Paving the Way to Basilicata Climate Adaptation Strategy: A GeoDesign Workshop

Gerardo Iula[1], Giusy Grasso[1,2], Alessia Lavecchia[1,2], Francesca Perrone[2(✉)], Simone Corrado[1], Rachele Vanessa Gatto[1], Alfonso Annunziata[1], and Francesco Scorza[1]

[1] Department of Engineering, University of Basilicata, Viale dell'Ateneo Lucano 10, 85100 Potenza, Italy
{gerardo.iula,giusy.grasso,simone.corrado,rachelevanessa.gatto,alfonso.annunziata,francesco.scorza}@unibas.it
[2] Faculty of Architecture, Sapienza University, Rome, Italy
francesca.perrone@uniroma1.it

Abstract. This paper explores the application of the Geodesign approach to territorial planning for climate change mitigation and adaptation in the Basilicata region, as a contribution to the downscaling of the Italian National Strategy for Adaptation to Climate Change (SNAC) and the National Adaptation Plan (PNACC). As part of the GD-CURE research project, a spatially explicit and participatory methodology was implemented, integrating suitability analyses, impact modeling, and collaborative scenario design. The use of the GeodesignHub platform enabled structured engagement with a broad range of stakeholders—including local authorities, technical experts, researchers, and civil society representatives—facilitating the emergence of informed, context-sensitive, and collectively defined solutions. Land-suitability maps served as a critical tool for translating abstract climate objectives into actionable and spatially grounded interventions, addressing key sectors such as energy, agriculture, forestry, water resources, coastal zones, transport, settlements, and industry. This process supported the identification of territorial priorities, reduced implementation uncertainties, and anticipated potential land-use conflicts. The findings suggest that the Geodesign approach can enhance multilevel governance and foster a culture of climate adaptation rooted in spatial evidence and cross-sectoral collaboration. The experience in Basilicata offers valuable insights for replication in other regional contexts and contributes to the development of integrated, effective, and resilient territorial climate strategies.

Keywords: Climate Change · GeoDesign · Climate Change Adaptation · Spatial Planning · Participatory Governance · Land Suitability Analysis

1 Introduction

Within the broader framework of European and national climate adaptation policies, the European Union has significantly reinforced its commitment through key frameworks such as the Paris Agreement and the European Green Deal [1], setting out targets that

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require the proactive engagement of public authorities at all levels of governance [2, 3]. In Italy, the National Climate Change Adaptation Strategy (SNAC), adopted in 2015, constitutes the main national initiative for addressing climate adaptation. It provides a comprehensive reference for integrating adaptation measures into national, regional, and local planning processes. The strategy is structured around four core objectives: reducing the vulnerability of natural, social, and economic systems; enhancing their adaptive capacity; leveraging emerging opportunities; and promoting coordinated action across multiple governance levels. Complementing the SNAC, the National Adaptation Plan to Climate Change (PNACC) defines a methodological framework to guide regional governments in developing localized strategies, emphasizing participatory processes, climate risk assessment, and the identification of priority actions [4]. In this context, regional administrations are called to establish adaptive governance models based on solid scientific evidence and the active involvement of socio-economic stakeholders. A notable example is the Basilicata Region, which faces significant environmental vulnerabilities including landslides, floods, heatwaves, and rural depopulation. To address this issues, Geodesign methodology is applied steering planning practices toward integrated and sustainable governance [5–9].

Italian regions have shown uneven commitment to climate change adaptation, largely due to the absence of a unified national framework. This has resulted in fragmented, heterogeneous strategies, often embedded in broader sustainability agendas. Such variability hampers interregional collaboration, knowledge exchange, and coordinated responses to cross-boundary climate vulnerabilities. Lombardy was the first to act, issuing guidelines in 2012, followed by a strategy (2014) and an action plan (2016) to reduce planning and funding fragmentation. Emilia-Romagna followed in 2018, notably integrating both adaptation and mitigation through the Under2MoU. Since then, several other regions—including Sardinia, Aosta Valley, Piedmont, Molise, and Liguria—have developed strategies, while others (e.g., Puglia, Trento, Friuli-Venezia Giulia) are still in progress. Some, like the Central Italy coordination among Abruzzo, Marche, and Umbria, have adopted cooperative approaches, linking environmental and seismic risks. Despite these efforts, a major shortcoming persists: the lack of spatially explicit planning. Most strategies rely on generic risk matrices, failing to identify localized vulnerabilities and adaptation priorities. This a-spatial approach weakens implementation, resource allocation, and impact. To bridge this gap, adaptation must be rooted in territorial specificity and aligned across governance levels, fostering a shared adaptation culture.

