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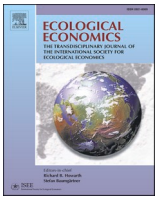

Beyond the surface: An analysis of the institutional regime in the extractive industries in Sweden and Spain

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ABSTRACT

Mineral raw materials consumption is expected to increase in the near future. Their extraction is frequently associated with adverse effects on renewable resources, such as water and biodiversity, and rivalries with other interests. In this article, we investigate how existing institutional regimes safeguard the sustainability of resources affected by mineral extraction. We apply an Institutional Resource Regime analytical framework to two case studies, in Sweden and Spain, to identify regulatory incoherences and gaps that lead to unsustainable use of resources employed in extractive activities, and the changes required to shift towards integrated institutional regimes. We find that in both cases extractive activity operates within complex institutional regimes which do not guarantee sustainability as a result of 1) ongoing pollution from historic mining, 2) weak policy enforcement, 3) a mismatch between property rights and public policy, 4) lack of mandatory instruments that promote a deeper understanding of the cumulative effect of land use changes. We reflect on the role of land use planning and strategic environmental assessment in moving towards more integrated institutional regimes. We conclude that a clearer definition is needed of the limits within which extraction can take place sustainably, setting priorities in terms of raw materials consumption and the importance of a wider discourse on responsible mineral consumption.

1. Introduction

Human activities and global consumption, production, and trade patterns have significant impact on the earth and its various subsystems and processes (Barbier and Burgess, 2017). OECD (2019) forecasts that by 2060 global population and income are expected to increase by 1.5 and 2.7 times respectively, causing a doubling in mineral raw materials consumption. For instance, sand consumption is expected to soar 45% in the next four decades (Zhong et al., 2022), straining natural resources and potentially creating shortages in the market of key construction materials produced by sand (concrete, glass, etc). Energy transition measures necessary to cap CO_2 emissions exacerbate the dependency on raw materials and the need for responsible sourcing is becoming more salient (Kügerl et al., 2023). Several thresholds of human impacts and disturbances on earth system processes have already been exceeded (Rockström et al., 2009; Hoff et al., 2014). While there is a general agreement that a transformation towards sustainability is urgent, requiring structural changes and lowering consumption and production patterns, global resource consumption is not following that trend (OECD, 2019). The global implementation of resource efficiency measures, the increased potential for circular use of resources and the partial decoupling of materials use from economic growth will contribute to attenuate the demand for raw materials, but extraction will continue to be a necessity.

Extraction of raw materials is frequently associated with adverse effects on renewable resources, such as water and biodiversity, and rivalries arising from claims on mineral deposits overlapping with other interests (Mancini and Sala, 2018). Regulating these claims in a way that preserves the renewable capacity of resources is important. In this article, we examine the institutional regimes that regulate the behaviour

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of stakeholders with a vested interest in the resources affected by mineral extraction, such as land, water, and biodiversity.

Articulated criticism in the last couple of decades towards traditional environmental policies implemented in Europe, highlights a handful of limitations of such policies in protecting natural resources (Knoepfel et al., 2007; Biermann, 2021). Hence a holistic analysis of the regulatory landscape affecting the use of resources in mining areas is needed, in order to comprehend the full picture and identify institutional flaws. This analysis goes beyond environmental policy analysis, including all forms of regulatory instruments that enable or restrict the use of resources, stemming from public policy (PP) as well as property rights (PR). In this paper, we adopt an Institutional Resource Regime (IRR) approach to examine how existing institutional regulations affect the management of resources altered by mineral extraction. IRR suggests a resource-based sustainability framework and builds on the hypothesis that integrated institutional regimes are more likely to manage resources in a sustainable manner than less integrated regimes. Institutional regimes are considered integrated when all resources are regulated coherently (see section 2 for further details).

This study builds on this hypothesis and applies IRR as an analytical framework to assess the institutional regime governing the extractive sector in two case studies in Europe, as a means to appraising the sustainability of extractive practices regulated within these institutions. So far, IRR has been applied to assess the sustainable management of various renewable resources, such as water (Varone et al., 2002; Kampa and Bressers, 2008; Bolognesi and Pflieger, 2019), nature parks (Gerber, 2018), coffee (Andrés, 2019) but also artificial resources such as housing (Nicol and Knoepfel, 2008) and infrastructure (Nahrath et al., 2011). However, resource-based approaches have never been used to evaluate institutional regimes governing resources altered by mineral extraction (Lieberherr et al., 2019). We aim to contribute to bridging this knowledge gap in this article. Our research question is: *Which regulatory incoherences and gaps can lead to an unsustainable use of resources employed in extractive activities?*

The next section provides an overview of the theoretical underpinning of this paper, reflecting on the institutional resource regime framework and its relevance for non-renewable resources. In the subsequent methodology section, we operationalize IRR and explain our data collection process through interviews and focus groups for two cases, Boliden Area in Sweden and Canteras la Ponderosa in Spain. Next, we present our findings from both cases, with a focus on the description of the respective institutional regimes. Afterward, we discuss our findings in the context of the scientific literature. In the last section, we conclude and provide recommendations for the extractive sector and for future research avenues.

2. Institutional resource regime analytic framework

Institutional Resource Regime (IRR) has been proposed as an analytical framework to explore the institutional conditions that can lead to sustainable resource governance (Blake et al., 2020). In the IRR framework, the focus shifts from pollution restriction to the management of the use of "stocks" of a resource in a way that will safeguard the renewal capacity of the resource system (Varone et al., 2002; Knoepfel et al., 2007; Gerber et al., 2009). In line with the planetary boundaries concept (Rockström et al., 2009), the IRR framework suggests that the sustainability of a resource system can only be guaranteed if all the users and beneficiaries jointly use the resource within the boundaries that safeguard its renewal capacities. This includes direct use, such as extracting units of a resource as input factors for production; indirect use, such as using a resource for the absorption for pollutants; or immaterial use, such as for aesthetic or cultural purposes (Varone et al., 2002).

IRR identifies two layers of formal rules that regulate rivalries and conflicts amongst uses: property rights and public policy. Precisely due to this double foundation, the IRR framework combines policy analysis with property rights theory to enable the identification of the most important regulatory dimensions which can lead to unsustainable uses of resources. To apply the IRR framework we need to define what the resource is with regards to extractive activities.

2.1. Definition of main concepts resource, actors, and regulations

A resource can be understood as the relationship between an actor, a practice, and a subject (Kebir, 2004). Kebir (2004) conceptualizes the resource as a system linking an object to a production system: "*The resource is considered here as a system in which objects are created, destroyed, identified as useful and implemented as part of the production of goods and services*" (Kebir, 2004, p. 26). From a social constructivist perspective, an object becomes a resource when its potential to contribute to goods and services is recognized. While the demand for production input might be unlimited, there are natural limits to the objects of production, posing the challenge of managing growing demands within these natural boundaries. This justifies the shift from natural resource management towards the management of the institutional regimes of natural resources (de Buren, 2015), as it is the uses and users of the natural objects that need managing, not the objects themselves.

In the 20th century, the term resource also came to represent surface and subsurface productions: i.e. agriculture, mining and oil resources that are considered 'natural resources' (Gerber et al., 2009). As IRR's premise is closely linked to safeguarding the renewal capacity of resources, it seems from the outset that this framework is applicable to renewables only. Knoepfel et al. (2007) suggest that the management of natural resources should concern itself with renewable resources since non-renewable resources are easier to substitute with the help of technological processes. As a result, only a few studies have adopted an IRR framework to analyse the sustainable use of non-renewable resources, such as geomorphologic sites (Reynard, 2005).

