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Do Land Use and Land Cover Scenarios Support More Integrated Land Use Management?

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Abstract: In agricultural landscape management, the conventional top-down approaches that primarily focus on market-led responses struggle to preserve the landscape elements essential for environmental sustainability. To address this deficiency, land use and land cover change (LUCC) scenarios promote an integrated understanding of landscape dynamics and highlight the inconsistency between the compartmentalisation of the public sector ("siloisation") and the necessity for management that reflects the interdependencies of socio-ecological systems. This study investigates the extent to which the creation and dissemination of LUCC scenarios lead to modifications in the values, attitudes, and behaviours of local actors engaged in land management, giving particular emphasis to the role of these scenarios in encouraging integrated management. To accomplish this objective, we interviewed local actors who actively participated in the co-construction of the scenario narratives or learned about the scenarios during dissemination workshops. We then analysed the data via a thematic and lexicometric analysis. The findings highlighted the dual function of these scenarios as a catalyst for pre-existing political will to promote integrated management and as a tool for raising awareness about major environmental challenges. At the group level, the outcomes encompassed aspects such as basing political decisions on the results of scenarios and fostering collaboration between institutions. These outcomes were observed among the actors involved in co-constructing scenarios or those with pre-existing motivations to pursue integrated management initiatives. Additional personal outcomes included an increased awareness of environmental challenges and the consolidation of non-formalised knowledge. We argue that combining co-construction and dissemination enhances the outcomes of scenarios considerably.

Keywords: co-construction; dissemination; impact pathways; integrated management; LUCC scenarios; outcomes of scenarios

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1. Introduction

We live in an era in which scientific knowledge emphasising the urgent need for socio-economic paradigm shifts is broadly available [1–3]. Within the scientific community [4–6] and public discourse [7], terms such as "sustainability" and "low-carbon transition" are gaining increasing prominence. However, despite scientists highlighting the importance of valuing and protecting nature for its intrinsic value [8], capitalist systems primarily rely on a neoclassical approach [9,10] that disregards scientific knowledge and citizens' mobilisations against this approach. In the European Union's (EU) rural context, the environmental degradation caused by intensive agriculture and the limited ecological ambition of the recently approved Common Agricultural Policy (CAP) reflect the reticence to change the traditional paradigm [11,12]. Notably, the CAP remains the agricultural economy's fundamental pillar, even if it struggles to promote environmental sustainability and fails to conserve the landscape elements essential for preserving biodiversity, water, and soil [13].

In northwestern France, where this study was conducted, the bocage (hedgerow network) is iconic. Not only does it possess significant cultural and economic value, but it also exerts a considerable influence on biodiversity, field microclimates [14,15], soil–water transfers [16], and groundwater quality [17]. Nevertheless, despite laws and local initiatives promoting bocage maintenance, the length of hedgerows in Brittany continues to decline [18,19]. This reduction in hedgerow length benefits farmers who take advantage of selling wood and a simpler landscape mosaic that facilitates crop production by facilitating labour. This local example shows the failure of the current land management practices and specific top-down measures in translating scientific knowledge into practice. Instead of relying solely on market-led responses that target specific sectors, researchers have highlighted the urgent need to address sustainability issues with an integrated approach that reflects the interdependencies of the socio-ecological system [20,21].

Policy integration refers to "the collaboration of actors from two or more policy domains to integrate aims and concerns derived from one policy domain into another" [22], (p. 553). Initially applied to marine policy [23], integration is now gaining recognition in environmental management, which frequently confronts complex, cross-sectoral challenges [24]. However, a persistent barrier to achieving integrated policies lies in the division of public administration into "silos", composed of relatively stable groups of actors responsible for sub-sectoral policies, each with a specific perception of environmental issues [25]. This "pillarisation" or "siloisation" of the public sector complicates interagency collaboration and hinders a holistic approach to addressing interconnected problems [24,25]. In a framework proposed by Metz and Glaus [26], the authors highlighted how policy integration can be promoted not only by changing the legal framework, but also by favouring the involvement of actors in multiple policy-making sectors. The capacity of public institutions to deliver integrated policies has been examined at various spatial levels (e.g., see Candel et al. [27] for the EU level, Molenveld et al. [28] for the national level, and Metz and Glaus [26] for the catchment level) and across different environmental issues. Within the context of water management, Morgue et al. [29] showed that the little integration between water and land-use issues is one of the most significant challenges in achieving sustainable management.

While there are certain limitations to its application [30], developing sustainability science has been acknowledged as a promising approach to promoting policy integration and enhancing decision-making capacity [31,32]. Indeed, through the involvement of non-scientists in the generation of multidisciplinary, action-oriented research, sustainability science can create bridges between different actors, services, and projects [33].

LUCC scenarios have been recognised as valuable tools for achieving these objectives in land management by offering a spatially explicit representation of how land use and land cover could evolve over a pre-defined timeframe in response to socio-economic factors (such as demographic pressure and economic incentives favouring specific crops) and environmental variables (including climate change). They often combine narratives describing the drivers of LUCCs with mathematical models that translate these narratives into maps and vice versa [34].

This study aims to examine the outcomes, defined as changes in the values, attitudes, and behaviours of local actors [35], arising from creating and disseminating some catchment-level LUCC scenarios, including their role in promoting integrated management.

To meet the goal of this paper, we draw upon a range of previous research. Notably, Akkerman and Bakker [36] investigated the process of learning at boundaries and identified the fundamental mechanisms that facilitate this learning. These mechanisms include identification, which involves acquiring knowledge about the practices of others; coordination, which entails establishing stable and ongoing exchanges; reflection, which involves developing broader or alternative perspectives on practices; and transformation, which encompasses the co-construction of new practices. Besides investigations on learning in the presence of boundaries, a wide range of potential research outcomes has been studied (e.g., [37–39]) and categorised across various levels. For instance, Hamilton et al. [40]