The research GeoDesign for Climate URban nEutrality (GD-CURE) aims to develop effective tools and methods to support territorial governance in climate change mitigation, adaptation, and the green transition[10–13]. Adopting a multi-scale approach, the project integrates local, national, and macro-regional perspectives into sustainable urban and territorial development strategies. Central to the project is the creation of spatial decision support tools based on Geodesign methodology, guiding collaborative planning and knowledge-building. This paper discusses the preliminary results of the regional scale implementation of the research based on evidences from GD_CURE Basilicata Workshop assessing impacts on co-planning and capacity building [14–16].

Global mainstream policies on climate change mitigation and adaptation identify urban green transition as a crucial component for achieving global goals. The research

delivers a Geodesign Workshop on the topic "supporting the strategic design for Basilicata Adaptation Strategy" in Decembre 2024 finalising through Geodesign method the complex process of downscaling national policies and tools (especially list of mitigation/adaptation actions) to the specific features of the case study context. This entails local contextualization of global climate change objectives within the governance framework outlined by the National Adaptation Strategy (SNAC) and the National Climate Change Adaptation Plan (PNACC).

Through the participatory process based on Geodesign, supported by specific effective tools defined by the research group, the strategic territorial governance laboratory had been realized delivering co-design perspectives strengthening decision-making processes in implementing climate adaptation and mitigation measures within the Basilicata Region. Participants include young researchers in disciplines related to climate governance, as well as representatives and technicians from major administrations, professionals, qualified non-profit organizations, and active local associations.

Research contributions provide a preliminary selection and evaluation of actions compatible with the regional context's territorial characteristics, and referred to the domains defined by the International Geodesign Collaboration (IGC) Global Climate Geodesign Challenge (GC). The domains considered include: Energy (ENE), Agriculture (AGR), Forest (FOR), Ocean (MAR), Settlement (URB), Industry (IND), Transportation (TRA) and Water (WAT).

A structured four-step approach was used to develop a comprehensive set of adaptation and mitigation options tailored to the Basilicata Region. The process involved: (i) identifying key sectors requiring climate action; (ii) establishing classification criteria and sub-criteria for potential interventions; (iii) selecting relevant, feasible, and high-impact actions, drawing on authoritative sources such as the European Climate Adaptation Platform (Climate-ADAPT), Italy's national adaptation strategies (SNACC and PNACC), and the IPCC's Fifth and Sixth Assessment Reports; and (iv) conducting a comparative analysis of the selected measures using a framework of 16 criteria covering general, functional, and operational aspects. The final list of actions represents the input for an interactive support tool designed to support decision-makers, public authorities, academics, and territorial professionals in collaborative scenario development and assessing the expected outcomes of various adaptation and mitigation strategies.

In the following sections of the paper main methodological and operational steps of realizing Basilicata Geodesign Workshop are discussed highlighting main results and findings.

2 Methodology

2.1 Geodesign as a Method

GEODESIGN represents a suitable framework in order to develop place based strategic design in urban and territorial planning practices. [17]. Moreover, it demonstrates as a comprehensive methodology a horizontal applicability in any decision process concerning territorial transformation issues. In the peculiar application of this research we adopted GEODESIGN as a main tool to support strategic climate adaptation/mitigation design in the regional scale. According to C. Steinitz [18] GEODESIGN represents an

inclusive approach (it involves not only technicians but all actors involved in decision making processes) supporting *"informed negotiation"*.

The specific application of GEODESIGN is not only oriented to consensus building on effective design or strategy, but mainly to generate an extensive learning process addressed to different stakeholders' groups.

During Basilicata workshop the methodological framework formalized by C. Steinitz was adapted to tackle specific topics and implementation issues delivering effective contribution to be further assessed in a multidisciplinary framework in order to become policy orienting result on regional climate mitigation.

