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Policy documents considering biodiversity, land use, and climate in the European Arctic reveal visible, hidden, and imagined nexus approaches

Highlights

- Arctic climate, biodiversity, land use, and local communities are interlinked
- We analyzed the nexus approach in policy documents from the European Arctic
- Documents underestimate the active role of local communities and biodiversity
- Implementation of nexus approaches can promote holistic environmental governance

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In brief

Governance in the Arctic works better when it takes a nexus approach, considering climate change, biodiversity, land use, and Indigenous and local communities not as separate entities but in combination. We studied this approach in policy documents and found that the documents underestimate certain interactions of the nexus. Indigenous and local communities are often seen as victims, not as active drivers of change. Also, biodiversity is not only "impacted" but plays a key role in shaping Arctic futures.

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Policy documents considering biodiversity, land use, and climate in the European Arctic reveal visible, hidden, and imagined nexus approaches

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SCIENCE FOR SOCIETY Governance in the Arctic works better if it looks at climate change, biodiversity, land use, and Indigenous and local communities not as separate entities but in combination. Such a holistic approach is facilitated by the concept of "nexus." We show how this approach is applied in policy documents at pan-Arctic, cross-border regional, national, and subnational scales. We found that, depending on the scale, documents underestimate certain interactions of the nexus. We call for stronger emphasis on these links. Policy recommendations implying a nexus approach suggest various strategies: ecosystem approaches, technological solutions, authoritative regulations, co-production of knowledge, or adaptive co-management. Among these, we endorse co-management, considering Indigenous and local communities not simply as victims but as active drivers of change. Also, policymakers should be aware that biodiversity is not only "impacted" but plays a key role in shaping Arctic futures.

SUMMARY

The Arctic is experiencing rapid and interlinked socio-environmental changes. Therefore, governance approaches that take the complex interactions between climate change, biodiversity loss, increasing land use pressures, and local livelihoods into account are needed: nexus approaches. However, an overview of whether and to what extent Arctic policies address these nexus elements in concert has been missing. Here we analyzed a large sample of publicly available assessment reports and policy documents from the terrestrial European Arctic. Our results show that, although nexus approaches are widely adopted in Arctic policy reporting, the emphasis varies among the governance levels, and documents underestimate certain interactions: local communities and traditional livelihoods are seldom seen as actors with agency and impact. Practical implementations were identified as potential advancements in Arctic governance: ecosystem-specific, technological, and authoritative solutions; co-production of knowledge; and adaptive co-management. Implementation of nexus approaches can promote more holistic environmental governance and guide cross-sectoral policies.

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INTRODUCTION

The Arctic region is warming two to four times faster than any other region in the world,[1] putting stress on the environments and social-ecological systems (SESs) adapted to cold conditions and seasonality.[2–4] Higher temperatures, melting sea and land ice, together with thawing permafrost and changing snow conditions, are transforming ecosystems faster than elsewhere on the planet. Interactions and dynamics between organisms change, with potential knock-on effects across trophic levels.[5] Plants grow faster and taller and at higher altitudes than one human generation ago.[6–8] Other Arctic biodiversity transitions[9] include changes in phenology (timing of leaf emergence, flowering/senescence of plants), vegetation composition, and plant traits (e.g., leaf and stem characteristics), all of which contribute to the overall functional diversity.[10–12]

These changes in climate and biodiversity alter key ecosystem functions, such as carbon sequestration and sink/source dynamics of Arctic soils,[13] along with the potential release of carbon dioxide and methane from thawing Arctic permafrost.[14] Boreal and temperate species are projected to expand their ranges northward, thus potentially increasing overall species richness, at the expense of endemic Arctic species.[15] Ongoing changes pose threats to local livelihood activities and, in so doing, may erode culturally unique human-environment interactions, including many environmentally sustainable practices.[16,17] Traditional livelihoods (e.g., hunting, fishing, gathering, small-scale forestry and agriculture, and herding activities) in the Arctic are in close interaction with the environment and the land, and all of them remain important components of Arctic culture and tradition today.[18] They are being shaped by the ongoing environmental changes, and, at the same time, local communities continue to shape ecosystems through their livelihoods and cultural management practices.

Currently, in the transition toward a sustainable future, a rich and diverse pool of natural resources makes the Arctic attractive for economic development and can turn some challenges posed by climate change into opportunities—for some at least.[2,19] Increased activity and industrial development demands increase the built area, such as road and rail infrastructure for transportation, settlements for employees, and infrastructure for power transmission lines.[20,21] Although the economic development in the Arctic brings opportunities to some, the distribution of risks and costs of the long-term developments is not necessarily equal among Arctic peoples.[20] For example, infrastructure development and fragmentation decrease the flexibility of reindeer herding practices in space and time, which has been identified as key to reducing vulnerability of this traditional livelihood to climate change.[22–24]

Given their complex cultural and natural resource-based dependency on the local environment, local communities practicing traditional livelihoods are highly susceptible to climate change, biodiversity loss, and intensifying land use. While the Arctic Peoples are used to a dynamic environment and constant adaptation, the changes are now happening faster than ever before in human history and are even accelerating.[25,26] Understanding and managing the effects of multiple simultaneous changes is especially critical in the Arctic, where intertwined socio-environmental challenges impact landscapes and SESs. It is increasingly recognized that, due to their synergistic or amplifying effects, outcomes of the previously mentioned processes may be unexpected, and their impacts are not only additive. Solutions to current socio-environmental problems cannot be designed by focusing on single challenges[27]; instead, holistic approaches are needed.[28,29]

We consider a nexus approach as a key for Arctic policies to cope with the intertwined socio-environmental challenges. According to Wormbs and Sörlin,[30] "no other region of the world has as many scientific assessments per capita as the Arctic". However, so far, an overview of whether Arctic assessments and policy documents address these nexus elements in concert has not been presented. A nexus can be defined as a set of context-specific critical interlinkages between two or more elements.[31] The nexus approach provides an integrated framework for addressing multiple sectors or drivers simultaneously. In so doing, implementation of nexus approaches can guide cross-sectoral policies and promote more holistic environmental governance and policy coherence.[31–33] Over the past decade, academic interest in the nexus approach has rapidly increased, especially in research that focuses on complex socio-environmental challenges.[34–36]

