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A systems approach for the sustainable development of coastal-rural regions

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Tools and approaches to support evidence-based policy making and strategic planning are central to achieving long term sustainable development. In particular, where coastal communities are concerned, their complex nature demands methods capable of capturing a holistic picture of the socio-ecological interactions at play. This paper presents a system approach, combining qualitative and quantitative methodologies – participatory stakeholder engagement tools with system dynamic modeling – within a co-creation process, in order to identify problems and set up evidence-based business roadmaps and policy actions. These actions are focused on coastal-rural synergies and cross-sectoral collaborations in order to drive coastal-rural regions towards a sustainable future. The paper outlines the process by which researchers work collaboratively with local stakeholders to co-produce business roadmaps and policy actions, to be used as strategic guideline for local development.

Keywords: system thinking, systems dynamics, cross-sectoral collaborations, stakeholder engagement, coastal-rural development

1. Introduction:

Coastal-rural areas are complex socio-ecological systems which face a wide range of challenges that involve a diversity of stakeholders from multiple sectors. Within the source-to-sea continuum, the sea, the coastal area and its (rural) hinterland form a single unique ecosystem (Granit et al, 2017). The sea and coastal zones are the natural continuity of inland areas, with land-based ecosystems and sea-based ecosystems intrinsically linked through the flows of water, sediments and nutrients; one not only benefiting from the other, but also impacting it and vice versa (Akinsete et al., 2021). The water resource is a key element in the relationship between inland rural areas and coastal zones, supporting multiple productive uses along waterways from the source to the sea. It accumulates sediments and nutrients vital to coastal and marine ecosystems as well as human activities, creating a relationship of dependency between downstream and upstream activities of coastal and rural communities (Dzwaire et al, 2010). As such, conflicts often arise when the resource becomes scarce or its environment polluted due to the inevitable impact of unsustainable practices inland (e.g.

over-use of water resource, fertilizer and pesticides; soil degradation; release of chemical compound) on coastal areas and marine water (Zandaryaa et al, 2021). The sustainable development of coastal areas is therefore intrinsically dependent on the sustainable development of inland areas. In Europe, these hinterland areas are primarily classified as rural areas representing more than 90% of the territory as a whole (Council of EU, 2006). From an economic perspective, coastal-rural areas face a certain dichotomy between dynamic well-developed and attractive coastal zones with a high concentration of activities (on land and at sea), a generally lower unemployment rate¹, and the corresponding less attractive rural inland areas characterize by depopulation and economic decline (Akinsete et al, 2021; Li et al, 2019). The concentration of activities and population centers in European coastal zones can however also create pressures not only on that specific region, but also on natural and agricultural land in adjacent rural area (Carels et al., 2006). In addition, it affects these areas through rural gentrification and its resultant negative externalities on rural communities (Stockdale et al. 2010). However, the high activity concentrations of coastal zones can also be considered an opportunity for rural development by fostering business opportunities that support the rural hinterland due to the afflux of newcomers (Council of EU, 2006).

The sustainable management of these complex interactions between coastal and rural activities, resources, and stakeholders requires integrated coastal-rural governance, and the related policy frameworks need to reflect these interdependencies; overcoming multiple barriers and challenges. On one hand, coastal areas operate under a fragmented governance system characterized by an overburdened policy framework which consists of a collection of sectoral policies from the local to the regional and global levels. They also involve a vast range of institutions working in silos within each of these levels, often with limited interaction (Pittman et Armitage 2016; Kelly et al. 2019; Assche et al. 2020). On the other hand, rural development strategies and management plans rarely take into consideration cross-sectoral impacts from activities taking place in the coastal zone. On both ends, local sectors and institutions often follow a linear train of thought, evolving within their own sphere of influence, administrative jurisdiction and spatial implementation, with a low level of interactions between one another (Granit et al. 2017; Voulcoulis et al. 2016). In this context, developing sustainable cross-sectoral strategies at a coastal-rural territorial level is a challenge at any level of governance. We argue that a paradigm shift towards systems thinking and systemic approaches at the local level could be beneficial, as it allows for the development of a deeper understanding of the system as a whole across the source-to-sea continuum. Such an approach also enables the effective implementation of transformative holistic policies such as the European Green Deal² and the United Nation 2030 Agenda³.