Despite minerals being non-renewable, the discourse on sustainable mineral resource extraction can still unfold from a renewable resource sustainability perspective, since an increasing demand for minerals has its toll on renewable resources. The resource in this case is a composite of overground and underground natural objects, many of which constitute renewables such as water and land. These natural objects also support the production of goods and services outside the mining sector. More importantly, natural objects constitute systems in their own right with their own identity and value (Kebir, 2004). Many of them are also endowed with value as part of other, non-economic systems such as natural, social, and cultural systems.

2.2. Defining sustainable extraction: Extent & coherence

The IRR framework proposes two concepts to evaluate the state of regulations of a resource: extent and coherence. Extent refers to the number of uses regulated by the institutional regime in relation to the total number of uses that exist. The extent to which uses of a resource are regulated is also closely linked to global resource quota[1] and how quotas are translated into national/regional boundaries and limitations on individual use rights (Knoepfel et al., 2007).

Coherence refers to the content of different regulations of the resource. Coherence within the property rights regime establishes the degree of precision in the property rights system. An example of incoherence would be multiple property claims on the same parcel. Coherence within public policy refers to the degree of integration of policies. An example would be incoherencies between exploitation policies and conservation policies. In both cases, policy and property rights integration refers to internal coherence of an institutional regime (Bolognesi and Pflieger, 2019). Coherence between property rights and public

[1] Referred to as the Earth's "Rules of the game" (Rockström et al., 2009)

policy is referred to as external coherence (Bolognesi and Pflieger, 2019) and it depends on whether rules emerging from public policies and property rights target the same users (Gerber et al., 2009). An example of this in the context of extractives would be the approval of a permit to extract overlooking the impacts it has on affected property rights holders.

A high extent and coherence of regulations means that the institutional regime is integrated, as shown in Fig. 1. The central hypothesis of IRR is that the closer the resource regime moves towards an integrated regime, the higher the likelihood that the resource will be used sustainably and within its natural boundaries. Under IRR's hypothesis on sustainable resource management, an integrated regime would ensure that raw materials extraction is only permissible as long as its impact, along with the impact of all other users on the same resources, stays within the natural constraints necessary for the resource's renewal.

IRR builds on Ostrom (2010) work on polycentric governance of common pool resources whereby it emphasizes the role of power dynamics, interests, and institutions in shaping the outcomes of resource management. However, despite a general consensus that an integrated institutional regime yields superior policy outcomes and ultimately safeguards sustainability, there is a gap in empirical evidence that supports this hypothesis (Candel, 2017). Policies and ownership titles affect how resources are used by defining user rights, however they do not take effect until these rights are activated. Understanding how rights emerging from policy and ownership titles are activated, the required time and tools, in other words understanding local regulatory arrangements (de Buren, 2015), is equally important to fully establish the impact that institutional regimes have on the sustainable use of resources.

Since our study is an early application of IRR to the extractives sector, the scope of the study is limited to the appraisal of the institutional integrity, and does not address empirically how integration, or lack thereof, affects sustainability. We argue that integrated institutional regimes are pivotal in establishing the necessary conditions for sustainable governance within extractive industries. The importance of high extent of regulation is based on the premise that a lack of regulation of some of the uses of a resource can result in its over-exploitation (Knoepfel et al., 2007; Gerber et al., 2009). Similarly, incoherence can constitute a major cause for over-exploitation of resources especially when failing to consider and regulate cumulative impacts of multiple users, albeit there could also be a risk of over-regulation.

In this study, the IRR framework is applied to unravel institutional gaps and incoherence in the polycentric governance structure of resources impacted by extractive activities in Europe, whereby multiple centres of authority, decision-making, and resource allocation exist. While traditional analyses focused solely on extractive companies, raw material reserves or mining in conjunction with another policy area, our study innovatively adopts a systemic approach, examining the broader sphere of renewable resources affected by extractive activities. This study would be incomplete if we did not account for policy implementation gaps, considering the numerous studies on the significance of the complex interplay between actors and rules (Knoepfel et al., 2011; Schweizer, 2015). While we do not conduct a full analysis of local regulatory arrangements to identify the mechanisms which different actors use to active or block rights prescribed in policy and/or ownership titles, we have identified implementation gaps that can threaten the sustainability of resources affected by extraction. In the next section, we outline our approach to investigate these dynamics further.

3. Method and data

3.1. Case study approach and selection

This research adopts a multiple-case study approach. The selection of the two cases we present in this study has been motivated by three main reasons. First, we selected two extractive operations that focus on different types of raw materials, namely metal mining, for which we selected Boliden Area in Sweden, and construction materials extractions, for which we selected Canteras la Ponderosa in Spain. Extraction of different raw materials affects different renewable resources, consequently, the two cases selected are complementary to one another. Second, these two cases allow for institutional analysis of both underground (Boliden Area) and surface extraction (Canteras la Ponderosa) operations. In both cases, the mining operation areas and their supporting infrastructure overlap, often in a disruptive manner, with other claims on land, water and other natural resources, however, we expect different types of disturbances in both cases. Finally, the cases represent two different regulatory landscapes, in Sweden and Spain. Although not designed as a comparative case study, aspects of policy and property rights analysis that are relevant in both cases will be discussed by drawing comparisons between the two cases, to identify context-specific challenges and transferable practices.

Boliden Area comprises three underground mines, located in the mineral-rich Skellefte field in the county of Västerbotten, Sweden, and is operated by Boliden since the 1920s (Albrecht, 2018; Boliden, 2021). The mines supply ore to the concentrator at Boliden, which is also home to leaching plants for gold and tellurium production (Boliden, 2021). Canteras La Ponderosa was established in 1978 and it consists of two

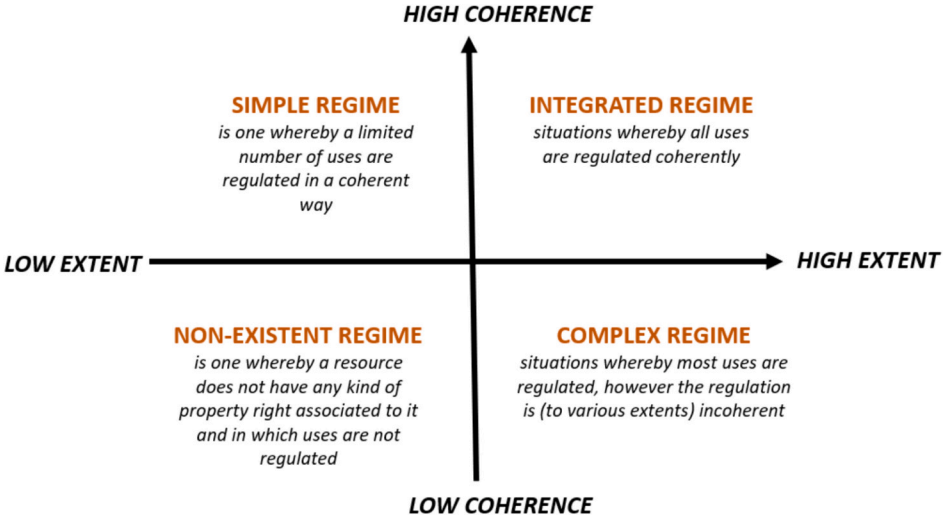

Fig. 1. Four types of regimes according to extent and coherence, adapted from Gerber et al. (2009).

open pit quarries located in Alcover and Riudecols Municipalities, both approximately 30 km from the city of Tarragona. The operation involves the extraction, crushing, sorting, and distribution of limestones and granite for public works and private construction enterprises (Ponderosa Aridos y Hormigones, no date).

3.2. Data collection

Our data collection and analysis followed the key steps of IRR application identified by de Buren (2015), as presented in Fig. 2:

We examined the institutional regimes governing resources altered by mining at the scale of the extraction 'functional space'. The extraction functional space was defined as the area included within a 5 km radius from the extraction site, however, we considered the boundary of the functional space as adaptable to the policy areas and levels of governance under scrutiny.

