base cation loss leads to soil acidification.

Several US guidelines on residue harvesting link soil CEC to site suitability for forest biomass harvesting. In particular, in Mississippi, suitability for forest biomass harvesting with CEC ranges from slightly limiting (>10 cmol kg^{-1}), to moderately limiting (5–10 cmol kg^{-1}), to very limiting (<5 cmol kg^{-1}) (Titus et al., 2021). Alternatively, in the UK the emphasis is placed on the "acid-base status" of the underlying soil type when assessing site sensitivity to forest biomass removal. Soils characterized by high acidity and low base status are categorized as "high-risk" due to the potential deficiency in base cation nutrients (ibid.).

Soil Sensitivity and Soil Organic Matter (SOM): SOM encompasses all organic components in the soil and is essential for maintaining soil structure, fertility, and water-holding capacity. Forest biomass harvesting potential is considered to various degrees limited at sites where soil has low SOM, i.e., 10% and less, according to the different US guidelines (Titus et al., 2021). At the same time, organic soils, which contain high levels of SOM, are not suitable for forest biomass harvesting either, especially in areas like ombrotrophic peats where rain is the primary nutrient source and, consequently, fertility remains low, regardless of CEC (ibid.).

Compensatory measures to restore the site´s characteristics include extending the rotation period before the final harvesting of stands, which helps to boost the total organic matter accumulated over the course of a rotation (ibid.).

Physical Soil Quality: The use of heavy machinery to harvest and transport logging residues usually results in increased soil disturbance. It can damage vegetation cover, compact the soil, reducing its porosity and air spaces, cause soil erosion and increase the number of water-filled local depressions (Ranius et al., 2018; Solberg et al., 2005; Titus et al., 2021; Wielgolaski et al., 2005). The potential damage for physical soil quality from the use of machinery is found to be larger for stump extraction (not practiced in Sweden see 3.1) than for slash harvesting. Meanwhile, some studies show that slash harvest mostly leads to increase in soil temperature (Ranuis et al., 2018).

To reduce erosion, soil compaction, or rutting, it is a commonly recommended practice to conduct harvesting activities only when soils are either dry or frozen, limiting the number or frequency of entries into the area, and keeping harvest residues on skid trails and across the entire harvesting site (Titus et al., 2021). Moreover, in Finland, harvesting should be modified to reduce rutting if the following size is exceeded: >10-cm depth for >5% of the rut length on the site (ibid.). Then, Finland also identifies areas that are deemed unsuitable for the removal of harvesting residues, such as dry (xeric) upland site types (ibid.).

Soil Organic Carbon (SOC): there are initial adverse impacts of logging residue extraction on carbon storage that are, however, temporary, and carbon stocks are largely replenished over the span of decades (Ranuis et al., 2018). In particular, empirical findings from northern coniferous forests indicate that stump extraction has minimal and temporary impacts on carbon stocks and respiration rates (Eggers et al., 2020; Ranuis et al., 2018; Titus et al., 2021).

Adopting modified forest management practices, such as fertilization and extending rotation periods, could offset carbon losses due to logging residue extraction, potentially leading to a quicker restoration of carbon stores to levels comparable to those achieved with stem-only harvesting (Ranuis et al., 2018).

The situation in Northern Sweden (by BFR)

Track formation and soil compaction

All driving within stands increases the risk of track formation and soil compaction. Soil compaction can lead to altered conditions in the root environment for future forest generations, which in the worst case can result in reduced growth (Skinner et al., 1989; Dyck and Mees, red.; Wästerlund, 1994; Hakkila, 1989).

Track formation is partly an aesthetic problem but can also damage ancient remains and create conditions for the transport of finer materials and water-soluble organic compounds to surrounding watercourses. In addition, the forest fuel assortment entails additional driving in connection harvesting and terrain transport of the forest residues.

Considering that we are also moving towards warmer and wetter winters where periods of frost become increasingly rare in the country, there is reason to take this problem seriously.