This article presents a methodological framework for systems innovation, developed for the purposes of gaining a more holistic understanding of the dynamics within coastal-rural systems and facilitates triggers of sustainable change. Within this methodological framework, researchers worked collaboratively with local stakeholders to co-produce business roadmaps and policy solutions for the sustainable future of coastal-rural areas, combining qualitative

¹ (in half of EU coastal regions, unemployment is lower than the national average¹ -),

² https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

³ <https://sdgs.un.org/2030agenda>

and quantitative holistic systemic approaches. These outputs are based on stakeholder engagement and systems dynamics models, co-created with stakeholders during a series of coastal case study workshops representative of the diversity of European coastal-rural areas. Starting from stakeholder system mapping, system dynamics models for land-sea interactions are developed and used to identify key points of intervention. Multi-sectoral workshops are used to co-create a common desirable future for coastal-rural areas taking into consideration the system as a whole. These future visions are adopted as a starting point to develop transition pathways and co-produce strategic business roadmaps for coastal-rural areas

2. Methods: Overview of the COASTAL framework

2.1 A combination of system approaches

System approaches are based on “systems thinking” and are used to solve complex problems which call for innovative solutions. These cases often involve multiple interconnected and interdependent elements and stakeholders (stock and flows relationships). The benefits of a systems approach, in this context, is that it enable a complete overview of the system as a whole, taking into account dynamic behaviors and feedback loops (Ross et al., 2015). Systems approaches are particularly well suited to driving sustainable development (Meadow, 2015), as it allows stakeholders to develop a shared systemic theory of change (Stroh, 2015). As such, these approaches are well suited to the examination of coastal-rural socio-ecological systems. Systems approaches include various tools and methods using quantitative and qualitative data with different functions, such as for example understanding the system, fostering dialogue and communication, co-design solutions, and assessing the progress of a given action.

The results from this study are based on using such system dynamics modeling and participatory approaches, it employs a combination of quantitative and qualitative systemic methods to better understand coastal-rural interactions and identify solutions to support the transition to a sustainable future (see Figure 1 below). The starting point was a wish to gain a better understanding of the system itself through co-producing knowledge in a collaborative manner in order to be able to co-design tailor made solutions to complex local challenges. This entails combining knowledge from both scientists and local stakeholders through the definition of qualitative and quantitative system dynamics models for coastal-rural interactions.

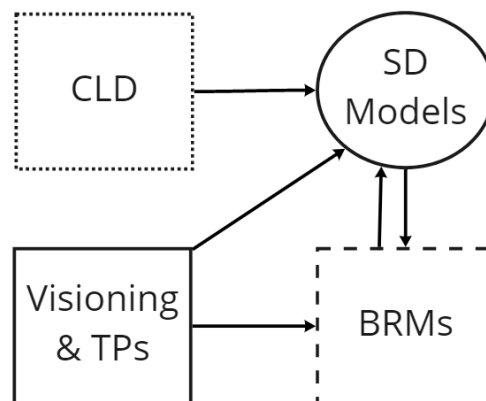


Figure 1: Main components of the COASTAL frameworks. CLD: Causal Loop Diagram; SD: System Dynamic; TPs: Transition Pathways; BRMs: Business Roadmaps. Square represent qualitative

approaches (participative approach), circle represent a quantitative approach, small dashes is the starting point and large dash is the outcome.

This process produced causal loop diagrams (CLD) derived from local stakeholder input (co-production of mental maps in sectoral workshops), as a basis for quantitative system dynamics modeling (Wolstenholme, 1999). The latter are then used to quantify the interactions (stock and flows) between the multiple variables of the system, and identify the key points of intervention. Multi-actors workshops are used to validate the models and foster cross-sectoral dialogue and collaboration. The co-production of a common vision between coastal and rural actors sets up the goal to be achieved. Coastal-rural sectoral transition pathways (TPs) are built as illustrative trajectories for the system transition and used as supporting tools to co-design action plans able to reach the desired state of the system (the vision) within the framework of business roadmaps (BRM) for coastal-rural synergies.