We adopted a mixed approach, combining back-and-forth data collection between document analysis and field research (de Buren, 2015). Fig. 3 indicates how each phase of data collection informed the next one.

The first step of data collection was a desk review of land use databases and policy documents to identify uses and users of the natural resources within the identified functional space. The uses and users were identified and inventoried by an analysis of: 1) the land uses within the functional space and 2) the land and water ecosystems disrupted because of an extraction operation (see Figs. 4–6 below). Relevant institutions, regulations, and use rights were then identified. This initial step revealed tensions between different stakeholders, as reported in literature, guiding the selection of interviewees and formulation of semi-structured questions.

In the second step of data collection, we interviewed representatives of user groups including: the companies responsible for the extractive operations, a local residents stakeholder group in Alcover (Spain), a member of Mala Sami Village, and a water stakeholder group in Sweden. Additionally, we interviewed representatives of key regulators including county and municipality administrations, the mining inspectorate, the Sami Parliament, Sveakog, regional and national water authorities. 17 interviews took place during our Boliden Area site visit in September 2021 and 14 interviews took place during our Canteras la Ponderosa site visit in March 2022.

After conducting a preliminary thematic analysis of collected data, highlighting tension areas reported by interviewees, we identified data gaps, prompting a second (and final) round of empirical data collection in March and April 2023 for the Boliden Area case study. This round was conducted online and involved a Focus Group with strategic planning and nature conservation experts, an interview with a water management expert, and an interview with a lawyer and Sámi member.[2] This data was further complemented and triangulated by document analysis, including EU and national legislation, regional and local development strategies on mining, water and environmental protection, forest protection, land use planning, reindeer herding, and Sámi land rights.[3]

3.3. Operationalization and data analysis

Thematic analysis of data was conducted to identify cases of unregulated uses, affecting the extent of the regime, and cases of policy incoherence. The thematic analysis started with open coding, identifying recurring issues, patterns, and phrases brought up by different interviewees, followed by the organization of the codes into potential themes (bottom-up). After identifying the main tensions and areas of regulatory gaps (themes) the analyses moved back to document review, to check for consistency and refine the themes (top-down). The preliminary findings were then discussed in the final focus group and interviews (bottom-up) focusing on particular themes for which the data was deemed inconclusive.

Building on existing definitions of Extent and Coherence (Bolognesi and Pflieger, 2019; Gerber et al., 2009), we specified types of misalignment and gaps that would lead to a low extent and/or low coherence, as shown in Table 1 below. It is important to note that this study only evaluates the coherence between policies governing extractive industries and those regulating other impacted resources like water and ecosystems. The scope of this study does not extend to evaluating coherence between other policy areas, i.e. between land use planning and water.

3.4. Limitations

In our data analysis, extent and internal/external coherence are evaluated as low whenever policy gaps and incoherences are identified. An appraisal extending beyond the binary scope of low/high extent and coherence has not been conducted. As there is no established way of appraising policy extent and coherence (Bolognesi and Pflieger, 2019) our assessment remains confined to the dichotomous framework of either low or high extent and coherence, lacking the necessary granularity to explore the intricacies inherent to different types of complex regimes.

This study presents a snapshot of the institutional composition regulating two different types of extractives in two complementary case studies. Its novelty lies in presenting a polycentric analysis of the regulatory landscape affecting the use of resources during extraction through IRR. However, we have not identified or sought to explain the mechanisms that lead to policy misalignment and gaps, and therefore institutional complexity, neither have we empirically tested the main IRR hypothesis which suggests that an integrated regime leads to sustainable resource management. This would require a temporal study of the evolution of all the policies covered here in each sector, which is beyond the scope and resources of this study.

4. Findings

4.1. Sweden: Natura 2000, water, reindeer herding

4.1.1. Defining the resource, uses, users and realm of regulations

The three mines and concentrator constituting Boliden Area affect several land uses, ecosystems, and water systems, the use of which is shared with a diverse group of stakeholders. The main land uses, ecosystems, and water systems comprised in the 5 km radius from extraction operations are shown in Fig. 3. Current uses include 1) extraction operations, 2) nature protection areas (including protected biotopes, strict nature reserves, natural monuments, and Natura 2000 areas), 3) urban land uses (such as Boliden town), 4) water protected areas and 5) reindeer husbandry grazing land (of which only the areas indicated as areas of national reindeer herding interest are shown in Fig. 3). The Institutional Regime which regulates the different and often overlapping interests of stakeholders is composed of several sectorial public policies and property rights regulated in line with the Swedish Constitution, Land Code, and subsequent Acts.

4.1.2. Analysing public policy coherence & extent

In the following sections, we present results on public policy and how it affects natural objects/resource use: the extent to which public policy regulates the use of a resource (water, nature protection, reindeer herding, urban land use) and the coherence of these regulations. More detailed findings are enclosed in the Supplementary Material 3.

4.1.2.1. Water. With regards to the current legislative and governance

[2] A detailed list of interviewees is provided in Supplementary Material 1

[3] A detailed list of stakeholders and regulations is provided in Supplementary Material 2

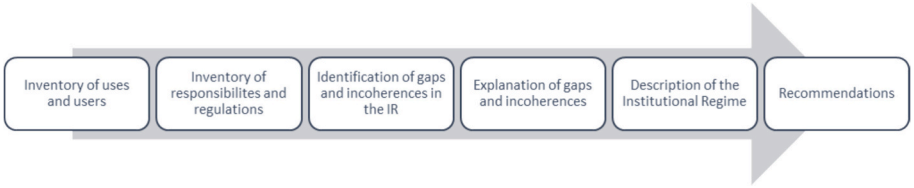

Fig. 2. Steps of implementing the IRR framework (Graphics by authors based on (de Buren, 2015)).

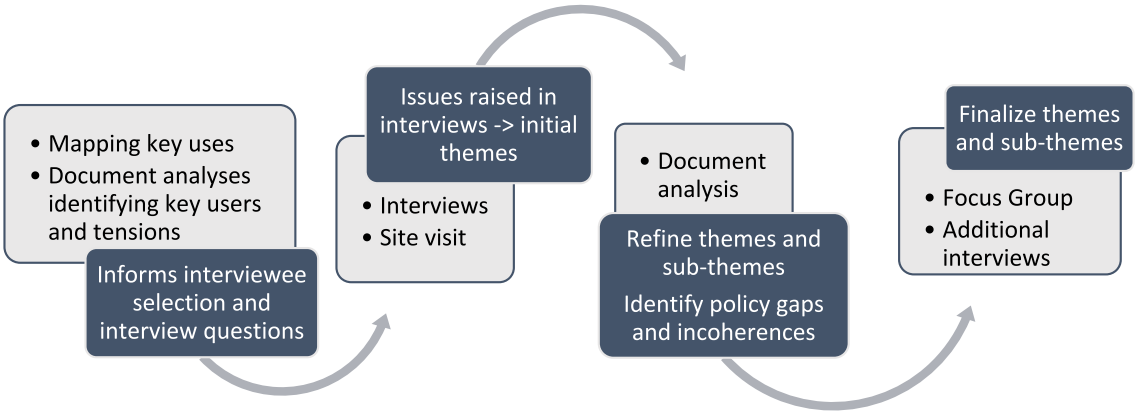

Fig. 3. A combination of top-down and bottom-up approaches for data collection and analyses.

framework (River Basin Management Plans, RBMP), public policy regulating water can be characterised as having a high extent. Regarding active extractive projects, the RBMP adopt a resource-based approach translating national regulations to a river basin scale (W3) and aligning efforts of different stakeholders in achieving defined water quality goals (W9). Accordingly, all the uses and services provided by water are regulated, including direct use (water as an input factor for production) and indirect use (water as an absorbent for pollutants) and do not indicate any incoherence with mineral public policy. However, when it comes to indirect use, pollution from historic mines is not tackled by regulations. This constitutes the only indirect use (with no active users) that current regulations do not tackle.