identified project-level (i.e., research credibility, saliency, and legitimacy), individual-level (e.g., increased system understanding), group-level (e.g., the direct use of research results in technical documents, increased collaboration between actors), and system-level outcomes (e.g., a systematic change in attitudes). Moreover, potential outcomes specific to scenarios have also been described. Notably, scenarios have been recognised as a potential support to enhance the comprehension of a complex system by coupling multiple pieces of information into a coherent and systemic perspective of how landscapes may transform [41,42]. In parallel, they can widen the range of elements, drivers of change, and potential futures under consideration [42]. Additionally, scenarios facilitate communication and collaboration among participants with diverse perspectives, enabling them to address problem framing collectively [41,43]. This collective effort can promote an integrated management that accounts for interactions between landscape elements and socio-economic transformations [44], thereby overcoming the "siloisation" of the public sector. The occurrence of these various outcomes can be subject to different time lags, and the process employed to generate and communicate the research assumes a central role in shaping these outcomes. Muhonen et al. [45] summarised how the interactions between scientists and other actors can take various forms, resulting in different impact pathways. They identified thirteen pathways through which research can have societal impacts, ranging from the linear "classical pipeline pathway", where scientific knowledge permeates society through "knowledge creep", to more complex models of interaction. Although the impact pathways and societal outcomes of this research have been relatively well-documented, scientists may lack a comprehensive understanding of the land management system, including an overall vision of its local actors and the relations among them [46]. This limited understanding of social dynamics can lead to ineffective interaction strategies and hinder potential outcomes. In addition, establishing a coherent spatial extent of scenarios is essential for promoting desirable outcomes. Indeed, developing scenarios that align with the operating boundaries of local actors can foster a rise in these outcomes. Nevertheless, a trade-off exists between spatial resolution and spatial extent [47], i.e., if the goal is to highlight the interactions between landscape elements and socio-economic changes (such as the development of different agricultural systems or changes in population density), a high spatial resolution, down to the field level, is needed. However, scenarios with a higher spatial resolution often cover smaller areas, which may not correspond to the operating boundaries of certain land management actors. For instance, water and land managers are often responsible for separate administrative sectors with jurisdiction over different yet overlapping areas [48]. Therefore, evaluating how a coherent spatial extent between scenarios and operating boundaries influences these outcomes is essential to enhancing the outcomes of scenarios. In summary, when evaluating outcomes, it is crucial to consider the mechanisms of information exchange between researchers and local actors, the timing of the evaluation, and the spatial extent of scenarios as factors that play significant roles in shaping the outcomes of scenarios.

In this study, we examine the outcomes of the LUCC scenarios published by Houet et al. [19]. These scenarios were co-constructed with water and urban land managers and disseminated to a broader audience through a series of workshops. During these workshops, we conducted a first short-term assessment to evaluate the usability of the scenarios (for detailed information and results, refer to [49]). Then, between 7 to 11 months after the workshops, we interviewed some local actors who participated in the co-construction process or the dissemination workshops to identify personal and group outcomes in the long-term. This article focuses on a long-term assessment of outcomes.

2. Context and Materials

The assessed scenarios were developed as part of the EU INTERREG project ALICE[1] and focus on evaluating the impacts of agricultural and urban changes on water quality, quantity, and biodiversity (through the lens of landscape connectivity). The scenarios

cover the Couesnon River catchment in northwestern France, which spans an area of 1130 km^2 [19], and consist of contrasting narratives illustrated by LULC maps.

Agricultural development could evolve in three directions: the "cerealisation", which favours producing cereals as biomass or biofuel; the "dairy intensification", which favours the intensification of local dairy/livestock production; and the "greening" direction, in which the CAP promotes dairy and livestock production based on grassland forage. Territorial development respects local urban management plans such as the BGINs policy, a local adaptation of the EU's Biodiversity Strategy that serves as a driver for changes in land use and land cover by limiting the possible expansion of urban areas. Territorial development is also driven by the social demand from inhabitants for certain types and locations of housing. Three different evolutions are proposed for this territorial development: in the first ("business-as-usual"), only the main BGINs are protected from urban sprawl, and the objective of zero urbanisation is not attained in 2040; in the second ("energy transition"), the urban sprawl is controlled, concentrated in the main urban areas, and the zero-urbanisation objective is met by 2045, strongly preserving BGINs; and in the third ("ecological citizen"), the zero urbanisation objective is not met. However, BGINs are strictly preserved, and local authorities favour ecological preservation and restoration.

Combining these 3 × 3 assumptions creates eight internally consistent scenarios (one combination is inconsistent). The five most contrasting scenarios (bold in Table 1) were selected to explore the widest diversity of possible future landscape changes.

Table 1. Combination of territorial and agricultural development assumptions. The five most contrasting scenarios (in bold) were selected to explore the widest diversity of possible futures. Source: [19].

		Territorial Development		
		Business-as-Usual	**Energy Transition**	**Ecological Citizen**
Agricultural development	Cerealzation	**DESERT OF CEREALS**	**ENERGY PERFORMANCE**	CONFLICTS
	Dairy intensification	**BUSINESS AS USUAL**	DIVERSIFIED BIOMASS	**DOUBLE PERFORMANCE**
	Greening	Ø	OPTIMISED BGINs	**GREEN ATTRACTIVENESS**

These assumptions were presented to, refined, and completed with stakeholders during a first participatory meeting. A second participatory meeting helped to specify them by considering local characteristics through narratives and participatory mapping. The researchers then refined and quantitatively illustrated the narratives and calculated the impacts of the simulated LUCCs on biodiversity and water resources.

The project was initiated by scientists who collaborated with water and urban land managers to develop the scenarios. The narratives were co-constructed with a panel of local actors and used as inputs for an LUCC model to simulate future landscape changes [50,51]. Then, the results of the scenarios were disseminated to a broad audience through 13 workshops (see Supplementary Material S1 and S2 and [49] for more details). During each workshop, the method and results of the scenarios were presented to an audience with the same professional activity. Following the Muhonen et al. [45] framework, we followed two pathways to create the research outcomes: the "collaboration pathway" for local actors who co-constructed scenarios and the "interactive dissemination pathway" for local actors who participated in the dissemination workshops. During the workshops, the participants engaged in discussions about the results of the scenarios and the implications they had for their respective professional activities. To assess the usability of the scenarios, an interactive polling system was used and the results indicated that local actors generally considered the scenarios to be legitimate, salient, and credible. Moreover, the scenarios were effective in increasing the awareness of future land management problems and understanding the interdependence of landscape elements [49]. The survey conducted during the workshops revealed that the respondents had high confidence in the research results, and this confidence did not differ significantly among the professional activity groups nor as a function of

familiarity with the study area. In addition, representatives considered the projected water quality and quantity trends to be more relevant to their professional activity compared to the biodiversity trends, while technicians and members of civil society expressed no significant difference.