2.2 Mind mapping and Causal Loop Diagram

First sector specific shared mental maps were developed with local stakeholders in dedicated workshops (3 from coastal sectors such as fishery, coastal tourism, blue industry and 3 from rural sectors such as agriculture, environment, rural development in each case study), to engage stakeholders in an open discussion, aimed at identifying the main issues, opportunities, obstacles and solutions in the context of land-sea interactions and their own sector, and the causality between key variables. The initial mind maps, which often had more than 60 variables per mind map, had to be substantially simplified, by combining variables and removing those that are superfluous. It is also important to land on variables that have data associated with it, whether qualitative or quantitative, in order to prepare for the later quantitative system dynamic modeling (2.3). The sector mind maps are taken a step further, to become Causal Loop Diagrams (CLDs), focusing on the proper representation of the feedback loops and stock variables in the system, identifying positive and negative relationships. Sectoral CLDs are then combined into one CLD, representing a full regional model of coastal-rural perceptions and interactions. In this condensing phase, data sources or proxies for data are also considered for the next phase of quantification. Figure 2 shows an example of the land-sea system where six sectors (agriculture, environment, spatial planning, fisheries and aquaculture, blue industry and tourism) were combined into one CLD. The methodology use to co-develop the CLD in multi-actor workshop with local stakeholders is explained in details in Tiller et al. (2021).

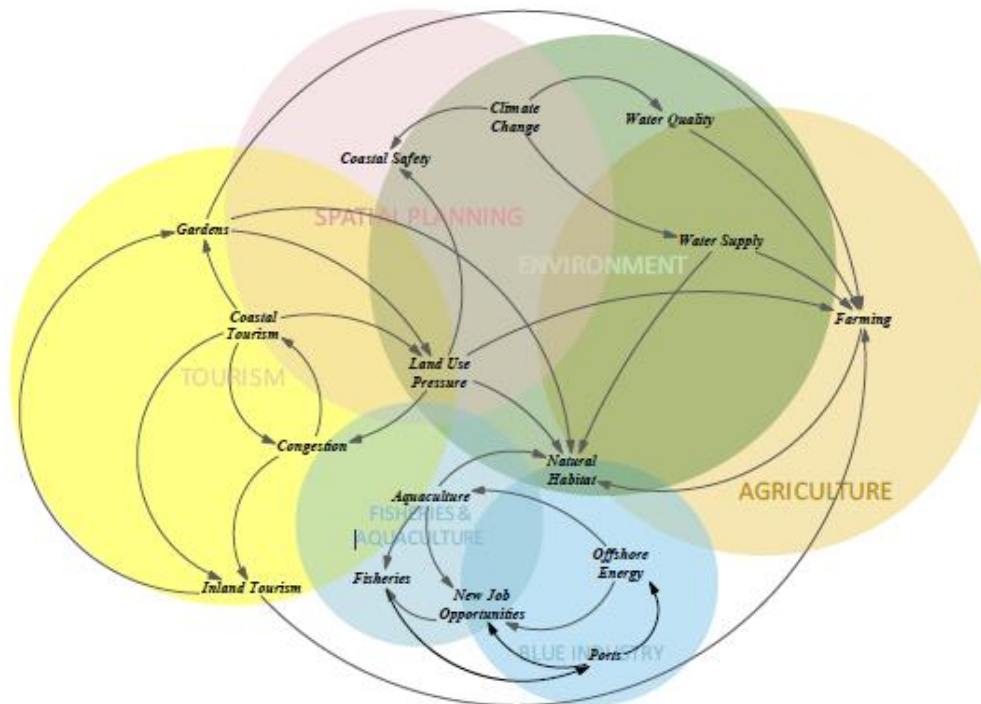


Figure 2: overview of a simplified CDL after combining six sectoral workshops. The different colors represent the different sectors (in de Kok et al., 2021).

2.3 Coastal Rural Interactions Models

The System Dynamic (SD) models translate the qualitative analysis of the system based (mind maps and CLD) into a quantitative models. These quantitative SD models are then used to formulate and support strategic business and policy analyses aimed at improving coastal-rural synergies in an evidence-based manner. On the one hand the SD models will allow assessing which business road maps are expected to work while one the other hand the business road maps can provide a framework for assessing the dynamics calculated by the SD models.