2.2 Organization and Structure of the Workshop

The Basilicata Workshop had been developed in presence, in half day agenda in order to compress participation efforts of invited stakeholders and exploiting effectively the whole preparatory activities delivered by the research group. The Agenda was structured in four main contents packages: i) the "introduction on GD-CURE project" topics, main research objectives and perspectives; ii) "policy framework focus" oriented to provide a clear position and an operational perspective for the workshop results, stimulating motivations of participants according with their own competences or responsibility; iii) a presentation of Climate Change issues for Basilicata region, a way to highlight the local context relevant feature defining main Climate drivers for the case study area presenting general data and specific elaboration through the mean of land suitability analysis; iv) "the workshop", oriented to achieve the contribution of participants, was supported by the main tools delivered by the research team, and finally produced a strategic spatial overview form the regional adaptation scenario coherently with the experimental objectives.

The Stakeholders was selected according to their specific competences on topics and policy framework area related to the Regional Climate Adaptation development processes. Four main groups were identified: local administrations, territorial professionals, relevant NGOs, researchers.

In particular, the territorial professionals represent a miscellaneous group of technicians who play a crucial role in downscaling policies, project and investments to the operational stage. They are grouped in professional categories (i.e. engineers, architects, agronomists, etc.) and the institutional Technical Chambers was engaged in order to stimulate participation in the workshop.

Main tools adopted in the workshop are: i) Geodesign HUB; ii) Climate mitigation action Handbook; iii) Interactive impact model tool.

After the site evaluations, the workshop was conducted with the support of the GeodesignHub web-platform [19] which is useful for both the co-design and negotiation phases. **Geodesign Hub** is a collaborative, web-based platform designed to support spatial planning and decision-making [20, 21]. It enables stakeholders to co-create and evaluate design alternatives using geospatial data, structured workflows, and scenario-based modeling. The platform facilitates real-time collaboration, allowing users to visualize the impacts of planning proposals across multiple themes (e.g., land use, environment, infrastructure). By integrating stakeholder input with data-driven analysis, Geodesign Hub promotes transparent, participatory planning processes.

The Handbook represents one of the GD-CURE research output including the list of actions selected for Basilicata Workshop case study. The work [22] provides an extensive description of the Handbook.

The interactive impact model tool [23] is structured into four main components: (i) Budget, outlining available financial resources across the IGC domains; (ii) Parameters, providing domain-specific information on action costs and mitigation impacts; (iii) Domain User Interface, allowing users to allocate budgets and construct alternative scenarios; and (iv) Results, displaying cumulative expenditures, mitigation effects, and the distribution of outcomes across domains for the 2022–2050 timeframe.

3 Results and Discussions

The technical knowledge that represents the background analysis and interpretations of the case study area had been developed by the mean of land suitability maps per each intervention domain.

Land suitability maps are spatial representations that assess the appropriateness of specific areas for various land uses based on a range of biophysical, environmental, and socio-economic criteria. The criteria adopted for producing the workshop's maps strongly depends form the adopted list of climate mitigation/adaptation actions and local territorial features defining feasibility and intervention priorities according to the case study features. These maps serve as essential tools in the workshop to drive in a very operative way extensive technical knowledge to operation interaction with participating stekeholders. These tools allow policymakers and stakeholders to identify the most suitable areas for the development of specific actions implementing a GEO based thinking in strategic design.

In the Basilicata region of southern Italy, land suitability maps have been developed during an Engineering Master degree studio involving students in applied across several key sectors: Energy (ENE), Agriculture (AGR), Forest (FOR), Marine and Coastal (MAR), Urban Settlements (URB), Industry (IND), Transportation (TRA), and Water Resources (WAT). This process adopted Geographic Information System (GIS)-based multi-criteria evaluation, combining data layers such as land cover, soil quality, slope, climate conditions, accessibility, legal constraints, and existing infrastructure [24, 25].

The aim is to spatially delineate areas with high, moderate, or low suitability for each sector, taking into account both the potential and the limitations of the territory. For example, flat, well-irrigated areas with fertile soils may be classified as highly suitable for agriculture, while regions with high solar irradiance and low environmental sensitivity may be prioritized for energy production. Coastal zones and marine areas are assessed for their potential in blue development, while urban and industrial suitability is determined by proximity to infrastructure and compliance with planning regulations.

This comprehensive and sector-specific mapping approach enhances strategic decision-making, supports sustainable development goals (SDGs), and fosters a more resilient and balanced regional development model for Basilicata [26, 27]. Figure 1 shows the land suitability maps for all investigation domains.