Here, we analyzed a large sample of publicly available assessment reports and policy documents from a subregion of the European Arctic and across international, European Union, regional, national, and subnational governance levels (Figure 1). We concentrate on two research questions: (1) to what extent do these documents address two or more of the Arctic policy elements together and (2) what kinds of approaches do these

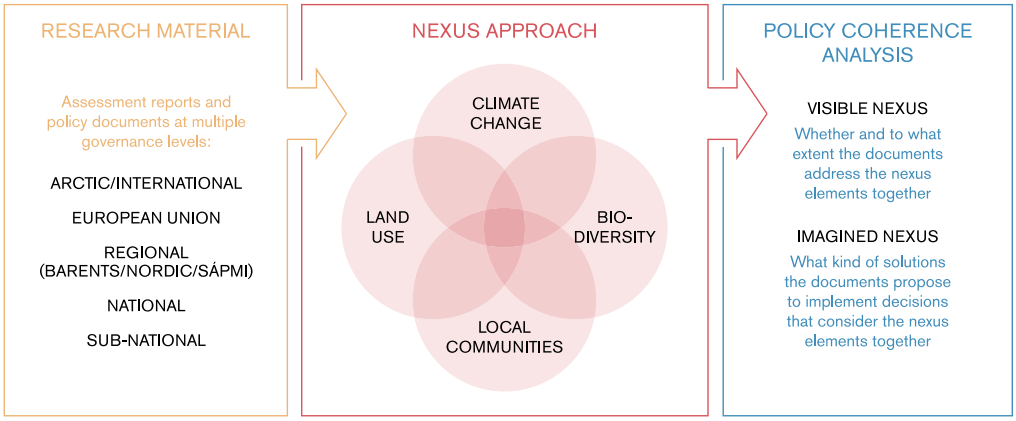

Figure 1. Research material, nexus approach, and analytical focus used in this study

documents propose for future implementation and advancement of nexus-based policies in the Arctic? Our results indicate that, across all levels, there is variation in how often the four dimensions of the climate change-biodiversity-land use-local community nexus are considered drivers of change as opposed to something being impacted. Most of the analyzed documents considered the "full nexus" in the sense of acknowledging interlinkages between at least three nexus elements simultaneously. Approximately half of the national- and subnational-level documents studied did not consider the full nexus. We consider knowledge gaps and policy recommendations listed in the documents to represent narratives about possible and desirable futures.[37] Knowledge gaps and policy recommendations implying a nexus approach demonstrate how Arctic policy is imagined to govern interlinking nexus elements in the future.

RESULTS

Methods summary

Policies addressing the Arctic nexus elements together are supporting each other in the overall aim of addressing climate change, biodiversity loss, land use, and local community development as intertwined elements of the same system; they promote the Arctic policy coherence.[33] Policy coherence has two dimensions: outputs (including policy objectives as well as policy design and instruments for achieving them) and implementation practices at different levels.[38] We study the output dimension by analyzing how assessment reports and policy documents, considered key outputs, address the nexus elements together. The implementation dimension is addressed by analyzing the policy recommendations and knowledge gaps put forward in the documents. To examine whether policies address nexus elements together, we applied document analysis[39] combined with qualitative and semi-quantitative content analysis[40] to a total of 80 documents, of which 15 were international, 13 European Union (EU) level, 9 regional (Nordic, Barents, Sápmi), 28 national, and 15 subnational (see Experimental procedures and Note S1 for details).

Visible nexus in the Arctic policy documents

The majority (76 of 80) of the documents analyzed acknowledged a connection or connections linking climate change, biodiversity, land use change, and/or local communities together (a material list can be found in Note S1). We did not identify recognition of linkages between any nexus elements in international level document I3, EU level document E4 or regional level documents R5 and R6 (see Note S1 for details). Our analysis captured nexus approaches in all of the national- and subnational governance-level reports.

Although the Arctic policy nexus was visible in most of the documents, our results suggest that some dimensions of the climate-biodiversity-land use-local community nexus were more commonly recognized than others (Figures 1 and 2; Table S1). Moreover, we detected differences regarding on which dimension(s) of the nexus the five governance levels focused. At the international level, the interactions between all nexus elements were acknowledged rather uniformly (Figure 2, relatively equal connections between the four elements), whereas the other spatial scales had stronger emphasis on specific dimensions (Figure 2, variation in the strength of the connections). For instance, in comparison with the other dimensions of the nexus, many EU-level reports acknowledged the interrelated nature of climate change and land use. At the regional level, in turn, land use-local community interdependencies were recognized by most reports. Further, at the subnational level, the land use-local community-biodiversity interactions were acknowledged by more reports than their interactions with climate change. Similarly, there were dimensions in the nexus that were less recognized than others: interdependencies between local communities and biodiversity at the national level, between biodiversity and climate change at the regional level, and between local communities and land use at the EU level.

Moreover, while the nexus approach emphasizes the interdependencies between the different nexus elements, our findings suggest variation in how often the four dimensions of the climate change-biodiversity-land use-local community nexus were considered drivers as opposed to something being impacted. The results indicate that, across all levels, the reports commonly discuss biodiversity as impacted by climate change, land use change, and local livelihoods (Figure 2, small biodiversity node sizes in comparison with other node sizes), rather than as a driver for climate change (e.g., buffering climate change impacts) or local communities (e.g., limiting customary practices). This