SD modeling (Sterman J.D, 2000) is widely used since the 1950s for problem analysis in applications ranging from logistics, control management, engineering and financial management to public policy. By nature, SD modeling is strongly problem-driven and an adequate SD model is not a complete representation of the system in all its detail, but a simplification of reality. After clarifying the problem at hand during the construction of the CLDs, and defining the way the problem(s) are connected to specific policy or management indicators and potential solutions, the models' problem scope is determined. Insufficient attention to this problem scope will lead to models which lack focus, and are not solving the problems or answering the questions of the intended users. Once the problem scope has been established the main components in a SD model, the stocks and flows, are identified together with the model structure and equations which represent the relationships between the different components and auxiliary variables that are needed in the calculation process. The results of an operational SD model are then presented to workshop's participants for a validation process which is an opportunity for reconsidering the model scope based on local stakeholder feedback. Here, the SD model development is an iterative process and should not

be narrowed down to the activity of quantitative (stock-flow) modeling but concerns the complete workflow, including exchanges with stakeholders and qualitative future narratives.

2.4 Visioning and Transition Pathways

Complementary to the system modeling approach, prospective sustainable scenarios (qualitative scenarios) and transition pathways are built to support the co-design of solutions utilizing a Transition Management methodology. It is a participatory methodology that is used primarily in the field of sustainability and governance in order to deal with persistent problems in order to facilitate sustainable change (van der Brugge and Rotmans, 2007). These scenarios design future-images from which individuals may work back to the present situation via a 'backcasting' process (Veeneklaas et al., 1995). By contrast, projective scenarios take the current situation in as a starting point, extrapolating along various trends to result in future images (Geurs et al., 2014). Those sustainable coastal-rural scenarios are descriptions of a potential version of the future, which consists of both qualitative and quantitative elements. Qualitative input comes from both the literature (combination of EU DG strategic visions and policies such as the European Green Deal) as well as visions of the future (Future Narratives) produced by local stakeholders within multi-actor coastal-rural workshops. The Future Narratives follow the principle of sustainable coastal-rural synergies, and are based on the identification of common elements throughout local and European visions and sustainable policy frameworks. They explore the state of key drivers in the context of the envisioned future, building a storyline around them (Volkery et al., 2008). The Future Narratives convey the potential to inspire participants, as well as mobilize individuals outside the process (Roorda et al., 2012), fostering dialogue across sectors, pointing out future collaboration opportunities. They are used as generic objectives for strategic development plans (e.g. business roadmaps).

Along the sustainable scenarios, Transition Pathways are constructed, describing possible routes from now to the envisioned future. The transition pathways provide a transposable blueprint for the initiation of sustainable coastal-rural transitions in different coastal contexts. Each pathway revolves around a subtheme and describes intermediate goals, barriers that need to be overcome, key enabling conditions to support the transition, actors that are/become important and essential actions/interventions. They provide insight into what is needed to reach the envisioned future and give direction to the subsequent development of agendas and strategies to support sustainable transitions (Roorda et al., 2013). Within COASTAL, the Transition Pathways can be considered as goal-oriented descriptions for the different transitions towards sustainability, exploiting innovative business and policy solutions aimed at the development of coastal-rural synergies. The transitions are thematically structured around the key sectors represented in coastal-rural regions (Agriculture, Tourism, Energy, Maritime activities). They serve as inspirational trajectories for the development of the business roadmap, providing examples of innovative solutions already deployed around the world within the dedicated sectors.