The scenarios envisioned LUCCs in the Couesnon catchment (Figure 1). The interest lies in the fact that farming activities have resulted in significant water quality issues, making residents particularly sensitive to water management tensions [52,53]. Additionally, water quantity tensions caused by climate change have recently emerged as an environmental problem.

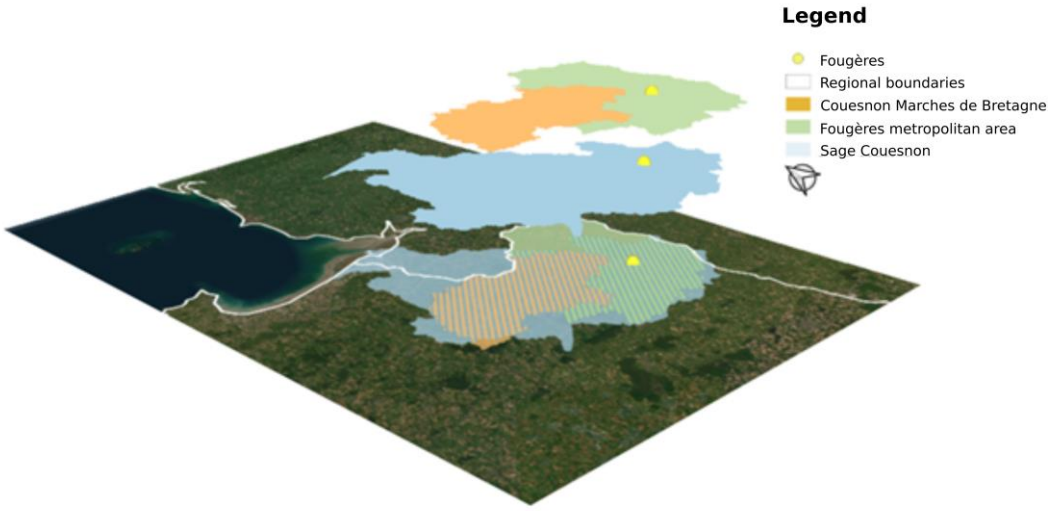

Figure 1. The extent of the scenarios covers the SAGE Couesnon (light blue). The intermunicipalities of Couesnon Marche de Bretagne (orange) and the Fougères metropolitan area (green) share the same urbanisation policy (i.e., SCOT Pays de Fougères). The yellow dots represent the city of Fougères. The sage Couesnon covers 1130 km^2.

The Couesnon catchment represents well the multiscale decision system while maintaining a manageable level of complexity, and scenarios were developed at a consistent extent for local water managers' structure, the "SAGE[2] Couesnon", an administrative organisation in charge of managing water resources sustainably. Regarding urban land management, the intermunicipality level serves as its main organisational level. Intermunicipalities are groups of municipalities that jointly manage local public services and promote sustainable development in urban and rural areas. The management of urbanisation within the catchment is often carried out through a "territorial coherence scheme" (SCOT[3]), which involves multiple intermunicipalities jointly coordinating a unique urban development plan. In the Couesnon catchment, there are nine intermunicipalities in total, with two of them covering a significant portion of the territory and sharing the same SCOT (Figure 1).

3. Methods

3.1. Interviews

To ensure a comprehensive understanding of the outcomes of the scenarios, we selected one to two interviewees from each workshop for an in-depth interview. The selection criteria aimed to include a diverse range of perspectives and roles within land management and focused on actors who had solid interpersonal connections with the other participants and a high visibility in the initiatives and actions taken by their organisation or group. The workshop sessions involved key actors from water management, agriculture, and urban planning sectors including farmers, technicians, and elected representatives at different organisational levels (see Supplementary Material S2 for details). To limit acquiescence bias, the interviews were conducted by a researcher who participated in the dissemination of the scenarios, but not in their construction.

The interviews were conducted 7–11 months after the workshops. Indeed, we considered that this time lag allowed for group effects to emerge while ensuring that the interviewees could recall the workshop supports and discussions. All the interviewees gave orally informed consent to participate in the study.

In total, we conducted 20 interviews that lasted 27–88 min (mean: 52 min). The objective of these interviews was to gain insights into the network of local actors involved in land management at various organisational levels and to understand the outcomes of the LUCC scenarios for these actors. The interviews were structured into three parts: (1) In the first part, a semi-structured interview approach was employed to understand the interviewees' professional activity, their relations with other land management actors, and the main benefits they derived from participating in the workshop. If necessary, a follow-up question about the salient points of the workshop was asked. (2) The second part of the interview involved a reactivation technique, where the interviewees were encouraged to revisit and further discuss the workshop situation with the aid of images. The aim was to gain insights into additional outcomes of the scenarios. To facilitate this discussion, a booklet summarising the methodology and results of the scenarios was provided, along with the interactive poll responses collected during the workshops. (3) The final part of the interview focused on framing how the interviewee had experienced the workshop and what the interviewee had considered to be the outcomes of the scenarios. This allowed for a detailed exploration of specific outcomes and ensured alignment between the interviewer and interviewee's understanding of the situation.

3.2. Data Analysis: Thematic and Lexicometric Analysis

The interviews were transcribed manually using Sonal software [54] and examined using a thematic and lexicometric analysis. The former was conducted on the entire corpus, allowing for a more refined understanding of the diagram depicting the land management actors, their interconnections, and the different organisational levels at which they operated. The lexicometric analysis, on the other hand, was performed on a sub-corpus using the Iramuteq[4] open-access software. The sub-corpus consisted of interview excerpts specifically related to the main outcomes of the workshops. Each interview extract was coded as a text associated with relevant variables, such as the interviewee code, the professional activity, and the correspondence between the interviewee's working scale and the spatial extent of the scenarios. To prepare the sub-corpus for this analysis, all the interview excerpts were compiled into a single file and acronyms were standardised. Additionally, compound words were combined into single units following the procedure recommended by Carmago and Justo [55]. The sub-corpus was then automatically lemmatised, with words categorised into active forms (i.e., adjectives, adverbs, nouns, and verbs) used for the analysis and supplementary forms excluded from the analysis.

Following the preparation of the corpus, we employed the ALCESTE method [56] to perform a descending hierarchical classification (DHC). This method sorted the text into classes that had highly similar vocabulary within their classes but different vocabulary between them. To quantify the associative strength between the words and their respective class, Iramuteq used the χ^2 test. Only words with an χ^2 of $\geq$3.84 (indicating a probability of 0.05 of being randomly associated with the class) were assigned to a given class. The resulting classes and their relationships were visualised through a dendrogram and a factorial correspondence analysis (FCA) resulting from the DHC [55]. The FCA plotted the most statistically significant words for each class on a two-dimensional plane. Once the classes were defined, we qualitatively analysed the extracts that contained the classified words.