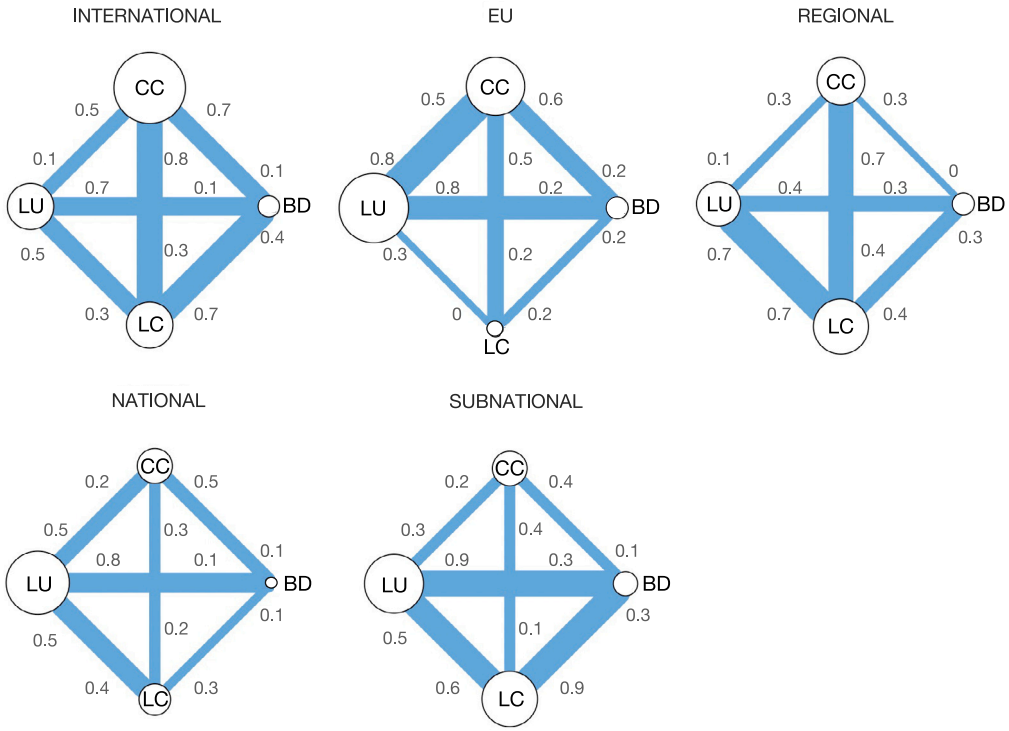

Figure 2. Network visualization for the co-occurrence of nexus elements in the material analyzed

The widths of the connection between climate change (CC), biodiversity (BD), land use (LU), and local communities (LC) illustrate the ratio of reports analyzed acknowledging each interlinkage. The value next to the connection indicates the ratio of reports that acknowledged the link and is located next to the source (driver) of that connection, standardized by the number of reports analyzed for that governance scale. Zero indicates no outgoing connection. The node sizes illustrate the total frequency of reports that identify each nexus element as a driver. See Note S1 and Table S1 for further details.

finding is also evidenced by a notable variation between the governance levels in acknowledging the agency of local communities in influencing biodiversity, climate change, and land use change (see differences in local community node sizes in Figure 2). For example, only a minority of the EU-level reports analyzed discussed biodiversity-local community interactions, and we detected no acknowledgment of the influence of local communities on land use. In fact, our results at the EU level suggest that, in comparison with the other dimensions of the climate change-biodiversity-land use-local community nexus, local communities were most rarely identified as drivers of change in comparison with the other nexus elements. On the contrary, the land use-local community interactions were acknowledged in most of the regional-level reports as well as in approximately half of the national and subnational level reports. At the international level, the local communities' influence, in particular on biodiversity, was well recognized. Similar governance-level differences can be detected in the frequency of reports that position climate change and land use as drivers (Figure 2, climate change and land use node sizes).

Most of the documents analyzed considered the ''full nexus'' in the sense of acknowledging interlinkages between at least three nexus elements simultaneously. All except one of the international-level documents and all but one of the EU-level documents considered the full nexus, at least acknowledging that more than two elements interact; the same applies to regional-level documents (Barents, Nordic, Sápmi). In many of the assessment reports, the biodiversity changes experienced in the Arctic ecosystems were considered to be driven by multiple pressures, such as climate change-driven permafrost degradation and growing pressures from increased human presence (like in the ones by Conservation of Arctic Flora and Fauna, CAFF). These pressures were considered as having harmful feedback to local communities and Indigenous peoples because of their ''dependence on the environment for food, lifestyle, and culture'' for example by the Arctic Monitoring and Assessment Programme (AMAP). The European Environment Agency explained the ''integrated framework for the risk of climate-related impacts,'' meaning that climate change, emissions, and land use changes are linked and that they are linked to socio-economic processes, risks, and vulnerabilities. Half of the national-level documents studied did not consider the full nexus. Holistic consideration of several topics was often outside of the aim and scope of these documents. Also, approximately half of the subnational-level documents studied did not consider the full nexus.

Ways forward by policy recommendations

Of the 80 documents, 33 gave policy recommendations or suggested solutions related to linkages between the nexus elements or full nexus (Table 1). Of the documents, 24 also listed knowledge gaps, further research needs or areas for further thinking and deeper dives related to interlinkages between the nexus elements (Table 2).

Table 1. Examples of policy or action recommendations implying a nexus approach suggested in the documents

Level	Arctic policy recommendations implying a nexus approach	Who implements?	Who is impacted?
International/Arctic	[I10, I13]protection, conservation, and restoration of degraded high-carbon ecosystems such as peatlands, wetlands, rangelands/pastures, and forests; afforestation, reforestation, agroforestry	conservation agencies, environmental protection agencies, government	
	[I3, I10]using a holistic approach and multistressor framework to ensure all sectors and downstream effects are considered	research institutions, government, environmental protection agencies, industries	
	[I9, I10, I13, I15]multiknowledge and multidisciplinary approaches through meaningful partnership across a range of actors to support adaptive and holistic wetland management	businesses, producers, consumers, land managers, and government/policymakers	Indigenous peoples and/or local communities
	[I11, I13]transformative changes across economic, social, political, and technological factors	government, policymakers, industries	
	[I13]response options throughout the food system, from production to consumption, including food loss and waste	food industry, waste treatment enterprises	
	[I13]adopting sustainable land management practices and improving access to resources and agricultural advisory services	government, local communities	
	[I4, I9]developing standardized climate-ecosystem monitoring, documentation and data collection of the impacts of extreme events, powered by collaboration with Indigenous communities and their local knowledge	Indigenous communities, scientists	
	[I13]land-use planning and management related to bioenergy	government, regional planning agencies, energy companies	
EU	[E5, E9]setting conservation targets in a spatially coherent manner across national scales, matching conservation needs	conservation agencies	
	[E9, E10]tailoring policies to address regional and local conditions and needs	government (especially at local levels)	local communities
	[E9]implementing a combination of "gray" (i.e., technological and engineering solutions), "green" (i.e., ecosystem-based approaches), and "soft" (i.e., managerial, legal, policy, and market-based approaches) adaptation options	government/policymakers, research and innovation institutions, conservation agencies	
	[E9]multilevel governance that bridges the gaps between the different levels of policy and decision-making	government (at all levels), local communities	