Ash recycling

The short-term growth effects of forest biomass harvesting, as described earlier, are likely primarily due to the nitrogen harvested with the forest biomass, thus withheld from the new forest generation or the remaining stand during thinning and clearing. If logging residues are not removed after final felling, it is a common practice to wait for 2-3 years for the branches to start decomposing before afforestation. When logging residues have been removed afforestation can start the same year resulting. The extra years can compensate for some of the losses in growth depending on the extraction. The results also show that growth reduction can be eliminated by compensating for the additional nitrogen uptake with nitrogen fertilization. Since there is no nitrogen in wood ash, no short-term positive effect of wood ash on forest production can therefore be expected, provided that the ash itself does not affect nitrogen availability in any way. It appears that experiments with ash recycling yield similar production responses as older liming experiments, where growth is stimulated on sites with a lower carbon stock relative to the nitrogen stock in the humus layer, known as the carbon-nitrogen ratio. The threshold value lies around ratios of 30. Liming or ash recycling on forest sites with carbon-nitrogen ratios well above 30 in the humus layer tends to result in growth reduction, while production increases on sites with values well below 30. On sites with values around 30, there is often no effect observed at all. Figure 5 displays results from several field experiments with ash recycling, where 1-6 tons of ash have been applied to young or juvenile forests across the country, which reinforces this picture. The carbon-nitrogen ratio is not typically available information in a stand register, so the relationship between the carbon-nitrogen ratio and soil fertility (site index) can be utilized. The threshold value for site index appears to be around 24, meaning that better site qualities may be positively affected by ash recycling, while poorer site qualities may react negatively.