Interview citations were translated literally from the original language (French) to English. Figure 2 represents the overall workflow followed to develop the Couesnon scenarios and assess their outcomes.

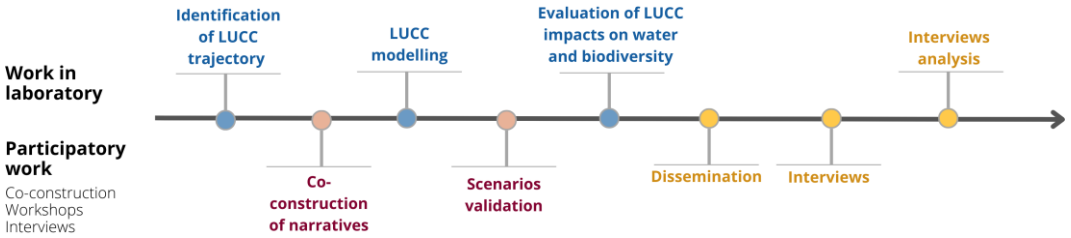

Figure 2. Overview of the method used to develop Couesnon scenarios (combining studies carried out by researchers only in laboratory—in blue—and steps involving local actors—in red) and assess their outcomes (in yellow). This study concerns results related to the steps marked in yellow.

4. Results

4.1. The Land-Management System

Figure 3 illustrates the influential documents, financial mechanisms, and local actors involved in the land management of the Couesnon catchment, including its water management, agriculture, and urban planning (additional information in Supplementary Material S3). The connections between levels and sectors were characterised mainly by administrative, financial, and technical aspects. Administrative connections involved the integration of documents into lower-level directives and legal documents. Financial connections encompassed funding projects and providing incentives. Technical connections provided support in defining policies and administrative documents. The actors were classified based on their sector (i.e., water management, agriculture, or urban planning), their organisation level (i.e., communal, sub-regional, catchment, regional, national, or Europe), and their type (i.e., administration, political, technical, or civil).

Water management primarily occurs at the catchment level, as reflected in the scenarios' spatial extent. The Local Water Commission (CLE[5]) and the Syndicat of the Couesnon catchment are, respectively, in charge of approving and implementing the Water Development and Management Plan (SAGE). The SAGE is connected to urban planning through legal documents and human interactions involving technical support.

On the other hand, the integration between water policies and agriculture relies on farmers who apply for funding mechanisms. These mechanisms primarily come from the EU and are supplemented by regional funding and sustainable farming projects, with the Breizh Bocage and Terre de Source[6] projects being prominent examples. At the local level, the development of an agricultural system that benefits water quality and quantity depends on the availability and willingness of farmers. In the current administrative system, the regional level appears to be effective for promoting integrated water and agricultural policies, as it encompasses political and administrative organizations that cut across different sectors.

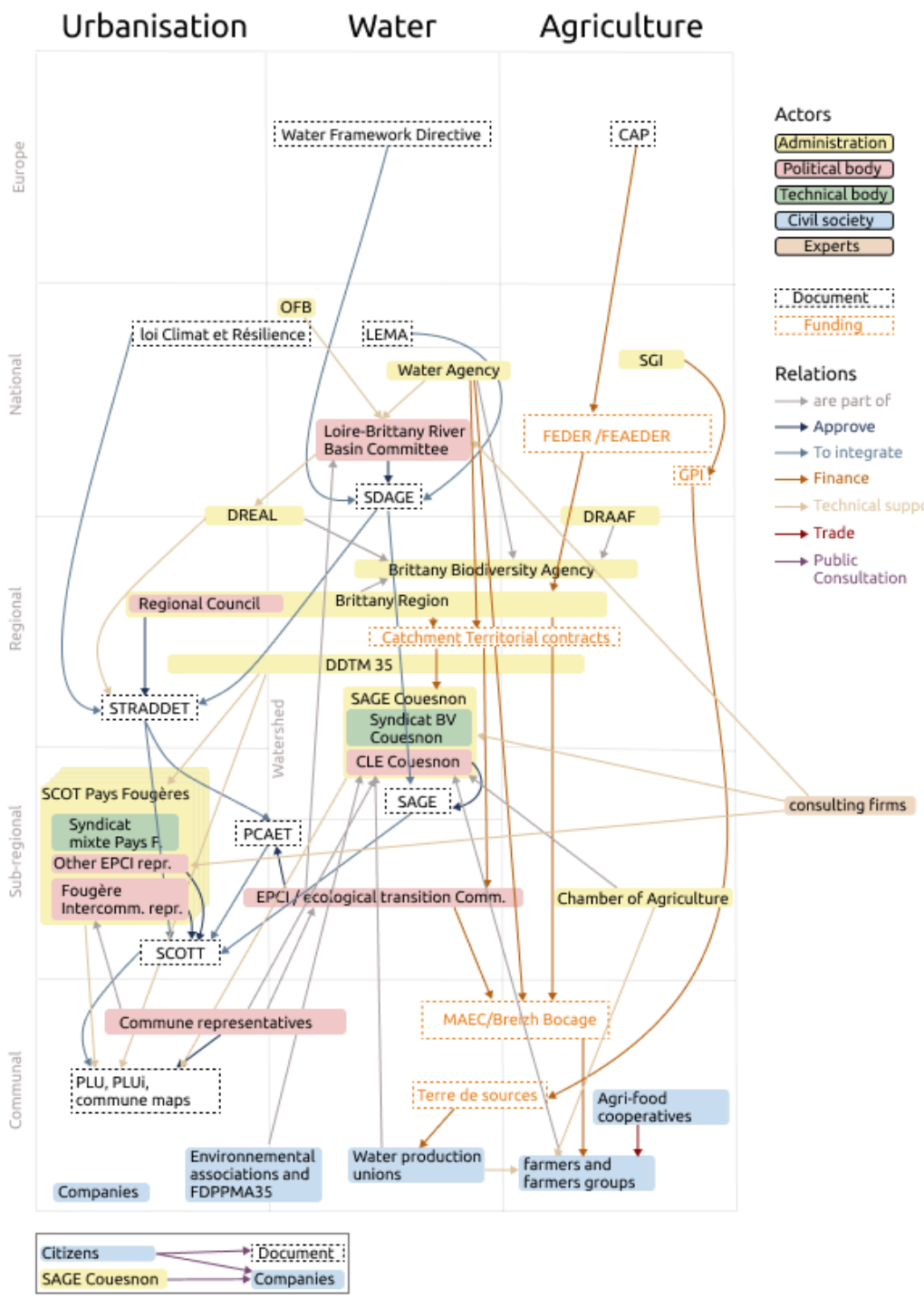

Figure 3. Actors involved in managing water in the Couesnon catchment and their relations with urban planning and agriculture actors. The diagram is not exhaustive and does not represent elements of agriculture or urban planning that are not related to water management.