Even though the legislative framework is clear on use regulation and does not pose incoherencies with mineral policy, we identified internal incoherences a) inconsistencies regarding different stakeholders' perceptions on the validity of the RBMP policy objectives and design, and b) problems with implementation of RBMP measures. The former refers to establishing a baseline water quality (W1), insufficient data (W2), standardisation of water quality (W3), and correlation between water quality and environmental quality standards (EQS, W4). While industry representatives mentioned that "the ecological status does not tell the full story" (SW18), a representative from the Bothnian Water District Authority explained that even though Sweden has a different approach to measuring EQS, a government investigation revealed that Sweden still adheres to the general principles of the European Water Framework Directive and that the way EQS are measured is valid from a water quality perspective.

Regarding problems with implementation by lower levels of governance (local/municipal level and regional) several interviewees mentioned a lack of sufficient resources and capacity for policy implementation (W7). Interviewees from the local authorities mentioned that there is lack of guidance for implementation ("Since they started with the Water Directive work in Sweden, they've always been talking about how the municipality is the most important part of the work.... They have to give us the guidance how to do it and how to make it effective."; SW15) as well as lack of sufficient funding ("We would like to work more with it [water] and we have been applying for more money from our political board. […] It's always a tight budget, so it's hard to get any money out of it. "; SW15).

4.1.2.2. Nature protection. The current legislative framework regarding nature protection policy regulates resource use to a high extent. The designation or exemption (N2.1, N3.1, N3.2: Exemption from biotope protection regulations can be granted for exploration and exploitation operations, and other types of operations, after a request following Chapter 7, Section 11 of the Environmental Code) and protection of conservation areas (N1.1, N2.2: A county administrative board or municipality may in special circumstances grant exemptions from the rules it has issued for a nature reserve: The Swedish Environmental Code, Chapter 7, Section 7) and the relationship to active mineral exploration and exploitation are clearly laid. However, we identified internal incoherences in the form of policy implementation gaps with regard to pollution protection from historical and future abandoned mine sites (N2.2). In other words, similar to water, nature protection regulations cover the current and future uses to a high extent but they do not tackle historic pollution.

4.1.2.3. Reindeer herding. While uses affecting reindeer were all regulated (high extent), we found internal incoherences between public policy regulating reindeer herding and public policy regulating other land uses (R4: Areas of national interest for reindeer husbandry are marginalised by other land uses, including mining). Our analysis indicates that mineral resource activity and its institutional setup (R1: insufficient consultation; R4: marginalisation; R2, R5: unregulated collaboration) does not account for the cumulative effect (R3) that different uses (transport, energy provision) and users have on reindeer conservation goals.

Land use maps indicate that areas of national interest for reindeer husbandry are fragmented by various developments, including mineral extraction operations. This becomes particularly pertinent with the new Consultation Act which does not confer Sámi representatives veto power regarding the dedication of new mineral exploration or exploitation areas (Sámi consultation law approved in 2022, legislation takes full effect in March 2022 for the national government and March 2024 for local governments). This constitutes a breach of the international

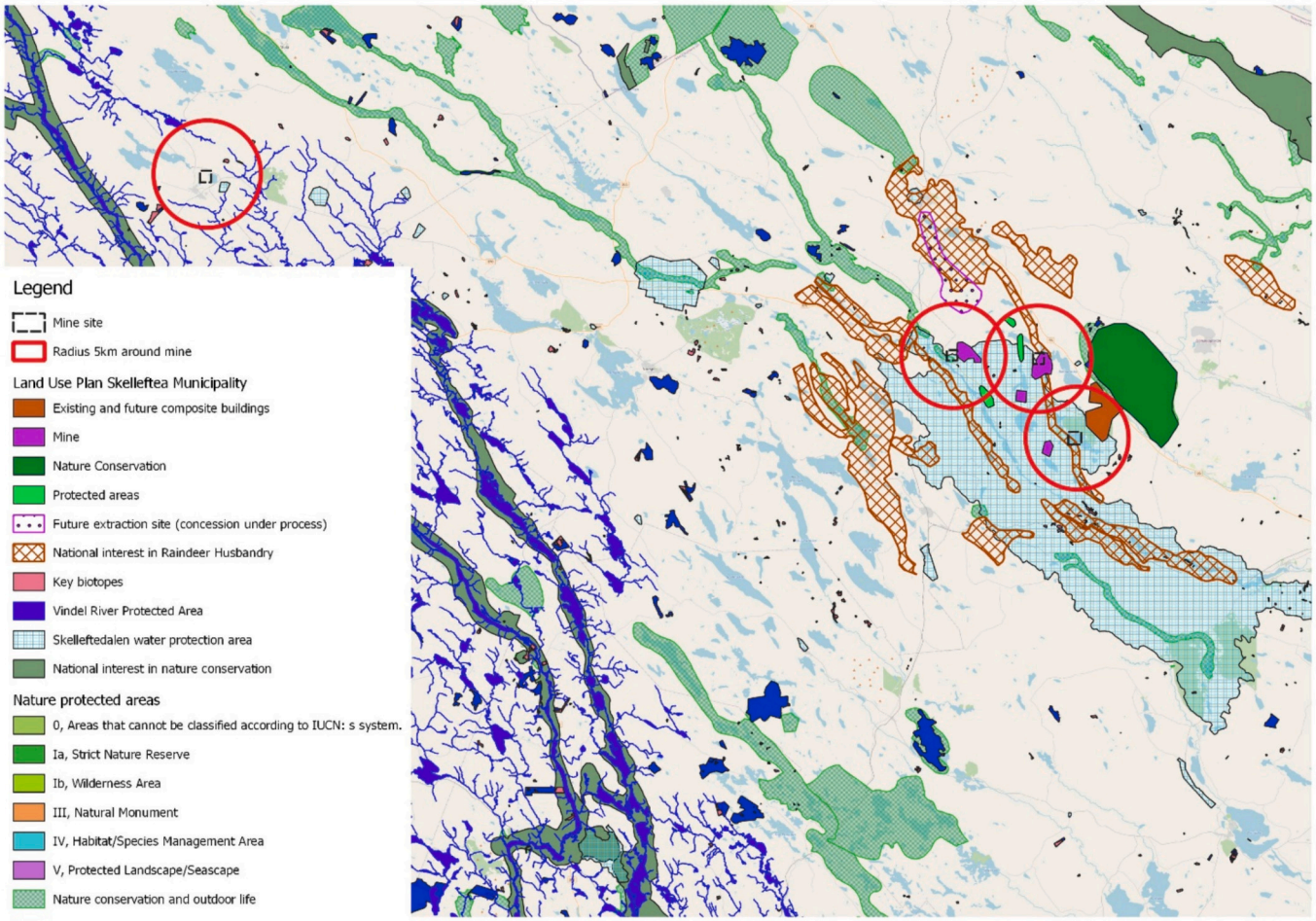

Fig. 4. Inventory of land uses, ecosystems, and water bodies affected by the extraction operations in Boliden Area (Source: Authors, based on mapped information from: (Skelleftea, 1991; The Sami Parliament (Sweden), 2010; Swedish Environmental Protection Agency, 2022))
The new comprehensive plan of the Municipality of Skelleftea is under way

conventions and treaties signed by Sweden, endangering the survival of the Sámi people and culture. Consequently, there is a lack of institutional consensus on the maximum impact that the resource can withstand (a "quota") without compromising reindeer's natural adaptivity.