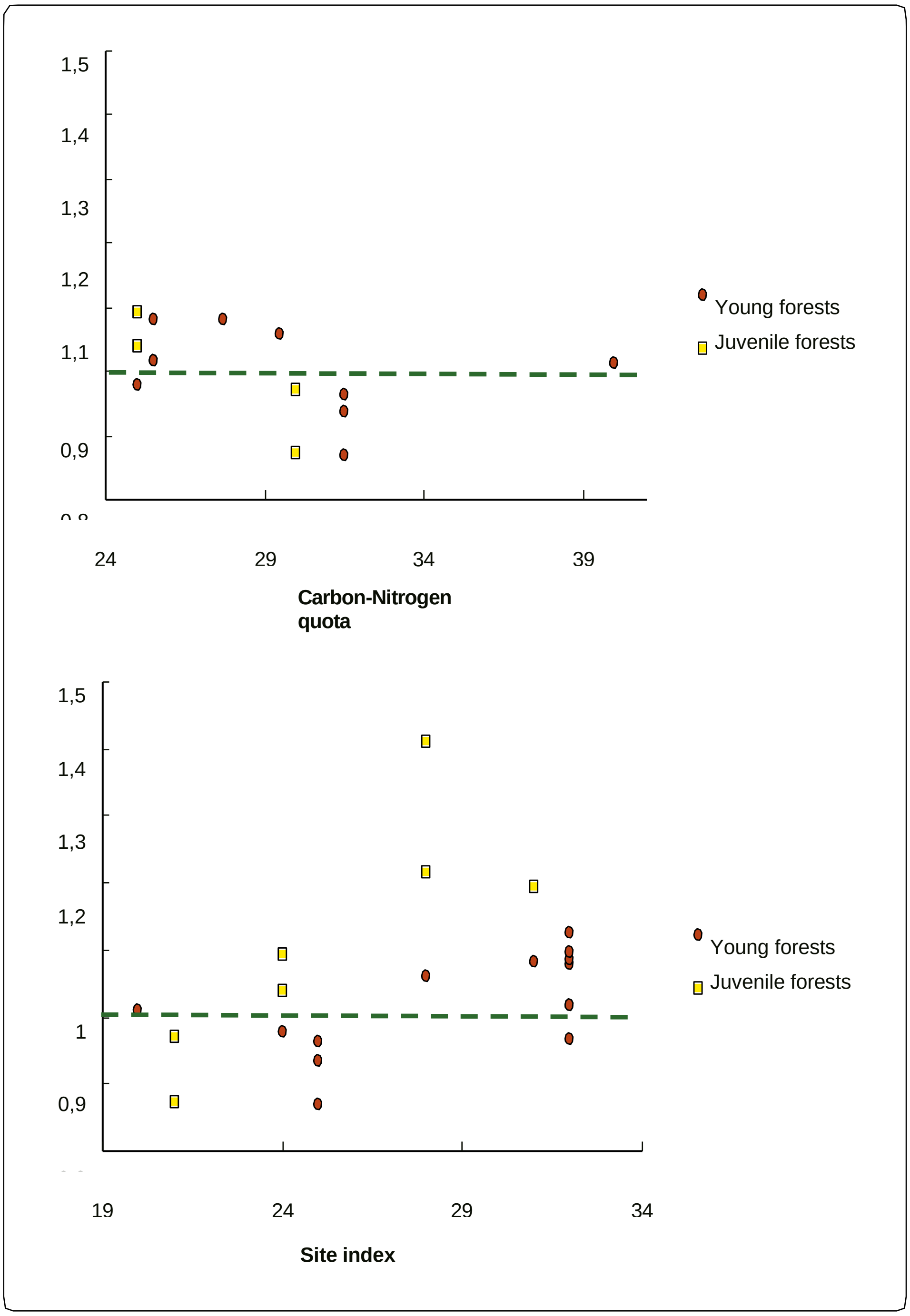

Figure 5 - Results from field experiments in Sweden. Relative growth for young forest and juvenile forests after ash recycling (applied doses of 1-6 tons per hectare). Source: Data from field trials compiled by the author, Gustaf Egnell.

The need to compensate for nutrient losses caused by air pollution and/or forest biomass harvesting with ash or other nitrogen-free products has been debated for a long time, and in many cases, the conclusion is that it is unnecessary from a forest production perspective on mainland soils (Sikström et al., 2001).

However, there are soils where wood ash has a known and significant effect on forest production – namely on forest soils defined as peatlands with an organic soil layer that is 30 cm or thicker. Many of these soils have been drained in the past to stimulate forest production. Forest production on these soils is primarily limited by low potassium and phosphorus availability. Adding wood ash to such soils can significantly increase production (Silverberg and Hotanen, 1989; Egnell, 2014).

3.2.3 Potential burden on biodiversity

Global overview (by Ecologic Institute)

Habitat Structure and Quality: Removing logging residues from forests can disrupt the habitats of various species (Titus et al., 2021). For instance, deadwood and leaf litter provide essential habitats for insects and microorganisms, especially those adapted to the abundant sun-exposed dead wood created by large-scale disturbances. In particular, in Swedish managed forests, 53% of the dead wood-dependent species (beetles such as Carabids, fungi, and lichens) were detected on slash or stumps (Ranius et al., 2018). Even though slash and stumps occur in high abundance, some of the species inhabiting these substrates are regarded as rare or declining, which typically means they occur in very low densities. For species occurring in low densities in abundant habitats, it is extremely hard to estimate their distribution area or other aspects relevant to determining their red-list status (ibid.). In such a way, slash and stump harvesting (not practiced in Sweden see 3.1) can negatively affect their populations at the landscape level but rather in a short-term perspective only (ibid.). As compensatory measure to restore desired habitat characteristics, creation of high stumps as well as retention of other biomass types (pre-existing downed wood, the forest floor, and roots) are recommended for harvest residue removal (Titus et al., 2021). Still, it is to point out that the majority of landscape-level populations, including endangered and rare species, are mostly found in other types of deadwoods and are not impacted by the harvesting of logging residues (Ranius et al., 2018).

Population State: Slash extraction is found to negatively affect the population density of game species or the condition of individuals that rely on these logging residues for sustenance (Ranius et al., 2018). This is especially relevant in case of extracting pine or broadleaf slash instead of spruce (ibid). For reindeers, the connection between logging residues extraction and the food availability is less evident (ibid.), although the former is likely to reduce grazing potential in Northern Sweden (Eggers et al., 2020). The most important biotope for reindeer herding is open pine forests with abundance of soil and tree lichens, and extraction of logging residues is not practiced in that kind of forests in Sweden. Finally, in some cases, slash extraction was found to have impact on plant species composition up to 20 years after logging. Nonetheless, these results are highly variable and depend on differences in soil types, nutrient availability, and the degree of soil disturbance (Ranius et al., 2018).

Stand Structure's Vertical Heterogeneity: In a study modelling different management scenarios in Northern Sweden, increasing woody biofuel extraction was found to negatively affect mature broadleaf-rich forest and old forests in both biofuel extraction settings applied (business-as-usual, representing current practices, and bioeconomy, with intensified biomass extraction options) (Eggers et al., 2020). However, careful management planning is thought to allow for increasing woody biofuel extraction with small losses in biodiversity and ecosystem services, up to a certain point (ibid.).

A probable approach for preserving biodiversity while increasing woody biofuel extraction is harvesting biomass during dense early thinning phases. The concept is currently under exploration and is not yet technically or economically viable. It may eventually allow for an earlier acquisition of bioenergy, and concurrently preserve the forest´s vertical structural heterogeneity, which is advantageous for biodiversity (Eggers et al., 2020). This opportunity is especially relevant for Northern Sweden since this region possesses a considerable potential to increase extraction rates of primary woody biomass, currently low due to the greater transport distances, as mentioned earlier.