4.2. Lexicometric Analysis

In order to gain insights into how the interviewees perceived the scenarios, we applied a lexicometric analysis (DHC) to the semi-structured section of the interviews, which addressed the primary outcomes of the workshops. The analysed corpus consisted of 6424 instances, including 486 hapaxes (7.6%), with an average of 338 occurrences per text (Table 2 reports the most recurrent words and their frequency).

Table 2. Most recurrent words of the semi-structured section of the interviews and their frequency.

Words	Frequency	Words	Frequency
Go	42	Small	14
Scenario	38	Couesnon	13
Questioning	30	Feel, tool, interesting	12
Water, thing	25	Project, become aware	11
See, territory	23	Remember, word	10
Level	20	Take, talk, moment, cereal, arrive	9
Representative, find, think	18	Return, put, river catchment	8
CLE	17	Energy, true, work, tendency, use, Scot, look at, mark, culture,	7
Allow, people	16	covid, change, climate change, Brittany, opinion, agriculture	

Overall, 747 active forms and 98.4% of the text segments were included in the analysis, which is considered to be an effective use of elementary context units [55]. The application of DHC to all the interviews revealed that the discourse was organised around four principal semantic blocks or classes, as depicted in Figure 4.

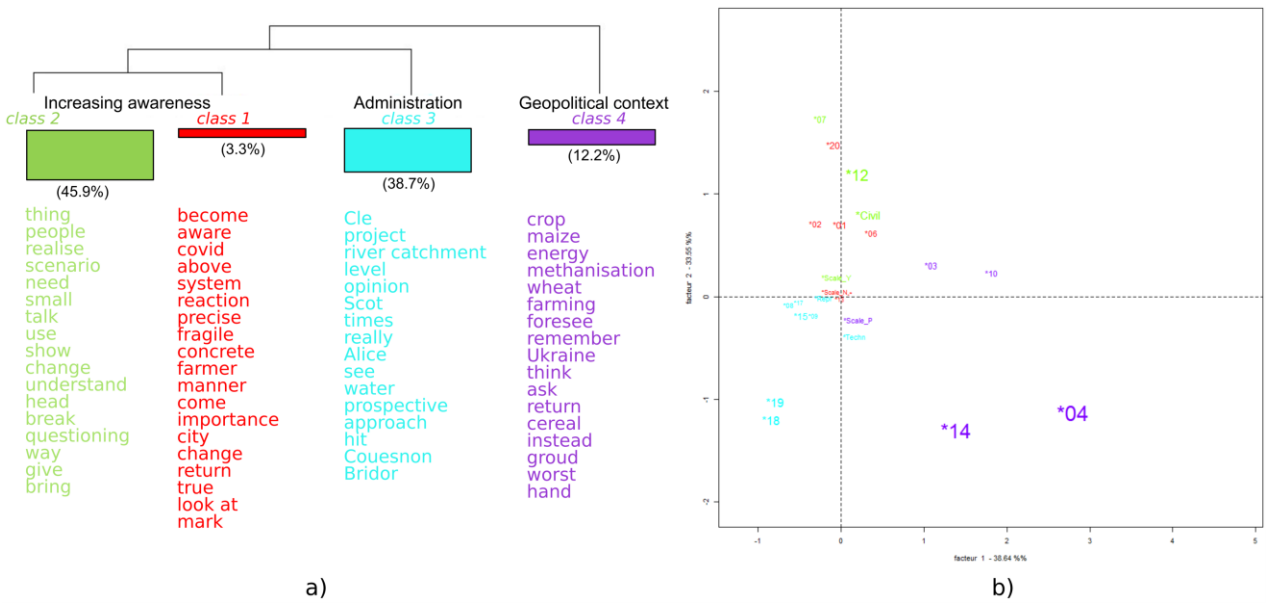

Figure 4. (**a**) Dendrogram of the four lexical classes obtained from descending hierarchical classification (DHC) of the active words, with the percentage of all classified words in each class, and (**b**) factorial correspondence analysis (FCA) of variables in each of the lexical classes obtained in the DHC. Variables are the interviewee code, the correspondence between the area covered by scenarios, and interviewee's organisation level and interviewees' professional activity. The spatial scale of the area covered by scenarios was considered to be completely consistent with that of the interviewee's organisation level (Scale_Y) when the latter was the Couesnon catchment (or entirely covered by it), not consistent (Scale_N) when the latter was another catchment or lay entirely outside the Couesnon catchment, or partially consistent (Scale_P) when the latter partially overlapped the Couesnon catchment (e.g., SCOT Pays de Fougères).

The first (the most significant) and second classes contained words associated with rising awareness. The third class focused on the practical application of scenarios within an administrative context, while the fourth class encompassed words related to the geopolitical context.

The technicians and elected representatives tended to employ more terms linked to instrumental applications, whereas the farmers and residents (coded as "civils") considered scenarios as a means to increasing awareness. When examining the scenario outcomes,

most interviewees mentioned words associated with agriculture and water, while words related to urban planning were notably absent[7].

During this phase of the interviews, there was minimal mention of the technical aspects of the scenarios, including their spatial extent, resolution, underlying assumptions, or the specific protocol employed during their development.

Conversely, analysing the contextual use of the words within the fourth class, it became evident how the interviewees connected one of the scenarios, which described an increase in cereal production and increased cereal planting, as a consequence of the war in Ukraine and the subsequent escalation in cereal prices.