We also identified external incoherences between public policies and property rights, particularly concerning use rights allocated to reindeer herders in relation to public policies such as the Mining Law and the demarcation of mineral deposits of national interest. These deposits sometimes overlap with areas of national interest for reindeer herding (R4) such as in the case of Skelleftea Municipality as indicated in Fig. 3. According to the Environmental Code, when multiple national interest areas overlap, preference is given to the land use that best contributes to sustainable development. A strategic planning expert in the focus group (SWFG1) argued this statement is very open to interpretation based on individual definitions of sustainability, which increasingly see mineral extraction as a cornerstone of the green transition. However, an interviewed Sami representative expressed scepticism about the government's prioritization of extractives, suggesting it was mostly motivated by economic reasons and may not guarantee sustainability ("The government states that the economic question is always the most important and this testifies as an old way of looking at sustainability. They (the government) point to a document from the 80s stating what sustainability is…"; SW19).

4.1.2.4. Urban land use. The regulatory framework on urban areas covers all uses of land to a high extent, since every activity with impact on land is legislated. The actual implementation in different local authorities varies with regards to a) decisions taken in an integrated manner (L1,L2), b) comprehensive and detailed planning documents (L3), and c) existing exploration permits and exploitation concessions integrated in the land use plan (L3). Even though the regulatory framework and decision-making processes are focused on urban areas, county administrative boards are highly involved in the permitting process (L3) and can advise on the in−/compatibility of such land uses. Decision-making regarding mining is mostly taken during the permitting process rather than as an integral part of land use planning.

4.1.2.5. Cross-cutting mineral policy affecting multiple policy and resource uses. The regulatory framework for mine rehabilitation (C1: guarantee fund and financial warranties) indicates gaps with regards to pollution prevention of abandoned mine sites as well as potential future mine closure and rehabilitation, as the actual rehabilitation costs might exceed the planned financial means laid out in the licencing process. Consequently, poor and neglected rehabilitation might endanger other resource uses such as water, reindeer husbandry, and forestry.

4.1.3. Analysing property rights and public policy coherence and extent

In Sweden, mineral rights ownership is separated from that of land, hence mining companies can conduct mineral extraction activity on someone else's property (Thorell, 2020). The most common way of accessing minerals in Boliden Area is through buying the land or signing an agreement with the landowner. The property owner has no exclusive

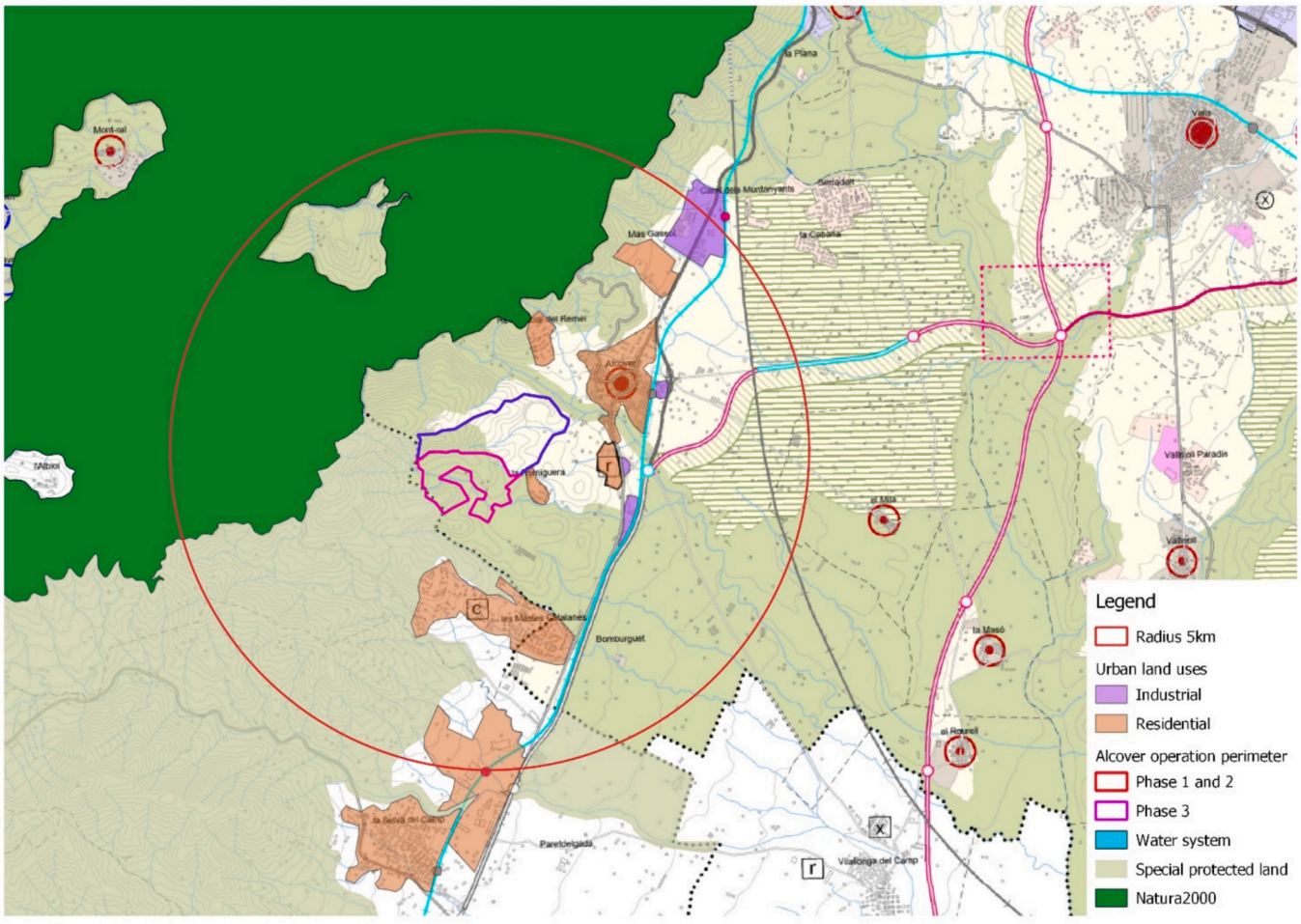

Fig. 5. Inventory of land uses, ecosystems and water bodies affected by the extraction operations in Alcover quarry (Source: Authors, based on mapped information of (Government of Catalonia, 2010; Canteras la Ponderosa, 2013; European Environment Agency, 2022)).

right to decide on minerals being claimed within their property. Cases of disputes between the permit holder and the property owner are addressed by the Chief Mining Inspector (Mining Act). However, when analysing property rights distribution, protection and management in the Mining Act and Environmental Code, we find that there is a weaker level of protection of reindeer herding rights in comparison to private property rights.

Reindeer herding rights can be understood as a bundle of rights which also include hunting and fishing rights, granted only to members of a Sámi reindeer herding community (Lawrence and Larsen, 2019). These rights, considered special property rights, are protected by the Swedish Constitution and have no temporal limitations (Swedish Sámi Parliament - Sametinget, 2014). Nevertheless, sectoral legislation such as the Mineral Act and the Environmental Code approach reindeer herding from the public interest rather than the property rights angle (SW19). In this sense, Sámi land rights are regarded similar to Allemansrätten (the right to access Swedish Nature; the right of public access) which allow Sámi reindeer herders to access pastures for reindeer herding, and it is a weakly protected right. The consequences of this are manyfold, as an interviewed member of one of the Sámi villages in Boliden Area explained (SW19). First, being viewed as state-granted means Sámi land rights are subject to government priorities and can be more susceptible to revision and revocation than private property rights. Second, safeguarding of reindeer herding rights is only done through consultation requirements, which is the responsibility of the private company/applicant, not the regulator. The existing legislation does not give Sámi people the legal position to negotiate with other land use interests from a property rights perspective. Third, loss of reindeer herding rights is not subject to compensation in the Mineral Act, which foresees 0.2% of the estimated value of the extracted mineral brought to the surface yearly as the only compensation paid, which is shared between the landowner and the state to support R&D. In addition, matters to do with land allocation for extraction, resettlement or compensation are part of the mining licence application process, overviewed by the Chief Mining Inspectorate, not the Environmental permitting process. The decision on land allocation follows agreements between the permit holder and the landowner, whereas formal agreements with use rights holders, such as reindeer herders, are not a requirement (SW19).