Lastly, it should be noted that according to (Ranius et al., 2018), while studies of species populations at the forest stand scale are valuable, evaluating the potential of maintaining species populations viable requires an understanding of the dynamics at landscape level.

The situation in Northern Sweden (by BFR)

Conservation of biodiversity has been high on The literature reviewed indicates that the agenda for many years and is manifested for forests by being directly addressed in two of the Swedish environmental quality objectives, namely “Living Forests” and “A Rich Plant and Animal Life”. Additionally, activities on forest land may indirectly affect surrounding surface waters, hence “Living Lakes and Watercourses” may also be impacted by forest biomass extraction and ash recycling.

The introduction of forest biomass assortment, as the third largest assortment alongside pulpwood and timber, has so far primarily led to increased harvesting intensity where more and more of the tree biomass is harvested during logging, along with some ash recycling activities. Now, there is increasing discussion about the need to also increase biomass production in our forests, for example through nutrient supplementation, fast-growing tree species and clones, shorter rotation times, denser stands, drainage, ash on forested peatlands, etc. As the relevant level to assess effects on biodiversity is at the landscape level, it is important to understand that it is the combined effect of increased harvesting, more intensive production systems, and potential ash compensation at the landscape level that should be considered, not each activity separately. However, this cannot be done simply, which is why much of what is presented here is based on studies of the effects of one or a few action groups at a time. The focus here is also on forest biomass extraction and ash recycling, which have the potential to affect biodiversity by:

- Reducing the amount of deadwood available for wood-dependent species to live in or on.
- Affecting the conservation considerations during logging, as the "new" assortment of forest biomass is also to be harvested.
- Formerly economically uninteresting trees and species with conservation values now becoming economically interesting for harvesting.
- Forest biomass can act as a death trap for insects when transported away, as freshly exposed logging residues act as trap material and attract wood-dependent insects from surrounding areas.
- The protective and shaded environments provided by logging residues decrease.
- Removal of forest biomass affects the forest floor and humus layer, which may have effects on the composition of species in the soil.
- Increased soil damage as logging residues cannot be used as substrates for forestry machinery or in stump harvesting, which can lead to increased flows of fine soil particles and organic compounds into surface waters, affecting biological life.
- Ash recycling may directly or indirectly affect fauna, flora, and fungi in the soil and surrounding watercourses.

In managed forests, a large part of the trees are harvested and removed to become timber or pulpwood, wood that previously formed an important basis for much of the forest's species diversity. Increasingly, significant portions of logging residues are now also harvested as forest biomass, and in a growing market, there is now also increased interest in harvesting stumps.

The prerequisite for all forest-dwelling species is the presence of trees and other vegetation. Some of the forest-dwelling species obtain their energy supply through photosynthesis. All other species are part of various food chains that either start from the decomposition of wood and other dead material or, to a lesser extent, from grazing on living plants. Dead leaves, branches, and dead wood are therefore a necessary energy source for the multitude of species and a prerequisite for high biodiversity in forests. There are approximately at least 10-15,000 species living in forest soil and a similar number predominantly living above ground. Nearly 7,000 forest-dwelling species are entirely dependent on various qualities of dead wood.

This knowledge formed the basis for the previous sub-goal under “Living Forests”, regarding enhanced biodiversity, which formulated that the amount of dead wood, the area of older deciduous-rich forests, and old forests should be preserved and strengthened by 2010 in the following ways: The amount of hard dead wood has increased by at least 40% throughout the country and significantly more in areas where biodiversity is particularly threatened.

Forestry now routinely leaves dead trees in the forest, and the amount of dead wood is gradually increasing. It is important that the increased interest in forest biomass assortment does not drastically change this development. The increased demand for forest biomass also makes it important to understand differences in quality between different types of wood.

Generally, coarse dead wood (diameter > 10 cm) harbors greater species richness than finer dead wood. This is due, among other factors, to the fact that coarser wood is a more heterogeneous habitat that can accommodate more species, and that coarse wood takes longer to break down, thus providing a more stable microclimate, which benefits certain species.

However, studies of the biodiversity on equal volume or area of coarse and fine dead wood show no significant differences (Kruys, N. and Jonsson, B. G., 1999).