(*Continued on next page*)

Table 1. *Continued*

Level	Arctic policy recommendations implying a nexus approach	Who implements?	Who is impacted?
	[E9, E10]transformational adaptation that involves managing more radical change rather than restoring a certain environmental or social state and sticking with traditional policy responses	EU, government, industries, society, citizens (all sectors)	
	[E10]better integration of environment and climate related concerns into sectoral policies, improved implementation		EC, relevant EU agencies, national government, local governments
	[E8]further work to keep engaging with local and Indigenous peoples who possess knowledge of Arctic ecosystems	EU, Indigenous peoples, research institutions	
	[E12]tackling the barriers that prevent a massive roll-out and scaling up of renewable energy	EU, energy companies	
	[E6, E10]more effective implementation of and funding for environmental policies to boost sustainable practices, such as precision agriculture, agroecology, carbon farming, and agroforestry	EC, member states, government	
	[E10]cross-sectoral policymaking; holistic, coherent policies that take into consideration different sectors and facilitate coordination	government, different sectors and industries	
	[E10]flood protection and drought management	relevant government agencies	local communities, agricultural sectors
	[E5]promoting both economic gains and environmental well-being	government/policymakers	
	[E5]protecting soil health, soil fertility, reducing soil erosion, and increasing soil organic matter; identifying contaminated soil sites, restoring degraded soils, monitoring soil quality	conservation agencies, environmental protection agencies, scientists	
	[E12]developing circular energy, biofuel, and biogas	government, energy companies, local communities	
	[E6]transforming the production methods, making the best use of nature-based, technological, digital, and space-based solutions to deliver climate and environmental results	farmers, fishers, aquaculture producers, technological innovation companies/agencies	
Regional: Nordic/Barents/Sápmi	[R1]recognizing the sustainability goals and Indigenous peoples' understanding of society-nature relationships	government, regional policymakers	Indigenous peoples
	[R9]protecting and improving the state of reindeer pastures impacted by industrial development	industries	reindeer herders
	[R6]enhancing climate resilience and protecting biodiversity	government	local communities

(*Continued on next page*)

Table 1. ***Continued***

Level	Arctic policy recommendations implying a nexus approach	Who implements?	Who is impacted?
National	[N3]promoting low-emission, sustainable, and climate-wise solutions	government/policymakers	
	[N3,N12,N16,N28]promoting Arctic food security by safeguarding the preconditions for local industries and traditional livelihoods, protecting Indigenous rights, respecting traditional knowledge	government, regional planning agencies, industries	Indigenous peoples
	[N3,N10,N15,N16,N27]protecting Arctic species and habitats, strengthening the restoration of degraded ecosystems, forestation, implementing stronger and climate-resilient conservation measures	government, conservation agencies	
	[N3]cross-border collaboration related to transboundary watercourses with Sweden, Norway, and Russia	different national governments	
	[N3]investing in climate-wise infrastructure and promoting circular economy and bioeconomy to bring new opportunities for employment and livelihoods	government, investors	Environmentally friendly industries and companies
	[N15]rapid cuts in emissions to protect species and ecosystems	industries, government	
	[N8]comprehensive planning of fell habitats and reindeer pastures in the face of growing tourism and the increasing exploitation of natural resources	tourism sector, policymakers, regional planning agencies	reindeer herders
	[N6]continuing the time series on species monitoring.	scientists; certain local communities who also conduct monitoring	
	[N10]developing new and sustainable solutions in the forest industry; e.g., how to utilize forests in the face of climate change	forestry agencies, environmental protection agencies, government, research institutions	
	[N12, N23]removal of subsidies, monetary valuation of ecosystem services, limiting habitat loss due to industrial development, substituting fossil energy with bioenergy and biofuels	government	corporations, oil and gas companies
	[N24]minimizing the burning of side production gas in the petroleum extraction	oil and gas companies	people and environment in general
	[N25]requirements for companies to make climate risk visible in their development plans	government	companies or different land-use sectors in general

(*Continued on next page*)

Table 1. *Continued*

Level	Arctic policy recommendations implying a nexus approach	Who implements?	Who is impacted?
Subnational	[S3]Indigenous participation when planning climate actions	Indigenous communities, decision-makers, government	
	[S6, S8, S10, S11]sustainable management of the mountains: regulation and enforcement of the regulations for hunting and reindeer herding, establishing of protected areas, enforcement of protection measures	Indigenous land users and organizations, conservation agencies, government	
	[S6]involving locals in monitoring the tree line change, better modeling to predict this	scientists, monitoring stations, local communities	
	[S8,S10]providing local people with increased information on protected species and imposing stricter control over poaching	government, conservation agencies	local peoples

Governance levels are considered separately. Stakeholders identified for policy or action recommendations are listed either as "Who implements" (responsible bodies; decision-makers, contributors, actors that impose effects) or as "Who is impacted" (target groups; beneficiaries, actors upon whom effects are imposed). When no clear distinction was found in the documents, cells are merged. For numbering and full references, see Note S1 and Table S2.