This incoherence has faced successful legal challenges in court on multiple occasions. However, regardless of many landmark cases, such as the 1981 Skattefjäll (Taxed mountain) case and the recent Girjas case, there is a political resistance to align the national legislation with the principles highlighted by Supreme Court decisions (SW19). Although these court cases are outside Boliden Area, this gap in regulations can lead to more Sámi people pushing legal changes through courts, otherwise referred to as “the court case as a strategy” (SW19). (“This ultimately affects permitting time frames: It takes at least 10 years to open a mine in Sweden and then we don’t become as attractive for mining investments.” SWFG1).

4.2. *Spain: Natura 2000, air pollution, water*

4.2.1. *Defining the resource, uses, users and realm of regulations*

The main land uses, ecosystems and water systems comprised in the

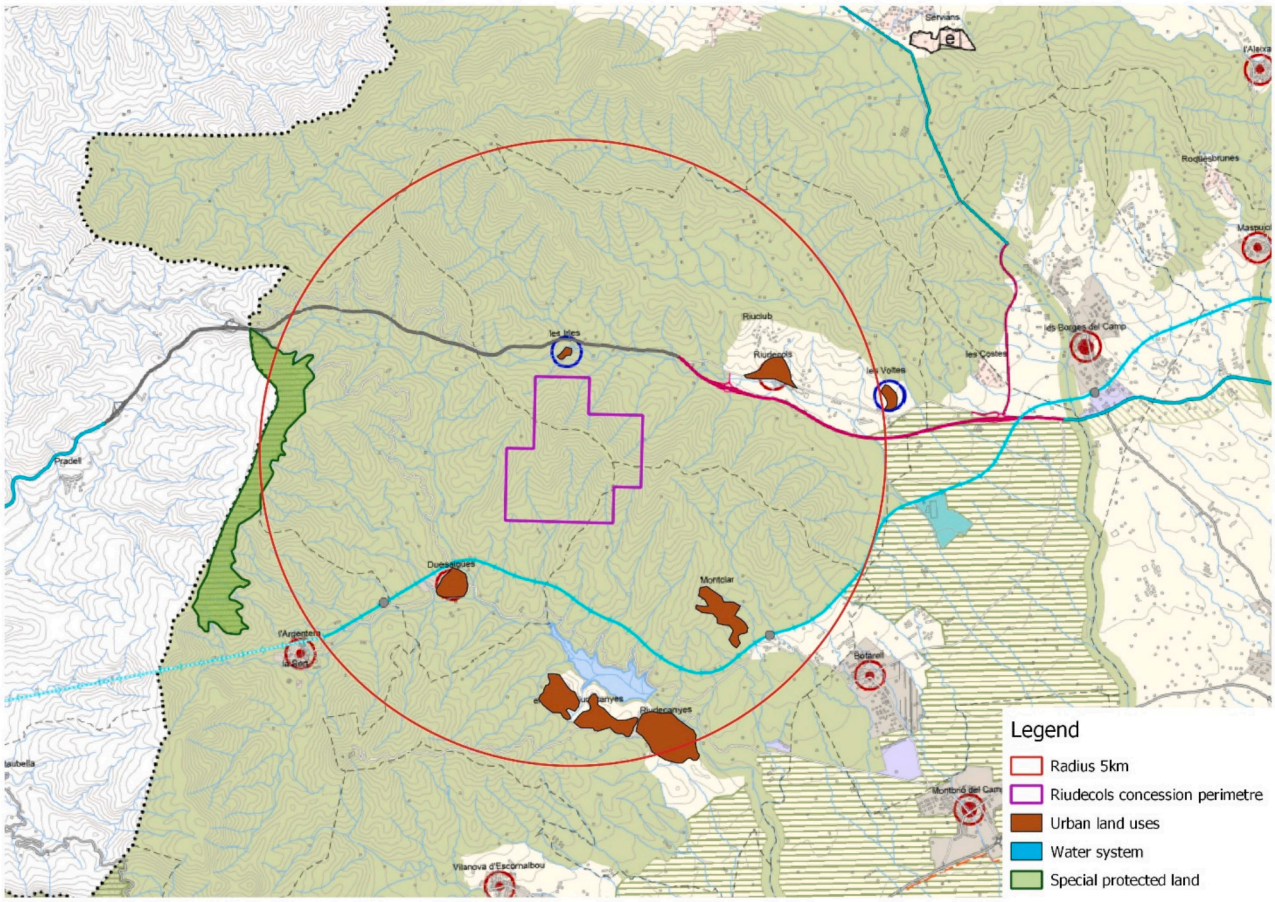

Fig. 6. Inventory of land uses, ecosystems and water bodies affected by the extraction operations in Riudecols quarry (Source: Authors, based on mapped information of (Government of Catalonia, 2010; Canteras la Ponderosa, 2013; European Environment Agency, 2022))

Table 1
Types of incoherences and gaps leading to low extent and coherence of regime (Source: Authors).

		Low Extent/ Coherence
Extent		One or more uses unregulated by the regime identified
Coherence	External Coherence	Horizontal misalignment *Example: Local land use plans (PP) do not account for the expansion of existing or future quarrying areas (PR)* PP & PR misalignment *Example: Loss of reindeer herding rights is not subject to compensation in the Mineral Act*
	Internal Coherence	Vertical PP misalignment *Example: Misalignment of EU – National – Local water policy objectives* Regulatory gaps *Example: No guidelines to evaluate the adequacy of environmental compensatory measures* Lack of enforcement *Example: Mine rehabilitation measures not enforced*

5 km radiuses from extraction operations are shown below in Fig. 4 for Alcover and Fig. 5 for Riudecols quarry. Current uses include: 1) extraction operations, 2) nature protection areas such as Natura 2000 areas and areas protected from national legislation, 3) water sources and 4) urban land uses such as the towns of Alcover and Riudecols, and smaller residential areas located closer to the quarries such as Residencia Remei in Alcover and Les Irles in Riudecols. The Institutional Regime which regulates the different and often overlapping interests of stakeholders is composed of sectorial public policies and property rights regulated in line with the Spanish Constitution.

4.2.2. *Analysing public policy coherence & extent*

In the following, we present results on public policy coherence: the extent to which public policy is able to regulate the use of a resource (nature protection, air quality, urban land use, water) and the coherence of these regulations. More detailed findings are enclosed in the Supplementary Material 3.

4.2.2.1. Nature protection. The current European, national and regional legislative framework on nature protection regulated uses affecting these areas to a high extent. Nevertheless, with regard to the institutional setting of mineral activity and nature protection, the case indicates several internal incoherencies between the regulatory framework and the actual implementation and interpretation by both authorities and companies alike. Incoherence between the regulatory framework and implementation refers to a lack of recovery plans and restoration programmes (Government of Catalonia, 2018) (N3), and a lack of ongoing review of the management measures in protected areas, on top of insufficient resources for active management of such areas (Government of Catalonia, 2018) (N5). An interviewed expert (SP16) pointed out that recovery plans and company restoration programmes are not enough and that the ratio between the effort to implement them and their result is often not proportional, while secondary data highlight the lack of management plans for Special Protection Areas for Birds (SPAs) (Government of Catalonia, 2018) (N2). In addition, we identified external incoherences between quarry expansion permits and regional planning for nature protection (N4)) and we observed variations in the

interpretation of conditions for mineral permits within nature conservation areas across different levels of governance. (N7, N8; approved strategic environmental impact assessment of the revised land use plan; EIA permit for this operation issued by the Catalan Environment Agency; challenged successfully in court).