3. Results: A strategic document for local development

3.1 A framework based on systemic interactions across sectors

The COASTAL business roadmaps are based on a business model canvas and adapted to the needs of a strategic roadmap document, with coastal-rural synergies for a sustainable future the main driver. The aim of the roadmap is to propose a set of business and policy solutions, able to support coastal-rural regions in the transition towards the sustainable future co-created by local stakeholders across sectors within the whole region. The coastal-rural system dynamic model (2.3.) allows the identification of key points of intervention within the coastal-rural system, and the simulation of different scenarios in order to reach the desired state. While scientists and local stakeholders identify and propose solutions, involving different sectors, based on local knowledge and national to international best practices. Here the generic transition pathways (2.4) serve as seeds for innovative solutions to emerge; solutions involving multiple sectors, fostering coastal-rural collaborations or land-sea synergies are favored. Once local actors along the source-to-sea continuum agree on the solutions to focus on, scientists, local experts, business representatives and local policy makers are asked to define the short, mid and long term actions required for the successful implementation of the proposed solution. In addition, the stakeholders identify the specific actors to be involved in order to successfully implement the solutions proposed. The proposed solutions/actions are then tested within the SD models under different scenarios (e.g. sustainable path, business-as-usual) to verify and quantify expected impacts.

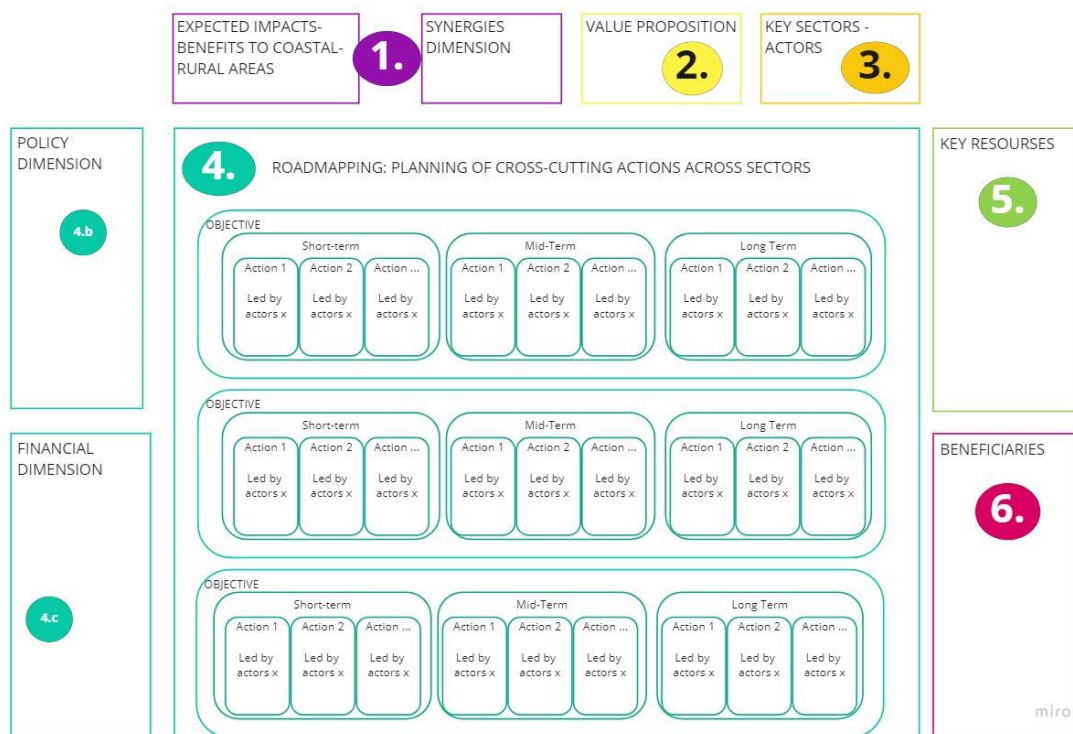


Figure 3: COASTAL Business Roadmap Canvas for land-sea synergies

The business roadmap canvas also includes a policy and a financial dimension as necessary drivers of change. Current policy barriers and governance hurdles preventing the successful implementation of the solutions are identified. Also the solutions must be in line with national and international sustainable policy agendas (European Green Deal, Agenda 2030) either as a means of local translation of such a policy, or as an example of a need of the

effective implementation of such a policy at local level. The financial dimension aims at highlighting the most important costs inherent to the solutions, which financial mechanisms ought to be mobilized, and from whom. Particular attention has to be paid to the expected impacts / benefits (Economic, environmental, social, governance) for the coastal-rural region as a whole to prevent sector-centric visions of the proposed solutions.