We clustered the policy recommendations and knowledge gaps from Tables 1 and 2 into five general categories. The first category is about ecosystem-specific solutions taking interlinked nexus elements into consideration. The policy documents proposed ecosystem-specific (e.g., wetlands, carbon-rich ecosystems) solutions for protection and restoration of ecosystems in a way that can mitigate climate change and recognize land use impacts and concerns of local communities. Furthermore, transboundary collaboration recognizing ecosystem boundaries in addition to administrative ones was put forward. This could also help to mitigate environmental hazards (e.g., floods, climate, droughts, soil erosion) across administrative borders. Especially EU-level policy documents highlighted the importance of setting policy targets across scales to meet sustainability goals and respond to Indigenous peoples' concerns, tailoring policies to local and regional contexts, and enhancing cross-sectoral and multilevel governance to address nexus issues.

The second category relates to co-production of knowledge among researchers and Indigenous peoples of intertwined nexus elements. For example, the policy documents suggest future-oriented thinking on adaptation strategies and environmental change and bringing forward realities of Indigenous peoples. In addition, mapping and monitoring ecosystems and their change as assessed by research and collection of Indigenous knowledge was proposed as a method of combining the various nexus elements. Data and closing the data gaps was often seen as a key to many policies, including emergency responses and building resilience. The third category identified links to technological solutions for developing renewable resource use, combining green and gray solutions for transformative change, developing circular economy and smart solutions, and engaging companies in designing and developing environmental solutions.

The fourth category links to adaptive co-management combining science, local knowledge, and local ecosystem management. Policy documents, for example, propose that impact assessment processes should include scientific knowledge and the knowledge systems of Indigenous peoples, that multiple stressors on Arctic species and ecosystems should be addressed by holistic interdisciplinary and transdisciplinary approaches, and that a more holistic approach could be supported by developing advisory services for agriculture. The fifth category links to authoritative solutions with an aim of informing people about ongoing changes and also enforcing regulations on local livelihoods, such as reindeer herding. Nevertheless, traditional livelihoods are seldom mentioned in the policy recommendations and knowledge gaps listed, especially at the international and EU levels.

DISCUSSION

More holistic environmental governance in the Arctic requires nexus approaches: taking into account the complex interactions between climate change, biodiversity loss, increasing land use pressures, and local livelihoods. An overview of whether and to what extent Arctic policies address these nexus elements in concert has been missing. The analysis presented here helps to close this knowledge gap. Above, we examined how assessment reports and policy documents at multiple governance levels considered these nexus elements together. The nexus

Table 2. Examples of knowledge gaps listed in the documents, with governance levels considered separately

Level	Knowledge gaps	Who implements?	Who is impacted?
International/ Arctic	[I10]mapping Arctic wetlands, developing the existing wetland classification systems, also acknowledging indigenous knowledge of wetlands and wetland use	government (e.g., environmental protection agencies), Indigenous communities, research institutions and scientists	
	[I11]developing inventories of understudied ecosystems	government, research institutions	
	[I2,I4,I12]improving understanding and more comprehensive data and projections of precipitation in the polar region, wetting/drying, greening/browning of the Arctic land surface, carbon dioxide and methane emissions from the permafrost, and how changes in these areas affect people environmentally and socio-economically (e.g., Indigenous communities and their food security)	research institutions, environmental protection agencies, data collection agencies, Indigenous peoples	
EU	[E3;E9]better monitoring of past trends of climate change and their economic, social, and environmental impacts	research institutions, data and monitoring stations, government	
	[E10]monitoring the climate-water-ecosystem-agriculture nexus	government, research institutions	
Regional: Nordic/ Barents/ Sápmi	[R8]adaptation strategies on how to face new environmental conditions and shifts in biodiversity and how to match political measures and decision-making to changed realities	government, research institutions	
	[R1]nesting local and regional narratives within global scenario perspectives to increase the possibility for comparing prospects for mitigation, impact, adaptation, and vulnerabilities across different municipalities, regions, and sectors	Indigenous communities, Indigenous associations, non-governmental organizations, government	
	[R8]baseline data on Sámi society, culture, livelihoods	researchers, Sámi communities	
	[R8]research on Indigenous peoples' rights connected to land and territories	lawyers, researchers, government	Indigenous peoples
National	[N5]exchanges of knowledge between researchers and Indigenous peoples in the Arctic	researchers, Indigenous peoples	
	[N6, N8, N9, N27]development of monitoring of habitats, ecosystems and their functions and changes (e.g., reindeer pastures), and rare species	researchers, monitoring stations, Indigenous peoples	
	[N25]further technological developments and research on renewable energy solutions separately and taken together	government, energy companies, research and innovation institutions	
	[N9]strengthening the communication between the reindeer herding communities, food safety authorities, and veterinary research to ensure better monitoring of diseases	reindeer herding communities, food safety agencies, research institutes	
Sub-national	[S7]better consideration of traditional knowledge (árbediehtu); intergenerational transmission of traditional knowledge and Sámi language to secure viable Sámi livelihoods and culture	Sámi communities, government	
	[S9, S10, S11]knowledge of the distribution, ecology, and threats faced by many rare species of insects, plants, and lichens	scientists (especially ecologists)	
	[S14]research-based knowledge needed in livelihoods like fish farming and reindeer herding	scientists, local/Indigenous peoples (e.g., fish farmers, reindeer herders, etc.)	

Stakeholders involved are also listed, either as "Who implements" (responsible bodies; decision-makers, contributors, actors that impose effects) or as "Who is impacted" (target groups; beneficiaries, actors upon whom effects are imposed). When no clear distinction was found in the documents, cells are merged. For numbering and full references, see Note S1 and Table S3.

approach provides a useful way of addressing multiple simultaneous environmental and societal challenges. The approach has been explicitly applied in the Arctic context; for example, by Chuffart et al.[41] (EU-Arctic nexus and the Green Deal) and Huntington et al.[42] (Arctic food-water-energy nexus). In 2020, the Sustainable Development Working Group of the Arctic Council launched the water, energy and food nexus study,[43] contributing to the attainment of the United Nations Sustainable Development Goals in the Arctic (https://www.arctic-council.org/news/nexus-between-water-energy-and-food-in-the-arctic/). The nexus approach is especially timely in the Arctic region, where mutually reinforcing twin crises of climate change and biodiversity loss, in concert with societal and geopolitical changes, are projected to lead to irreversible changes to ecosystems and human communities.[1,2,9,44] Here we discuss two aspects of the nexus approach corresponding to Nilsson et al.'s[38] dimensions under policy coherence: policy outputs and policy implementation. Our analysis provides insights into moving beyond policies addressing single challenges toward a more holistic approach, which also has potential to reduce conflicts and promotes synergies between and within different policy areas.[38] We emphasize that a nexus approach is a key for policies to be able to move toward a sustainable Arctic of tomorrow.