However, it is important to distinguish between the number of species and which species actually occur on different diameters of dead wood. Some species occur only on branches, while others occur only on coarse wood. A compilation of 3,600 red-listed species dependent on wood showed that most of these were dependent on stem wood, while only a smaller proportion depended on branch wood.

Additionally, finer wood is continuously added to our forests throughout much of the rotation period and in large quantities during harvesting. For example, in carbon balance calculations in forest landscapes, it is estimated that spruce loses 10% of its needle biomass and 2% of its branch biomass annually. The corresponding figures for pine are 25% and 5%, while the supply of coarse dead wood initially requires trees to grow and then is delivered randomly in connection with pests, storms, fires, or logging (primarily stumps).

This reasoning suggests that biodiversity, from a substrate perspective, can withstand quite extensive removal of logging residues from our common coniferous trees, while there is reason to be more cautious with the removal of logging residues from rarer tree species such as our noble hardwoods, especially oak, where a large number of rare wood-dependent insects utilize branch wood. In cases where rare wood in the landscape is used as forest biomass, the negative effect may further increase if rare insect species have time to lay their eggs in the forest biomass before it is chipped and burned. Forest biomass thus acts as a trap for rare species. To avoid or reduce this problem, based on knowledge of wood-dwelling insect ecology, it has been proposed that:

- Forest biomass from rare tree species in the landscape is removed before they have a chance to be colonized by insects during spring and early summer.
- Forest biomass from rare tree species in the landscape, which has been stored during the insects' flight period in spring and early summer, is stored for an additional year so that some of the trapped insects have time to hatch.
- Less valuable logging residues from coniferous trees are, if possible, used as cover over logging residues from rare tree species in the landscape.
- If there is no cover with coniferous logging residues, the topmost, most sun-exposed forest biomass is left in piles with logging residues from rare tree species in the landscape remaining.

These recommendations have been supported by subsequent research, where the highest number of beetle species and individuals have utilized the top layer in piles of oak logging residues. Furthermore, a comparison between logging residues from different tree species shows that the number of beetle species of wood-dwelling beetles is approximately equal for spruce, birch, aspen, and oak, while the number of red-listed species is higher for hardwoods.

Notably the commercial trees in BioFuel Region consists of pine, spruce and birch. Nobel hardwoods cannot grow in the northern part of Sweden (Egnell, 2014).

4 Screening results and recommendations

4.1 Overview

<table>
<tr><th colspan="2">Resources screened</th><th rowspan="2">Ordinal Baseline Rating</th><th colspan="2">Forestry (and forest biomass extraction) Management Practices</th></tr>
<tr><th>Category</th><th>Sub-Category</th><th>Potentially beneficial to the baseline status</th><th>Potentially detrimental to the baseline status</th></tr>
<tr><td rowspan="2">Water</td><td>Surface water bodies</td><td></td><td rowspan="2">- Ash recycling

- Restoration of surface water bodies (reverting hydromorphological alterations)

- Placing harvest residues away from affected aquatic ecosystems

- High-water-efficiency processes of production (e.g. for biochemicals)</td><td rowspan="2">- Combustion of fossil fuels and deposition of acidifying nitrogen and sulfur compounds leading/contributing to soil and surface water acidification

- Clear-cutting, intensive slash extraction, and any other biomass management/extraction practices leads to increased runoff, leaching of nutrients, and ultimately water acidification or eutrophication

- Abstraction of large volumes of water for the operation of new, large-scale production processes</td></tr>
<tr><td>Groundwater bodies</td><td></td></tr>
<tr><td>Land & Soil Resources</td><td>-</td><td></td><td>- Retaining forest biomass on vulnerable grounds

- Extract logging residues from suitable spruce dominated stands, following recommendations from the SFA.</td><td>- Overextraction of forest biomass leading to nutrient- and base cation stock depletion</td></tr>
<tr><td rowspan="2">Biodiversity</td><td>Endangered Species</td><td>6</td><td rowspan="2">- Leaving high stumps, snags and coarse woody debris

- Continued high environmental consideration in practical forestry

- Retaining diverse biotopes, biomass types and deadwood</td><td rowspan="2">- Overextraction of deadwood and leaf litter (deteriorating habitats for insects and microorganisms)</td></tr>
<tr><td>Critically Endangered Species</td><td>4</td></tr>
</table>