Through a qualitative analysis of the entire corpus, we observed that the interviewees discussed how the current geopolitical context disrupts the existing status quo, tilting the world toward one of the scenarios. Although we cannot assert a cause–effect relationship between participating in the workshops and an increased ability to identify connections among landscape elements, the interviewees demonstrated a notable level of transversality when discussing the current geopolitical context. For instance, the interviewees who mentioned the increase in cereal production also talked more broadly about the homogenisation of the landscape and its effects on water quality and the economy:

> *Three things struck me: the apocalyptic scenario [producing only] wheat, the fact that Brittany could get out of this dairy-based economy, and the fact that the most environmentally-friendly and alternative scenario was the least applicable. For me, it was a sort of: 'But why will this scenario, which is the most local, the one that respects the environment and people, not be the one ultimately implemented?'. And then we always come back to economic questions. And I wonder today, with the war in Ukraine, if we are not moving towards [producing] more cereals here, too? And thus, the whole landscape changes.*
>
> *(Interviewee 12, Resident)*

> *It allows us to ask questions from a land-use viewpoint, but also consider the energy aspect. What does it mean if a farmer produces energy, and what are the potential consequences on our soil?*
>
> *(Interviewee 13, Resident)*

4.3. Identification of Outcomes

The lexicometric analysis showed that the interviewees considered scenarios as a tool for increasing awareness and as a support for administrative procedures. The thematic analysis identified more specific outcomes of the workshop for each interviewee (Table 3). Following the framework of Hamilton et al. [40], we classified the outcomes as either individual or group.

4.3.1. Individual Outcomes

The most commonly mentioned outcomes of the scenarios were individual. These included an increased awareness of water tensions, a consolidated political viewpoint, and the acquisition of new technical knowledge or factual information. The interviewees expressed an increased awareness of the potential water and biodiversity challenges the region might encounter. They emphasised the significance of implementing appropriate measures to address these issues and mitigate their impact.

> *What will happen in 20 or 30 years if the area of maize increases by 30% to 40% as planned? That shocked me.*
>
> *(Interviewee 04—Elected representative)*

> *Above all, the awareness of the fragility and the importance of reacting. . . In the scenarios, you showed well that today's choices will have an effect on 2050.*
>
> *(Interviewee 15—Representative)*

Table 3. The presence (green cell) or absence (white cell) of outcomes for all interviewees identified by thematic analysis. Interviewees participated in scenario co-construction (CC) or in scenario dissemination workshops (W).

				Outcomes					
				Personal Level			**Group Level**		
Int. Code	**Role**	**Participation**	**Consistent Spatial Scale?**	**Rising Awareness**	**Consolidate Viewpoints**	**Learning/Assessing Current Situation**	**Collaboration between Actors**	**Base for Future Work**	**Decision Making/ Influence on Political Will**
03	Farmer	W	Y	■		■			
07	Farmer	W	P			■			
13	Resident	W	N	■					
12	Resident	W	Y	■	■	■			
20	Representative	W	Y						
04	Representative	W	Y	■					
05	Representative	W	Y	■	■				
15	Env. Representative	W	Y	■	■				■
02	Env. Representative	W	Y	■					
01	Env. Representative	W	P	■					
06	Water Technician	W	N	■					
17	Water Technician	W	N	■					
18	Water Technician	W	N		■				
08	Water Technician	CC	Y		■				
14	Water Technician	CC	P	■			■	■	
11	Agric. Technician	W	Y	■	■	■			
16	Env. Technician	W	P			■			
19	Env. Technician	W	P		■		■		■
09	Env. Technician	W	N						
10	Env. Technician	W	N						

According to the survey submitted during the workshops, the participants stated that the scenarios enhanced their understanding of territorial dynamics rather than the challenges specifically faced by the territory. Nevertheless, in the long term, the interviewees predominantly mentioned an augmented awareness of future water-related issues. Some interviewees also highlighted that the workshops served to consolidate their pre-existing, non-formalised awareness:

> *This study left a mark on me, and the fact that it reinforced my thoughts gives it strength. Because we tell ourselves: 'What I feel is confirmed by a serious study', and thus it allows us to be more confident in the debates that can take place elsewhere.*
>
> *(Interviewee 05—Representative)*

In the semi-structured interviews, the interviewees cited the specific details and results of the scenarios, indicating that they acquired specific concepts:

> *One-third of the Couesnon's flow taken by the city of Rennes. . . Some key figures like that. We were not aware of this. [. . .] If I recall, [the quantity of water] also shocked us. The volume did not change much, but it was the distribution. The water did not arrive at the right time for agriculture. And this is catastrophic.*
>
> *(Interviewee 03—Farmer)*

4.3.2. Group Outcomes

The outcomes reported by most interviewees were primarily at the individual level. Nevertheless, some group outcomes were also mentioned. According to the short-term survey, representatives and technicians were more inclined to use the results of the scenarios compared to members of civil society. Additionally, water resource data were perceived as more likely to be used than biodiversity data. The long-term interviews aligned with the survey results.

During the workshops, technicians and representatives acknowledged the effectiveness of multidisciplinary scenarios as a tool for promoting integrated management. In the interview conducted several months after the workshops, technicians of the Brittany Region and the SAGE Couesnon confirmed this observation, recognising an increased level of transversality in their activities. First, a technician of SAGE Couesnon recognised closer collaboration between the SAGE and SCOT, two entities with distinct areas of expertise (water management and land management, respectively):

> *There was interesting joint work between SCOT and SAGE when we worked together on the ALICE project. [. . .] The same list of people worked on their workshops. [. . .] Because of this exchange that was created, he [a technician from the SCOT] made me give several presentations to the SCOT environment commission about water-quantity problems. He saw that we were talking about [urbanisation] differently with the ALICE project, and he said to himself: 'This message via the SAGE and the ALICE project [. . .] allows representatives to see that tomorrow they will face water-quantity problems.'*
>
> *(Interviewee 08—Water technician)*

> *We wouldn't have participated if only BGINs had been considered; we wouldn't have been legitimate. That's also why [. . .] I said that I couldn't see myself working on this without the SCOT, which works on the land-use-planning part.*
>
> *(Interviewee 08—Water technician)*

The collaboration between SAGE and SCOT was strengthened throughout the entire co-construction process of the scenarios, enabling both organisations to solidify their exchanges and cooperation.

Another example comes from the regional administration, which is formed by specific departments and services in charge of agriculture, water management, and urban planning (see S3 for more details). In this case, technicians operating at the regional level participated only in a scenario dissemination workshop.