Table 1: The different components of the COASTAL roadmap for coastal-rural synergies

1.EXPECTED IMPACTS-BENEFITS TO COASTAL-RURAL AREAS	Economic (in terms of employment / Additional revenue...) Environmental Social Governance
1.SYNERGIES DIMENSION	Does the roadmap involve multiple businesses? Sectors? Is it built on synergies between sectors? How the actions contribute to land-sea synergies? How the actions foster coastal-rural collaborations?
2. VALUE PROPOSITION	How is the roadmap supporting the transition? Contribute to reaching the vision of the MAL? What is the added value brought by the roadmap to coastal-rural area? Which problem are we solving?
3. KEY SECTORS - ACTORS	Who to involve? Who will lead the implementation of the proposed actions? Who will directly contribute to the implementation of the business solutions? Who needs to be involved to support the implementation of the actions?
4. ROADPMAPPING: PLANNING OF CROSS-CUTTING ACTION ACROSS SECTORS	Prioritize actions (short-term; mid-term; long-term) per objectives or sectors Identify institution to be involves and or that should lead the actions <i>The combination of all the actions will lead to the achievement of the roadmap end goal (the stakeholders' vision)</i>
4.a. POLICY DIMENSION	Are there any policy barriers, governance hurdles for the implementation and success of the combined actions? What policy change/support do we need for the implementation and the success of the actions, if any? What change/support in terms of governance do we need for the implementation and the success of the actions, if any? Does the solution contribute to the implementation of the Green Deal? Does it need the effective implementation of the Green Deal to be successfully implemented? How?
4.b. FINANCIAL DIMENSION	Where is the most important cost inherent to the implementation proposed actions? What key resources are more expensive? What key activities are more expensive? Who will support the costs inherent to the implementation of the proposed actions? Who can finance the proposed actions? Potential financial support (loan/subsidies/tax reduction...) From whom? (public/private entities, local/national/EU level)
5. KEY RESOURCES	What are the key resources needed to implement the identified actions? - Physical/technological - Intellectual (brand patents, copyright, data) - Human - Financial Are the natural resources needed used and manage in a sustainable way?
6. BENEFICIARIES	Who will benefit from the implementation of the actions? Which Stakeholders? Which Resource/Ecosystem? Which segment? (Coastal area, Rural area? Hinterland?)

3.2 Key elements for the sustainable development of coastal-rural areas

As part of the COASTAL project, the methodology has been applied to 6 different case studies across the European Sea regions (Belgium, Sweden, Romania, Greece, Spain, France).

The main challenges those coastal-rural areas are facing is related to water resource management as a main mean of transport of excessive nutrients and pollutants to the coastal waters coupling with reduced river flows leading to water shortage episodes in the coastal zones and higher concentration of contaminants in river mouths. Preserved natural areas along the coasts and under-developed coastal-rural regions are also subject to increased urban development pressures affecting rural communities and ecosystems. Here, innovative and alternative business models are needed based on the sustainability and circularity principals to render coastal-rural regions attractive in terms of jobs and quality of life without further affecting the ecosystems.

The key combined intervention points identified to reach the common coastal-rural vision co-develop by local stakeholders are found within the agriculture and the tourism sectors which are currently major drivers of unsustainable changes. The coastal-rural business roadmaps include actions aiming at changing agricultural systems and practices for transitioning towards sustainable agriculture models (e.g. crop diversification, extensive and biological farming, short supply chain, local quality labels, support young farmers installation and training of sustainable practices). In parallel, sets of actions are targeting tourist actors in order to develop alternative forms of tourism such as ecotourism based on cultural heritage, nature and sport, favoring local entrepreneurship and local community involvement as opposed to the sea, sun, sand model. Synergies across those two sectors arise in the coastal-rural landscape with the development of agro-tourism, the promotion of local quality products based on the valorization of a unique territorial identity from land to sea. The third key element present in most of Business Roadmaps developed within the COASTAL project framework focuses on cooperation across sectors and actors via the transition toward new forms of governance aiming at an integrated coastal-rural management framework for a synergetic territorial development. It takes various forms (e.g. territorial management body, cluster of institutions) depending on the local context, supports a holistic management of the water resource throughout the source-to-sea continuum, favors cross-sectoral and science-policy-society dialogue, knowledge transfer and shared understanding.