4.2.2.2. Air quality. Air quality in Spain is regulated to a high extent by the national and regional legislation on air quality and atmosphere protection, in line with Directive 2008/50/EC on ambient air quality and cleaner air for Europe. However, our results indicate that external incoherences between environmental permitting and the land use planning process result in implementation gaps of air quality policies. Incompatibility of quarrying activities (PR) and the residential land use plan (PP) (i.e., with 50% of the mineral extraction areas not officially recognized in urban plans; SP10) results in air quality problems. Despite an approved environmental permit, dust emissions continue to degrade air quality in nearby residential area. This is often the consequence of land use planning decisions (PP) that are incoherent quarrying permit (PR), exacerbated by a lack of land policy instruments to serve as preventive measures (for example, the establishment of legally binding buffer zones around quarrying sites) (SP12).

4.2.2.3. Urban land use. All uses of land in Alcover and Riudecols Municipalities are regulated to a high extent by the respective local land use plans, as well as by the Regional Plan of Tarragona, in line with regional and national legislation on land use planning. However, in line with the analysis presented on air quality above, an external incoherence between the environmental permit (PR) and the local land use planning process (PP) lead to dust problems in nearby residential areas (L1,L3). Additionally, a number of internal incoherences were identified. First, the absence of land policy instruments to avoid future development conflicts between different land use types (L2; i.e. quarry and residential area expansion). Second, the incomprehensive legal requirements to involve certain stakeholder groups such as local residents in public consultation processes to account for different land uses (L2). Third, a lack of planned transport infrastructure in support of licenced extractive sites, resulting in the use of riverbeds as transportation routes, threatening their geomorphological quality (W3). Land use planning instruments do not safeguard mineral deposits of national interest (L6) and neither there is legal scope to designate 'no go' areas for mining (L7), resulting in a fragmentation of decision-making on a project by project level, without a comprehensive strategy.

4.2.2.4. Water. In Spain, water as a resource is owned by the state and its use is regulated by national legislation, regional legislation - Regulations of the Autonomous Region of Catalonia in this case - aligned with the European Water Framework Directive. Although water is regulated to a high extent, instruments and capacity to implement these regulations are lacking, indicating low internal coherence. For example, a change of policy paradigm away from a "hydraulic" towards an ecosystem-based one, in line with the WFD is not reflective of water policies and investments on a regional and local level (W1). There is a lack of understanding of the impact of every pollution pressure point into a water basin due to an incomplete assessment of EQS indicators (W2), as well as a strategy on prioritizing certain water uses over others (W4) which could affect decision-making regarding the location and management of quarries. Finally, there is a lack of internal coherence with land use instruments (local and regional plans) (W3).

4.2.2.5. Cross-cutting mineral policy affecting multiple policy and resource uses. Similar to the Boliden case, there are several policy areas that cut across natural resource use sectors. The overall regulatory framework for mine rehabilitation and closure covers all uses, but its lack of retroactive effect and flaws in implementation can lead to ongoing environmental pressures on all affected resources (air quality, nature protection, water). As mentioned by one interviewee "…if companies fail to comply with such an obligation, the restoration project is carried out by the ECA using the monetary guarantee deposited by the company during the permitting process. Often, this fund is not sufficient, leaving the public authorities with the only option of adapting the rehabilitation plan to the available funding" (SP12). The necessity to adapt the rehabilitation plan to match available funding indicates that the design and implementation of closure and rehabilitation measures are insufficient to protect natural resources.

4.2.3. Analysing property rights and public policy coherence and extent

The property rights and the use rights arising from them are clearly defined. We did not identify any overlapping property rights claims or differences in protection systems for property and use rights. However, we attribute the problem of air pollution caused by Alcover Quarry to Residencia Remei (north-east of the quarry) as partially stemming from public policy incoherence as explained in the previous section, and partially as an example of incoherence between property rights stemming from a land use plan and public policy regulating environmental impact assessments (EIA). EIA experts engaged with the permitting process focus only on the existing land uses when assessing the environmental impact that new operations will have in the territory, disregarding future development rights already approved by local land use plans (SP10). Future development rights approved in a land use plan constitute property rights which can be unlocked through a building permit. Although building permits are not always approved in areas where a land use plan foresees expansion of residential areas, it is difficult to retract these building rights without fair compensation. This gap between the land use planning process and the EIA permitting process creates problems as described in the Municipality of Alcover, in which ex-post measures, such as limiting the activity of the quarry during certain weather conditions, are not only inefficient but also do not provide a guarantee of any long-term sustainable coexistence.

5. Discussion: Assessing the institutional regime and challenges it poses to sustainable extraction in Sweden and Spain

In both Spain and Sweden, extractive activity operates within complex institutional regimes (Fig. 1). Table 2 below presents a summary of our evaluation of the extent and coherence of regulations for each resource affected by mining. In Spain, we have identified regulatory gaps and incoherences concerning Natura 2000 protected areas, water resources, urban land use and air quality in urban areas. Here, the IRR is complex primarily due to: a lack of internal coherence leading to weak implementation and regulatory gaps and a lack of external coherence leading to misalignment of renewable resource protection regulations and quarrying. In Sweden, regulatory gaps and incoherences exist particularly concerning safeguarding water quality and Sámi land rights in areas under pressure of extractives. Here, besides public policy gaps and misalignment between different policy domains, the institutional complexity also reflects incoherences between property rights and public policy concerning Sámi land rights.

The extraction of diverse raw materials in the two cases analysed instigate varied impacts on renewable resources, where surface extraction of construction materials (in the case of Spain) exhibits a pronounced influence on air pollution and natural protected areas, while underground metal mining (in the case of Sweden) disproportionately impacts water pollution and reindeer habitats. This in turn affected the differences in scale of the relevant institutional regimes. Although our analysis for both cases initially focused on a functional space within a 5 km radius around the extraction operations, the institutional regime in Sweden expanded to encompass key stakeholders of affected resources on a larger scale, such as water basins and reindeer pastureland. In contrast, the institutional regime in Spain, while still involving regional regulators, primarily impacted neighbouring users affected by air pollution, thus remaining largely local in scope.

Table 2
Evaluation of Extent and Coherence for renewable resources affected by mining in Sweden and Spain.

	Sweden			Spain		
Sub-System	Extent	Internal Coherence	External Coherence	Extent	Internal Coherence	External Coherence
Water	High *Historic mine pollution unregulated*	Low *Different perception on validity of objectives - Implementation challenges – capacities and resources*	High	High	Low *Misalignment of EU – National – Local policy objectives* *PP – PP* *Water and Quarrying; Water and Land use planning*	High
Natural Ecosystems	High *Historic mine pollution unregulated*	Low *Implementation challenges which do not tackle historic pollution*	High	High	Low *Lack of management plans for SPAs, insufficient resources for active management of protected areas*	Low *PR-PP* *Quarry expansion permit and nature protection regulation*
Urban Land Use	High	Low *PP – PP* *Decision making on mining during permitting phase, not planning*	High	High	Low Lack of land policy instruments (buffer zones) to avoid proximity of incompatible land uses. Incoherence between LUP and mineral deposits of national interest. Existing and future quarrying transport infrastructure not planned in LUP.	Low *PP-PR* *LUP does not integrate quarrying in decision making, leads to env problems* *Env. permits for quarrying do not consider emerging land uses in local LUP*
Reindeer Herding	High	Low *PP-PP* *(Reindeer herding – Mining)*	Low *PP-PR (Sami land rights – Mining Law &* Env Code)	–	–	–
Air	–	–	–	High	Low *Low safeguarding of air quality in residential areas neighbouring quarry site* *PP-PP* *Air quality regulation-LUP-Quarrying*	Low *PP-PR* *LUP (PP) does not account for quarrying rights (PR)* *EIA focus only on the existing land uses, disregarding future development rights already approved by local land use plans*

Building on IRR's premise that institutional complexity can lead to unsustainable resource management, we have identified the following regulatory incoherences and gaps which raise concerns on the sustainability of extractive activities in the two cases analysed:

No retroactive line of action: The implementation of the Water Framework Directive in both cases has increased efforts to regulate all the uses that affect water to a high extent. However, existing regulations do not tackle pollution from historic mines effectively. There is a regulatory vacuum in Spain and Sweden when it comes to tackling environmental problems occurring from abandoned mines. In line with studies in Sweden (Bindler et al., 2012; Fischer et al., 2020; Lidman et al., 2023) which measure the ongoing impact that small-scale historic mines have on surface waters, we conclude that the lack of institutional resources and instruments to deal with heritage mining can have devastating effects on renewables. The institutional gap allowing for this situation to unfold, threatens sustainable resource management across the country. Concurrently, the financial guarantees necessary for environmental rehabilitation are not always adequate in both cases, resulting in situations where taxpayers bear the burden of covering costs (Geological Survey of Sweden and Lansstyrelsen Vasterbotten, 2019).