> *It was good for us to have this exchange between the Region's services because sometimes we have different mind-sets. [The workshop] allowed a real exchange in transversality, regardless of the position of the services. [Before the workshops], a small group already existed, but it was not easy to lead. It was even a bit stuck. Sometimes there were misunderstandings, and it was difficult reach agreements. I think that [the workshop] was the starting point for moving forward. In the weeks that followed, we succeeded in making a common proposal to coordinate our policies on the bocage, water, and BGINs. It's not yet the end of the road, but I think that the work between technical services advanced a little afterwards. [. . .] For the moment, we don't have political approval. There are a lot of steps to go through. But it has made us think. That's for sure.*
>
> *(Interviewee 19—Environmental technician)*

It is worth mentioning that it was the technicians of the Brittany region who initiated the contact to organise the workshop, indicating a pre-existing motivation to enhance the cross-disciplinary nature of their policies. In this context, scenarios must be considered as tools that accelerate a pre-existing dynamic. The disparity in the spatial extent between the scenarios and their organisational level was not a limitation.

Furthermore, the scenarios directly influenced a decision-making process of the CLE, which cited the results of the scenarios in a notice regarding the potential establishment of the Bridor agrifood company in the territory.

> *For the CLE, there was a before and after [the ALICE project]. We saw it in the decisions that followed. [. . .] For Bridor, this was very clear. [. . .] Before ALICE, the question of the influence of today's decisions on long-term projections was not necessarily taken into account. [. . .] When the day for the notice[8] arrived, we did not oppose the establishment, because it is not our job, but we strongly warned that there was a limit that must not be reached. In fact, it was necessary to avoid situations with too much water consumption. [. . .] With the Bridor case, for all the representatives of the CLE it was like a little thing that happened, like saying: 'Ouch, we have a problem there! It's our water. We already don't have much of it. We have to think about our next decisions.' [. . .] There was a real shift, and this was felt in the relations between the territory of the Couesnon catchment through the CLE and Rennes. For the first time, we dared to say: be careful. You have to leave us some water. [. . .] It is this 'be gentle' that the CLE had never dared to say. We said it.*
>
> *(Interviewee 15—Representative)*

In this case, the members of the CLE referred to the scenarios as a scientific source, specifically highlighting the significant decrease in water availability in the catchment area by 2050. Based on this information, the CLE requested the agrifood company to provide a long-term estimation of its water consumption as a condition for obtaining permission to establish itself in the territory. Although this notice represents a single decision rather than a systemic change, the interviewed member of the CLE also emphasised the need for a transformation in the decision-making system. Indeed, the interviewee expressed the need to conduct a water resource availability analysis preceding an economic one, particularly when providing opinions on the establishment of industries.

4.3.3. Other Outcomes

In the months following the workshops, the main scientific and administrative partners were invited to the annual conference of the Brittany Biodiversity Agency. During this event, they presented the Couesnon scenarios as an example of a research project designed to support decision making. The research team and SAGE Couesnon also prolonged their collaboration to further refine the quantitative results of the scenarios and include them in the development of agricultural water use scenarios. In addition, the ALICE scenarios were referenced in the working version of the roadmap for the BGIN management of the Regional Directorate for the Environment, Planning and Housing (DREAL[9]), as an as an

illustrative example of how research can serve as both an awareness-raising tool and a resource for decision-making support.

5. Discussion

5.1. The Impacts of Scenarios on Integrated Management

Although the local actors generally acknowledged the need for more integrated management, joint initiatives among land management services were not the norm in our case study. Legal obligations ensure a basic integration between water management and urban planning, primarily at the local level (i.e., catchment and intermunicipality). However, this integration between water management and agriculture remains limited, reflecting the absence of significant mechanisms at the local/catchment level and the dominance of EU and regional policies [19].

In our study, the interviewees acknowledged the valuable role of scenarios in strengthening the collaboration between communities of practice, such as between the SAGE and SCOT, and between the different services of the Brittany region. Indeed, even though these services belong to the same organisation, they have different habits, missions, and tools. During the workshops that involved representatives from these organisations, the notion of a "boundary" was most explicit (i.e., the interviewees referred to different areas of expertise, mindsets, and tools). However, a shared vocabulary was already present in both workshops and the scenarios did not introduce entirely new knowledge. Drawing on the classification proposed by Akkerman and Bakker [36], learning occurred through a reflection process, in which technicians from different services or organisations simultaneously examined their practices and reflected on ways to coordinate them.

During the interview phase, technicians from the region made a joint proposal to coordinate their financial and administrative tools. However, political approval was still needed. While the scenarios contributed to strengthening collaborations, the exchanges that followed the workshops were not organised around scenarios, but rather focused on day-to-day working issues. In this sense, the scenarios did not directly foster integrated management, but instead shed light on existing organisational limitations and controversial policies, reactivating a social dynamic of inter-organisation/inter-sector collaboration.

5.2. The Influence of Spatial Scale and Impact Pathways on Scenario Outcomes

The spatial mismatch between the scenarios (Couesnon catchment) and administrative boundaries (Brittany) did not hinder cooperation efforts. To capitalise upon the pre-existing willingness to work transversally, regional technicians were primarily interested in the connections between landscape elements, which can be well represented by local and high-resolution scenarios compared to higher-level ones. Far from considering that the spatial extent and resolution of scenarios do not influence the promotion of integrated management, we argue that local scenarios were suitable in this case, despite not aligning with Brittany's boundaries. At the local level, the SAGE and SCOT occasionally collaborated to provide advice on local urban planning schemes. However, their technicians did not participate in scenario construction with the conscious objective of fostering collaboration between their organisations. Therefore, a consistent extent was crucial to generating interest among these organisations for a co-construction process. Ensuring a consistent spatial extent was also crucial for the instrumental outcome, as evident in the mention of the ALICE scenario results in the notice regarding Bridor's potential establishment. Indeed, the water quantity results stemmed from the scenarios accurately reflecting the local reality.

An adequate spatial extent also generated curiosity among the participants in the dissemination workshops who had no specific expectations, such as representatives of the intermunicipalities. Many of these representatives acknowledged that the scenarios helped them enhance their awareness of local water tensions. Beyond the individual nature of this outcome, an elected representative at the Pays de Fougères intermunicipality and at the CLE considered that this personal increased awareness facilitated collaboration among the representatives who participated in the workshop. Indeed, the scenarios facilitated

the establishment of a common understanding of the situation, particularly regarding water quantity issues, which became a widely recognised problem. To understand the complementarity between the co-construction and dissemination, it is worth noting that the representative who assisted us in organising the workshop for the intermunicipalities belonged to an organisation that was actively involved in the co-construction process and possessed in-depth knowledge of the process that led to the scenario outcomes.