Nexus in policy outputs

Prior research has criticized the nexus approach for not being able to move beyond its buzzword status or for remaining a mainly theoretical approach, and, thus, integrated approaches in sustainable development continue to be the exception rather than the rule.[29] Examined against the backdrop of such criticism and the argument that the nexus approach is in its infancy regarding its application and implementation, unexpectedly frequent and diverse nexus approaches were visible in the Arctic policy documents and assessment reports. Focus on integrated SESs may have contributed to frequent nexus approaches in Arctic research.[45,46] However, addressing nexus elements together in scientific papers or in policy documents are very different issues, even though the European Arctic may be an exemplary region in this sense, with local communities nesting within larger, wealthy nations. On the other hand, the interlinkages between the nexus elements were acknowledged to varying extent at different governance scales. Approximately half of the national- and subnational-level documents analyzed did not consider the "full nexus," three or four nexus elements together, even when the topic of the document indicated a holistic approach.

Local communities, as well as biodiversity, were often seen as something being affected, not as actors with agency or as active drivers of change. This has also been noted in earlier research; it has been pointed out that Arctic assessment reports have a limited view of environmental and societal drivers,[30] and the social and cultural complexity of the region is often forgotten. In our view, to maximize their impact, biodiversity assessments should increasingly incorporate a systemic view; they should consider complex feedback and interactions between species and biogeophysical systems (including subsurface) and human activities, all as parts of manifold SESs. In West Siberia and Northern Fennoscandia, for example, Indigenous Sámi and Nenets reindeer herders have reported changes in height and/or encroachment of woody plants and related alterations in reindeer grazing regimens.[6,47,48] Permafrost degradation interacts with reindeer herding as well.[49] A growing body of evidence suggests that traditional management practices of Indigenous peoples or local communities' ways of life can support conservation[9] and be part of solutions toward climate change mitigation. For example, grazing reduces vegetation height and shrub expansion through browsing and trampling, which, in turn, may influence regional climate change through land-atmosphere feedback.[50–52]

At different governance levels, various categories of human activity or sectors of industrial activity are seen as affecting the other nexus elements. Industrial/sectoral strategies were part of our selection of research material, and at the international level, these concentrated on oil and gas production and industrial pollution; at the EU level on forestry, agriculture, and energy sectors; and at the national and subnational levels on forestry and energy sectors as well as reindeer herding. The selected regional strategy papers (from Nordic, Barents, and Sápmi regions) concentrated on reindeer herding and other traditional Sámi livelihoods. Local Arctic communities have long used ecosystems (for example, as rangelands), and their relationship with the animals as sentient beings, and nature in general, has been central to their worldview and well-being.[53–55] This view of strongly coupled human-non-human interactions dovetails with part of the reports analyzed; land use, local communities, and biodiversity co-occurred in several reports at the subnational level as well as land use and biodiversity.

IMAGINED NEXUS THROUGH IDEAS FOR POLICY IMPLEMENTATION

It is crucial to address not only whether and to what extent existing policy outputs consider nexus elements together but also to consider how these policy documents imagine the role of policy innovations in endorsing Arctic SESs by implementing new practices. We consider that knowledge gaps and policy recommendations found in the documents analyzed represent narratives about what kinds of futures are possible and desirable.[37] These relate to the aspect of policy implementation—arrangements to put policy plans into action.[38] The knowledge gaps and policy recommendations can offer key insights into how abstract nexus approaches can be concretized. In practice, they demonstrate how Arctic policy is imagined to govern interlinking nexus elements in the future while operating within the principles of sustainable environmental governance.

For instance, the category "ecosystem-specific solutions" aims for ecosystem-based management[56] and matching ecosystem and governance scales to avoid scale misfit of environmental management.[57,58] Another example is provided by the categories "co-production of knowledge" and "adaptive co-management," which acknowledge the necessity of co-production processes to engage Indigenous and local communities and also address power relations and governance issues.[59,60] In this context, reindeer herding gains importance at pan-Arctic, regional, national, and subnational levels; reindeer are keystone herbivores in circumpolar SESs. Humans and their semi-domesticated reindeer herds have been affecting landscape-level tundra and taiga ecosystem dynamics for two millennia or longer.[61–64] Co-producing knowledge with herders and

understanding herding at least partly as environmental stewardship would be one way toward better climate change adaptation and mitigation and to avoid choosing policies that may have unintentional and unwanted local and regional side effects.

The categories link to quite different ways of thinking about policy and sustainability. There is no single type of solution to improve the nexus approach, but scientists, technology developers, policymakers, and local communities can and should each have their role and strengths in improving and implementing the nexus approach.

Hidden nexus and other limitations of the study

We found that a nexus is occasionally tacitly considered in policy documents and assessment reports. A key limitation of our methodology is its inability to identify the "hidden" nexuses in documents when they use integrative concepts or umbrella terms[65,66] that cover the interlinkages between the nexus elements without mentioning them explicitly. Several concepts, functioning as umbrella terms and implicitly capturing the nexus approach, were found in the documents analyzed: bioeconomy, circular economy, green transition, resilience, one health, sustainability, and environmental justice, among others. Use of such terms may be an indication that a nexus is actually considered even though the words "climate change," "biodiversity," "land use," and "local communities" do not appear in the text. Therefore, when conducting nexus-related analyses, new methods are needed to capture hidden nexuses through scrutinizing umbrella terms. Furthermore, umbrella terms relate to discourses taking different stances on nexus elements. For example, bioeconomy and circular economy emphasize economic aspects and environmental sustainability. Resilience links to nexus elements as drivers and to the adaptive capacity of SESs, including local communities. Environmental justice starts from Indigenous and local communities' perspectives; they consider fairness aspects of climate change, biodiversity loss, and land use impacts on local communities and the local agency. Therefore, future policy document analyses could focus on the ways in which the documents connect the idea of nexus to key concepts and discourses taking different positions on how the nexus should be thought about and dealt with.