4. Discussion

The holistic COASTAL framework has enabled the development of systemic business roadmaps by **allowing the co-identification with local stakeholders of combinations of cross-sectoral actions in coastal-rural areas**, within a co-creation process involving qualitative and quantitative system approaches. Thanks to the deep stakeholder engagement process, the framework can support the emergence of actions anchored in the reality of the local context, answering the needs of coastal and rural actors. The approach takes into account cross-sectoral effects over the source-to-sea continuum while being scientifically validated in terms of expected impacts over a period of 10 to 30 years. By engaging stakeholders in every step of the process using systemic tools (Causal Loop Diagram, System Dynamic models, visioning), the methodology favors the development of systems thinking amongst local actors, even to those with historically limited knowledge and understanding of spill-over effects of their own practices, and lack a holistic overview from upstream to downstream. It allows local decision-makers, businesses and experts to reach the level of understanding needed for formulating holistic development strategies across sectors. The combination of participative approaches and systems dynamic models fostered dialogue

around shared environmental and management issues (e.g. coastal water pollution, policy gaps etc.), a better understanding of cross-sectoral interdependencies and benefits of working together (e.g. synergies between shellfish industry and agriculture sector, tourism and nature conservation) and the need to commonly develop sustainable solutions for the benefits of both people and the natural environment. Identifying and prioritizing actions following a co-creation process favors a sense of belonging to one and only territory, to be managed according to needs, opportunities and constraints of both coastal and rural activities. This co-creation process which involve local stakeholders (local experts, policy-makers, industries) creates a high degree of acceptance within the whole region while the scientific cross-validation process generates a robust evidence-driven basis for strategic regional management and the production of Business Roadmap translatable into development plans by regional policy and decision makers. The will to bridge the research-implementation gap is at the core of the methodology. Decision makers are involved from the start of the process with the aim of creating a direct channel for communicating the project progress and outputs, as well as aligning the research process with the policy agenda in order to co-develop strategic documents realistically implementable. The research teams leading the process at local level are anchors in the local territory and able to support the stakeholder engagement process beyond the project lifespan.

Nevertheless, combining qualitative and quantitative systemic approaches, is not always straight-forward; it requires flexibility and adaptability, and the development of a common set of glossary terms across disciplines (e.g. scenarios have multiple definitions and uses across disciplines). The timing of the various components of the framework is also important; for instance the development of the system dynamics models (quantitative aspect) should go hand in hand with the stakeholder engagement process (qualitative aspect) in order to capture and assess innovative solutions coming from local stakeholders (knowing that the business roadmap is inherently dependent on the model's system boundaries and variables, if the solutions proposed have to be tested and validated using the models). In addition, aligning the scale of operation can prove challenging as it has been the case within the COASTAL project. In this case, the capabilities of the models developed to assess the solutions proposed vary, as the generic scale of the models doesn't always match the scale of the solutions proposed. As a result, an action within the business roadmap doesn't always have its corresponding variable in the systems dynamic model. In such cases, it is possible to aggregate multiple actions converging toward the same goal into one variable within the model in order to get a quantification of the solutions' expected impacts within the coastal-rural system (e.g. increasing tourism attractiveness, raising awareness). Finally, the success of the methodology depends on the involvement of trans-disciplinary researchers, experienced modelers as well as persons able to implement participatory approaches, engage with local stakeholders, facilitate workshops having a holistic approach capable of guiding participants in a systemic way, and trigger "outside the box" thinking in envisioning the future of the coastal-rural territory.

Conclusion

The combination of qualitative and quantitative systemic approaches is well suited to co-develop holistic solutions for the sustainable management and development of coastal-rural regions. The use of systemic tools with local stakeholders allows scientists to harness local

knowledge while guiding participants to think in a systemic way. In addition, this combination provides scope for the quantitative assessment of the expected impacts of changes within the system along multiple time horizons (short to long term), while identifying potential undesirable effects in a long terms from initial short term benefits (feedback loops).

The methodology proposed has been successfully used to co-develop a common agenda for actions in six coastal-rural regions, co-producing local strategic business roadmaps. However, careful planning of activities and the involvement of experts capable of navigating various disciplines and the combination of the different approaches is a pre-requisite.

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