Although our assessment is based on a specific case study, we believe that the lessons learned can be applied more broadly. Indeed, the complementarity of the co-construction and dissemination pathways could be relevant for any research on sustainable study. Moreover, the dual role of the scenarios, serving as catalysts for pre-existing political will to promote integrated management and as a tool for raising awareness, can be transferred to other scenarios.

5.3. Limitations and Open Questions

The findings of this study indicate that scenarios are effective in facilitating group outcomes, including for organisations operating at higher organisational levels. However, although the workshops encouraged interdisciplinary exchanges among organisations working at the same level, the interviewees did not report inter-level outcomes. Creating ad hoc workshops mixing actors working at different organisational levels could help to explore the potential of scenarios in generating inter-level discussions. Additionally, considering that economic factors significantly influence farmers' decisions, incorporating economic indicators into scenarios (e.g., yield loss due to climate change and biodiversity decline) would promote the integration of agriculture and water management at the local level.

The interviewees recognised the contribution of the scenarios in reflecting on agriculture and water tensions. However, there was a notable lack of discussion regarding urbanisation and biodiversity, despite their significant role in the scenarios. Only two interviewees, who were either involved in the entire scenario construction process or consistently engaged in the dissemination phase, discussed urbanisation. These results may have been influenced by the selection of interviewees, which included several farmers and agricultural technicians, but only one urbanisation technician. However, even the non-specialist interviewees, such as the residents and representatives, predominantly focused on agriculture and water. This suggests that sustained and repeated interactions between scientists and society can effectively foster a multidisciplinary perspective when analysing complex phenomena like landscape changes. Conversely, when these interactions are brief, the increased awareness of complex dynamics and expected challenges is limited to the concepts previously considered important.

Determining the ideal timing for assessments presents numerous challenges. From a research perspective, project schedules impose some constraints, while on the administrative side, the calendar of official document revisions may be hard to access. Similar to the call for open science, there is a need for easier access to the updated schedules of administrative document decisions at the institutional level. In addition, long-term assessment results can evolve, and instrumental outcomes may emerge during the revision of local technical documents such as SCOT and SAGE. This raises questions about the appropriate time lag between the dissemination of scenarios and the assessment of their contribution to integrated land management, which ultimately depends on the administrative and political context. Therefore, the time lag chosen for our study could be considered to have yielded middle-term outcomes when considering the institutional perspective.

The instrumental use of the scenarios became possible due to their dissemination. By sharing the results with representatives, a common foundation for discussion was established, rooted in scientific evidence together with political and economic discourses. In this case study, representatives perceived the involvement of scientists as a "neutral" party, bringing scientific elements rather than political convictions, which was crucial to considering water tensions as factual. With a limited window of opportunity to address

climate change [57], scientists are increasingly assuming political positions and actively advocating for climate action. Without questioning the appropriateness of scientists' advocacy [58], this raises the question of when scientists should maintain a "neutral" position and when they should speak out. Answering this question extends beyond the scope of this study, but it underscores the importance of expanding the existing literature to explore how and under what circumstances scientists should assume specific political positions.

Finally, while the scenario-based high resolution maps facilitated awareness and collaboration at the regional and sub-regional levels, caution should be exercised in generalising these results to the application of lower-resolution scenarios at the national or continental levels. Furthermore, we recommend the inclusion of self-assessment in future scenario-based scientific projects during the co-construction and dissemination phases, an additional step that is often overlooked but valuable for enhancing the effectiveness and impact of scenarios.

6. Conclusions

The primary objective of this study was to assess the outcomes of land use and land cover change (LUCC) scenarios, particularly their role in promoting integrated management. Based on our analysis of a local case study, we conclude that:

- Despite the general acknowledgment of the need for more integrated management by local actors, joint initiatives among land management services remain rare.
- While the scenarios did not provide the necessary knowledge in a suitable format to technically support water management, they were successful in enhancing the collaboration between communities of practice. This was particularly evident for actors who were involved in the co-construction and those who participated in the dissemination workshops, where the concept of "boundary" was most explicit.
- The scenario dissemination workshops played a crucial role in initiating integrated management initiatives. However, technical discussions on integrating land management services relied more on external sources rather than the scenarios themselves.
- Consistency between the spatial extent of the scenarios and operational boundaries was crucial for engaging local actors in the co-construction process and for instrumental outcomes to emerge. However, when there was already a political will to promote integrated management, the alignment with operational boundaries was not as essential.
- The co-construction and dissemination pathways demonstrated a strong complementarity in fostering social outcomes.
- Overall, these findings highlight the potential of LUCC scenarios to drive collaboration and integrated management, although further efforts are needed to optimise their knowledge transfer and application in technical decision-making processes.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land12071414/s1, S1: Presentation of the Couesnon spatially explicit scenarios: S2: Details of scenario-dissemination workshops; S3: Main actors involved in managing water in the Couesnon catchment and relations between.

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Notes

1 INTERREG ALICE project: a project that combined international partners from five countries of the Atlantic region. This article focuses on the outcomes of scenarios developed for France. https://project-alice.com/alice-project/ (accessed on 22 December 2022)

2 "Schéma d'aménagement et de gestion de l'eau" in French

3 "Schéma de cohérence territoriale" in French

4 Available at (accessed on 5 June 2023): http://iramuteq.org/telechargement

5 "Commission locale de l'eau" in French

6 Terre de source official webpage (accessed on 1 December 2022): https://terresdesources.fr/

7 The word "ville" ("city" in English) was included in the dendrogram. However, in the corpus, it was not used concerning urbanisation but to a duality between urban and rural residents

8 Extract from the notice translated from French: "The Bridor file establishes forecasts up to 2030. However, industrial activity is expected to continue beyond that date. The results of the ALICE project conducted by scientists in the Couesnon catchment have highlighted the risk of a decrease in the water flow by half during the low-water period by 2050. Global changes are announced by the IPCC for a horizon further away than 2030 (2050 and 2100) and can no longer be ignored. The Bridor file, like all ICPE and Water Law files, should be able to assess impacts of their activities beyond the date on which their investments are planned." Available at: https://www.liffre-cormier.fr/wp-content/uploads/2022/02/2021-09-02_Avis-CLE-COUESNON.pdf (accessed on 22 December 2022)

9 "Direction Régionale de l'Environnement, de l'Aménagement et du Logement de Bretagne" in French

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