4.2 Recommendations

According to the reported data for the second cycle of implementation of the WFD in Sweden, water resources (concretely, surface water bodies) are an area of concern in the Bothnian Bay and Bothnian Sea River Basins. Diffuse pollution (concretely, atmospheric deposition) is recurrent throughout and affects all rivers and lakes in the region. Further, habitat alterations that result from changes in morphology are also a significantly recurrent impact on rivers in the region, with alterations driven by changes in hydrology following. Any initiatives, including economic activities and management practices that facilitate or promote the restoration of the affected rivers should thus be favored. The reexamination of hydropower taking place at national level is one such example. In contrast, new changes in hydrology and morphology that result in habitat alterations where this is not yet an issue should be avoided. Overall, the scale and placement of any economic activities that could have substantial negative impacts on river and lake ecology should be planned very carefully to ensure that progress attained so far in meeting regulatory targets is not lost and instead continues to expand.

With forestry already being a central pillar of the regional economy in Northern Sweden, and with the increasing relevance of biofuel as a source to ensure energy security, it is also increasingly important to continue to employ biomass management practices that are known to favor water quality and avoid those associated with detrimental effects on water resources. Practices such as ash recycling and the placement of harvest residues far from already affected aquatic ecosystems are two such examples. Additionally, the production of materials from biomass residues, such as birch bark, necessitates attention to water and energy consumption, with innovative methods for the extraction process of valuable chemicals (e.g., tannins) providing options for efficiency improvements. Further, acidification has been identified as a recurrent impact on the region's waters. Regional experts link this with the combustion of fossil fuels and deposition of acidifying nitrogen and sulfur compounds. While this may not be directly related to forestry activities, it is important to avoid forestry management practices that have been associated with acidification in the past, to avoid aggravating the situation.

As regards groundwater bodies, no significant impacts have been identified so far. It is important that any expansion of existing economic activities, and/or development of new ones, is planned thoroughly and located smartly to avoid the exacerbation of existing pressures on currently affected aquifers as well as the affectation of others, especially as climate change sets on.

Recommendations to prevent potential burden on soil resources and long-term productivity

On land and soil resources, the implications for biomass production and forest productivity are particularly pronounced on less fertile sites. Current strategies to retain a proportion of logging residues can mitigate nutrient loss and, hence, support soil productivity. The planned extraction of logging residues on primarily spruce dominated relatively fertile forest land in northern Sweden has a potential to strengthen the bioeconomy. The present regulation regarding the extraction of forest residues, considering ecological restrictions according to the Swedish Forest Agency's recommendations,ensures that land and soil resources are managed properly.

While protected areas and low exploitation levels have resulted in favorable status of most species and habitats in the alpine region, only about 20 percent of species and 40 percent of habitats in Sweden achieve the overall aim of the EU Habitats Directive. Most species that do not achieve the overall aim are associated with agricultural land. (Naturvårdsverket, 2020). Biodiversity in Northern Sweden faces threats from increased biomass extraction, with potential negative impacts on habitat diversity and the availability of deadwood, crucial for many species´ survival. Since the new forestry act was implemented 1993 the amount of coarse wood debris has continued to increase. The species associated with the removal of logging residues are not equally endangered since this substrate is delivered as litter throughout the lifespan of the stand, 80-120 years.

Before approval of final felling operations in Sweden, a comprehensive plan to prevent potential negative environmental impact will be reviewed and monitored by the Forest Agency. Removal of stem wood does not pose a threat to long term productivity of forests but removal of logging residues can be problematic on poor soil as most of the nitrogen is found in the needles. Logging residues are removed only from relatively fertile spruce dominated forests and is not recommended in pine dominated forests on poor forest land. To prevent negative impact of removal, it is recommended to leave the logging residues in the forest during one season to dry and to drop as much as possible of the nutrient rich needles. To prevent soil damage, spruce dominated stands are normally harvested during winter on frozen soils and it is recommended that 30-40 percent of the branches are left in base roads for forest machines to drive on.

During a rotation period, thinning operations are carried out once or twice and final felling is carried out after approximately 100 years, removing most of the valuable stem wood. During these 100 years' time, nutrients are recycled when needles and twigs continuously litter from the trees. Litter is decomposed and nutrient is reused by the trees. Logging residues are only extracted once every 100 years after final felling and then removing approximately 60 – 70 percent of the residues.

If logging residues are not removed after final felling, it is a common practice to wait for 2-3 years for the branches to start decomposing before afforestation. When residues have been removed, afforestation can start the same year resulting in a higher rate of tree seedling survival and increased forest increment.

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