Our results are based on a large set of assessment reports and policy documents selected by an international expert group on Arctic issues (the authors) to represent a balanced sample of relevant Arctic documents. As with any literature review, a different selection of documents could have resulted in minor differences in results; e.g., in frequencies presented in Figure 2. That said, our numeric results are not intended to be taken as a quantitative assessment but as an illustrative starting point for more specific investigations. The generic definition of "nexus" (a set of context-specific critical interlinkages between two or more elements) makes it challenging to robustly estimate whether there is "adequate" use and a clear understanding of the nexus approach present in the documents analyzed. Also, comparable analyses from other regions do not exist. Without a baseline, it is hard to evaluate what constitutes an "adequate" level of the nexus approach. When dealing with any element of the Arctic policy nexus, any assessment report or strategy paper becomes stronger when feedback and interactions with other crucial nexus elements are considered. This said, it is easy to understand that certain sectoral strategies (for example, EU level document E6; see Note S1) and assessments with rather narrow scope (for example, international level documents I1 and I7; see Note S1) leave these complex interactions out of consideration and state that these are outside of the scope of the work.

Conclusions

Our study provides detailed new knowledge of whether and to what extent Arctic policy documents and assessment reports recognize the Arctic policy nexus: the combination of climate change, biodiversity change, land use, and local communities. Furthermore, we examined how challenges related to nexus elements were imagined to be tackled together through analysis of policy recommendations and knowledge gaps identified in policy documents.

Our work revealed some aspects of the existence or void of policy coherence in Arctic policy documents and assessment reports but also identified proposals of how this policy coherence could be strengthened. This increases our understanding of how Arctic challenges can be approached by integrating various policy sectors, like those related to energy production and climate change adaptation.

The potentially significant role of local Arctic communities and traditional livelihoods in environmental governance and societal adaptation is rarely recognized at some governance levels. Inclusion of local communities in Arctic governance may be incomplete at those governance levels because local livelihoods and their extensive land uses are seen only as something impacted, not as something with agency, impact, and related responsibility. The methodology used in the present paper can be applied, for example, when studying the temporal development of the nexus consideration in certain types of documents. Further research could also address nexuses of other elements or examine what specific themes are considered as important in policy documents under the broader categories of climate, biodiversity, and land use and identify the local communities that receive the most consideration who are the ones left behind. Analysis could also be applied beyond the Arctic.

The present geopolitical situation (the Russian war of aggression against Ukraine since February 2022 and its cascading effects) has led to unforeseen consequences for Arctic co-operation. Among others, international treaties, cross-border forums in the Barents and Sápmi regions, the role of the EU in the Arctic, and many Indigenous communities are affected. Hence, it is important for future research to investigate whether the Arctic governance regimens, goals, and collaborations in the policy documents analyzed are still valid. Are the relatively recent Arctic strategies by the Nordic countries and the EU all suddenly outdated? What will happen to the Arctic Council over the course of the next years and decades? Scenarios range from "back to the 1990s" optimism to long-term frozen conflict.[67] With so many open questions, we feel that our analysis (which also includes Russian documents) is timely and will open up new viewpoints and ways of analyzing current and future developments in the region. New collaboration structures will emerge at some point, and climate change and biodiversity loss know no borders.

EXPERIMENTAL PROCEDURES

Resource availability

Lead contact

The lead contact is Sirpa Rasmus (sirpa.rasmus@ulapland.fi).

Materials availability

This study generated no new materials.

Data and code availability

All of the literature reviewed in this study is publicly available online or available from authors upon request (the literature is listed in Note S1). The data for the Figure 2 networks are available in Table S1, analyzed using the igraph package[68] in the R Environment for Statistical Computing and Graphics.[69]

Material selection and document analysis

We used document analysis[39] combined with qualitative and semi-quantitative content analysis to examine whether policies address nexus elements together.[40] The first step was to select a set of documents relevant for the Arctic policy nexus. The spatial scope considered in this study was a terrestrial subregion of the European Arctic (for a definition of the European Arctic, see https://climate.copernicus.eu/ESOTC/2019/european-arctic). This subregion covers terrestrial regions of Northern Fennoscandian countries (Finland, Norway, and Sweden) and the European Arctic part of Russia. In this way, we were able to study a continuous area characterized by several land uses and traditional livelihoods and inhabited by Indigenous peoples where various different-level policies have an impact.

We did not carry out a systematic review. The reason for this is that policy documents and material in languages other than English are rarely found in scientific databases. Also, we did not aim to compile an exhaustive list of all relevant documents because conducting a qualitative content analysis on a very large volume of text would have been very difficult. Rather, we included a comparable number of documents from each governance level and, in the cases of national and subnational levels, from each country (Finland, Norway, Sweden, and the European Arctic part of Russia) and land use sector considered. The author group consists of researchers with a long experience of conducting research on climate, biodiversity, or land use or working with local communities within the study region as well as their interlinkages. Researchers fluent in languages spoken in these countries and knowledgeable about land use issues at these levels suggested documents, and the author group agreed upon the final set of 80 documents (Note S1).

The inclusion or exclusion of a document was determined based on its relevance to the study region and nexus studied and the year of publication. Because our focus was on present and recent developments, the material we considered spanned a period of approximately 10 years, with one document published in 2010 and the rest between 2013 and 2021. Many land use types exist, and livelihoods are practiced within the study region. We selected documents relevant for industrial and traditional types of land use and emphasized the ones that are, especially at subnational level, considered significant for local and Indigenous communities and traditional livelihoods. We were also interested in including documents by different actors (like scientific networks, governments, and Indigenous actors) with differing agendas. At certain governance levels (for example, EU) and from certain publishers (for example, the Arctic Council), abundant material regarding our research questions and study region was available. Because we wanted to keep the number of documents balanced between the levels and actors, there was some subjectivity in making the selection, and our aim was to include a broad range of topics covered by the documents. There is some subjectivity in the method, but the expertise in the author group allowed us to select a representative range and a manageable number of publicly available assessment reports and policy documents relevant to our study region across international, EU, regional, national, and subnational governance levels.