Policy enforcement and monitoring gaps: The application of the IRR framework in this study was not limited to evaluating institutional structure and policy design, but it also included the evaluation of the 'activation' process: the implementation of law. de Buren (2015) highlights that stakeholder power relations modify the implementation process of regulations which affects the degree to which the institutional regime can regulate all the uses of a resource. In both Sweden and Spain, not enough resources are dedicated to the enforcement and monitoring of water management regulations. In Sweden, water management authorities struggle to monitor the use of water resources on the ground, leading to incomplete information on existing and background contamination values. In Spain, lack of enforcement is reflected through irregular use of water and riverbeds leading to geomorphological degradation of water resources. Enforcement challenges are also present when it comes to regulating nature protection areas in Spain. A lack of evaluation systems and a lack of management plans for Special Protection Areas for Birds (SPAs) results in an incomplete regulatory landscape for protected areas. A deeper understanding of how actors activate their rights or influence the implementation of regulations requires a political approach to the discourse of environmental and resource management. In line with Schweizer (2015) "law activation strategy" (LAS) concept, further research on the interplay between legal rules, environmental outcomes and actors' power and behaviour in the extractives sector would be of policy and scientific interest.

Mismatch between property rights and public policy: In line with several other studies (Allard, 2018; Larsen and Raitio, 2019; Kløcker Larsen et al., 2022), we find that the current institutional regime regulating extractives in Boliden Area does not safeguard the sustainability of reindeer herding. There is a regulatory incoherence between user rights of Sámi people, as recognized by the Swedish Constitution and reinforced by several supreme court decisions, and the way these rights are reflected in the Mineral Act and Environmental Code. In combination with an unclear picture of the overall effects of different developments on reindeer, decision-making is incoherent regarding reindeer conservation goals. This indicates a differentiated system for the protection of property rights, raising concerns about legitimacy and justice (Downing et al., 2019; Drees et al., 2021) and reinforcing patterns of dispossession.

Lack of mandatory instruments that promote a deeper understanding of the cumulative effect of land use changes: The lack of such instruments results in failure to identify tipping points (Scheffer, 2010; Dakos et al., 2019) and safeguard the renewal capacity of natural environments and ecosystems exposed to multiple pressures, including extractive activities. This is the result of a policy misalignment between land use planning and extractives. In Spain, local land use plans do not take into consideration future extractive projects and associated land uses such as transport infrastructure. This has led to water resource overconsumption, i.e. for dust control when residential areas grew towards quarries, or riverbed degradation, i.e. when the riverbed is used as a transport route. In Sweden, land use plans consider mining reserves of national interest. However, they do not reflect on the implications of potential extractive activities on other land uses. In both cases, land use plans do not provide a picture of the cumulative effects of extractive activities and accompanying land uses, such as housing and transport infrastructure, on natural resources.

The Strategic Environmental Assessment of land use plans would be an adequate instrument to tackle this. Regional and local authorities in Sweden and Spain use SEA extensively for territorial land use plans (Balfors et al., 2018; Rega et al., 2018). However, the policy gaps indicated above, between land use planning and mining in both cases, should be addressed first for SEA to become effective. Additionally, SEA must include an assessment of different scenarios related to extractive interests in the territory, in conjunction with other land use changes that result in ecosystem disruption. And SEA is most effective when the use of the instrument is mandatory and the SEA authority is separated from the planning authority (Rega et al., 2018).

6. Conclusion

The discussion of the case studies presented an in-depth picture of the institutional regimes regulating extractive industries in two European countries, through an Institutional Resource Regime analytical framework. IRR offers an innovative way of approaching the topic of sustainability of raw materials extraction, especially by analysing it through a renewable resources lens. While IRR provided a useful initial framework for analysing the institutional regimes in the two cases, we also identified some limitations, specifically in terms of the evaluation of its two main dimensions, extent and coherence, within a restrictive high-low dichotomy. Further research on identifying different levels of regulatory extent and coherence would contribute in adding more nuance to institutional regimes, presently organized into four main categories, and their implications on resource sustainability.

In this study, we worked with the IRR hypothesis that integrated institutional regimes are likely to create conditions for sustainable management of resources. However, more recent research on policy integration suggests that expanding the range of regulations (extent) can have adverse effects on coherence. This phenomenon is often referred to as 'institutional complexity traps,' wherein achieving a balance between broad coverage and cohesive environmental governance becomes challenging (Bolognesi et al., 2021; Bolognesi and Nahrath, 2020). All policy areas covered in this study exhibit a high extent of regulation coupled with a lack of internal and/or external coherence. A temporal analysis of the evolution of one or more of these policy areas would contribute to understanding the process and mechanisms of potential institutional complexity traps. At the same time, another valuable research contribution would involve reevaluating the potential of existing policy instruments, such as Strategic Environmental Assessment (SEA), in policy integration. SEA serves as an early warning system for identifying the combined environmental effects of multiple interventions and identifying potential sustainability threats.

Finally, an integrated regime does not guarantee that all user demands will and can be met or that the resources are used sustainably. Additionally, addressing sustainable extractives from a renewables perspective—by recognizing thresholds for the biophysical domains of renewable resources—does not fully address the finite and inherently unsustainable nature of extracting non-renewables, aside from considering them easier to substitute through technological processes (Knoepfel et al., 2007). Focusing solely on the balance between advancing renewable energy technologies and conserving the environment presents a false dichotomy aligned with the weak sustainability perspective, which permits substituting natural capital with human-made capital and suggests that mining can continue if offset by

technological advancements and economic gains. However, there are limits to raw material resources within which society must meet its needs and predicting how substitutability of natural capital changes over time and how dependable future generations will be on certain natural capitals is difficult. Therefore, a discourse on setting priorities in terms of raw materials consumption to guarantee equity in the process is paramount. The sustainable extraction of raw materials discourse should go parallel to the responsible mineral consumption one. Recently, the European Commission passed a Critical Raw Materials (CRM) Act focusing on building the EU's capacity to supply CRMs. While the CRM Act is in line with the principles of other EU directives on the conservation of natural habitats, industrial emissions, and so on, the case studies presented here indicate how the full implementation of one directive, i.e. the Water Framework Directive, can limit the sustainable sourcing of raw materials substantially or even bring it to a halt. This will become more likely as we move to higher standards of nature protection, i.e. with the approval of the new Nature Restoration Law and higher standards for the protection of human rights, especially of indigenous communities. Therefore, an inclusive discourse on responsible consumption of raw materials is vital. This discourse would benefit from a wider inclusion of local stakeholders and local governance actors, and further efforts towards more sustainable transport and built environments.

CRediT authorship contribution statement

B. Dyca: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **GJ. Carsjens:** Writing – review & editing, Writing – original draft, Validation, Methodology, Conceptualization, Supervision. **A. Endl:** Writing – original draft, Methodology, Formal analysis, Data curation. **K. Gugerell:** Writing – original draft, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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