The second step was to analyze the documents to identify, in each, the nexus approach—the acknowledgment of the interactive nature between each pair of nexus elements (Arctic climate, biodiversity, land use, and local communities). Specifically, local communities with livelihoods or lifestyles that depend on local ecosystems were emphasized. The selected documents were published in several languages (English, Finnish, Swedish, Norwegian, and Russian) and were read by fluent, mainly native speakers associated with the author group. Key findings were translated into English for comparative analysis.

The question that was answered for each document and for each pair of nexus elements, was "how are these nexus elements considered in relation to each other?" Direct citations and short descriptions were presented in tables, which were then used to conduct further analyses. To visualize the findings, co-occurrence networks were constructed based on the frequency of reports acknowledging the connections between each pair of the nexus elements, also representing the governance levels (Table S1).

We also identified the acknowledgment of three to four nexus elements together ("full nexus"). An explicit mention of the word "nexus" was not counted. The regional, national, and subnational level documents considered our study region, but the international-level assessment reports had circumpolar Arctic scope, and the perspective of most of the EU-level documents was wider than that of the Arctic. Material relevant for our study region was emphasized when analyzing these documents.

We consider policy documents as plans for action. To capture the normative proposals for future policy implementation, the third step was to identify a set of policy recommendations made and knowledge gaps outlined that we interpreted as representing the nexus approach in the documents analyzed. We clustered the policy recommendations and knowledge gaps using qualitative content analysis and identified key proposals of how policies could better address the nexus elements in an integrated way in the future. We call this "imagined nexus" because both policy recommendations and knowledge gaps are future oriented and contribute to imagining desirable futures. Imaginaries provide grounds for transforming SESs through policy innovations by offering accounts of what kinds of futures are possible and desirable.[37,70] Finally, we discuss the "hidden nexus," as implied by umbrella terms used in the documents that cover the interlinkages between the nexus elements without mentioning them explicitly. Umbrella terms are integrative concepts; they are part of specific discourses, and their use and acceptance by policy actors shape policies and practices in reality.[65,66]

Questions guiding the analysis

The material was analyzed by answering the following nine questions per document. Detailed qualitative analysis on links between the nexus elements is found in the CHARTER (Drivers and Feedbacks of Changes in Arctic Terrestrial Biodiversity; https://www.charter-arctic.org/) project deliverable 6.1 ("Biodiversity and land use narrative synthesis based on an extensive literature review") available at https://cordis.europa.eu/project/id/869471/results.

1.1. How are climate (change/mitigation/impacts/feedback) and biodiversity (change/conservation/impacts/feedback) considered in relation to each other?

1.2. How are climate (change/mitigation/impacts/feedback) and land use (change/governance/impacts/feedback) considered in relation to each other?

1.3. How are climate (change/mitigation/impacts/feedback) and local communities (needs/agency/adaptation/supporting policies/participation/local knowledge, co-management) considered in relation to each other?

1.4. How are biodiversity (change/conservation/impacts/feedback and land use (change/governance/impacts/feedback) considered in relation to each other?

1.5. How are biodiversity (change/conservation/impacts/feedback) and local communities (needs/agency/adaptation/supporting policies/participation/local knowledge, co-management) considered in relation to each other?

1.6. How are land use (change/governance/impacts/feedback) and local communities (needs/agency/adaptation/supporting policies/participation/local knowledge, co-management) considered in relation to each other?

1.7. How is the "full nexus" considered (three to four aspects together)?

2. How are the linkages (climate-land use-biodiversity-local communities) shown in the policy recommendations given?
3. What are the knowledge gaps and research needs mentioned?

Co-occurrence networks

The co-occurrence networks were constructed for the four governance scales to illustrate potential interlinkages between the four nexus elements (biodiversity, land use, climate change, and local communities) in the analyzed reports. First, the material was investigated to capture the paired presence (co-occurrence) of nexus elements; in practice, any two nexus elements were

considered to co-occur when they appeared in the text together *and* the text indicated that one element influenced the other in the Arctic. For example, co-occurrence was recorded when a text discussed the impacts of climate change on biodiversity but not when the text only acknowledged that both climate and biodiversity are changing. This criterion was set to acknowledge the definition of "nexus" as a context-specific, critical interlinkage between two (or more) elements[31] and to measure how often each nexus element was considered a driver.

The networks were then generated by using the number of reports in which the different nexus elements co-occurred as network link weights (i.e., strength of the interlinkage, illustrated by link width in Figure 2), presented in Table S1. Thus, the network links visualize the frequency of reports that discuss each co-occurrence, not the frequency of co-occurrences within the reports. Further, the sizes of network nodes illustrate the frequency of reports in which each nexus element was presented as a driver to the other element. To enable comparisons between the four networks, the link weights and node sizes were standardized to 0-1 by dividing their values by the number of reports for each regional scale. Because the networks are for visualization only, the width of each link illustrates the total weight of the links between each pair of nexus elements.

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.oneear.2023.12.010.

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AUTHOR CONTRIBUTIONS

S.R., J.T.E., B.C.F., M.L., and M.T. conceived the study idea with input from all authors. J.Y., S.R., and J.T.E. designed the document analysis with input from all authors. M.L., M.T., M.K.A., N.S., D.E., T.H., S.R., J.Y., J.T.E., S.K., L.L., T. Komu, J.O.H., and C.R. collected the data (reviewed the material). S.R. and J.Y. designed the co-occurrence network analysis, and J.Y. constructed the networks. S. Sarkki and N.S. made the policy recommendation and knowledge gap analysis. All authors contributed to the writing of the early and final versions of the manuscript. All authors approved the manuscript for publication.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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