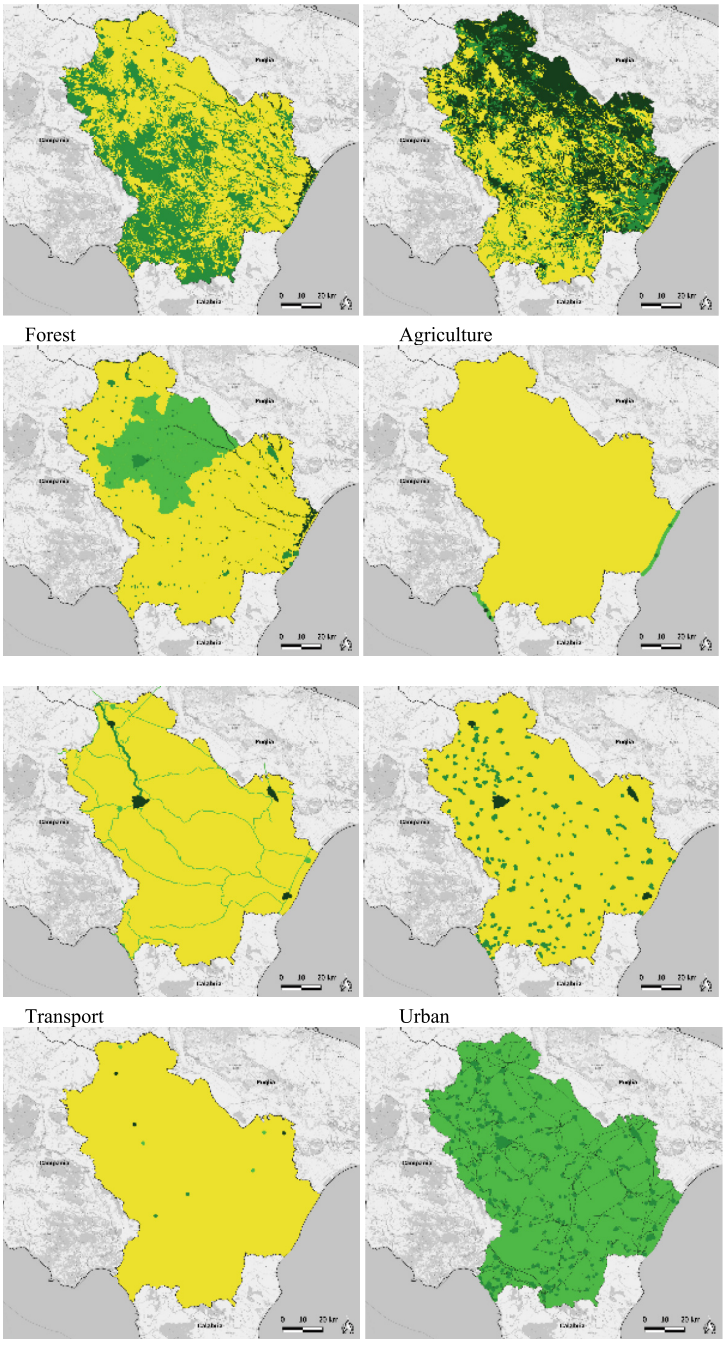

Fig. 1. Land suitability maps for Basilicata Workshop domains

The interactions among stakeholders facilitated the development of a comprehensive territorial strategy for climate change mitigation in the Basilicata region. Beginning with an analysis and discussion of domains and their corresponding actions, participants collaboratively determined the allocation of investments for each action, aligning them with spatially suitable implementation areas. Key elements used to guide and validate the decision-making process included the monitoring of a strategic Gantt chart, the total amount of planned investments, and the maximum territorial thresholds for feasible implementation sites. These controls were essential in building consensus and shaping a shared vision for sustainable regional Climate Mitigation Strategy.

The map in the next figure shows a comprehensive overlapping of actions covering the all domains proposed be IGC Global Challenge [28]. It expresses the complexity of territorial contribution to climate mitigation in Basilicata Region. It is relevant to affirm the effectiveness of the whole investigation process delivering a meaningful spatial design of a extremely complex planning issue without massive investments of resources in a compressed timeframe (See Fig. 2).

In particular, the proposed interactive tool was implemented during a geodesign workshop aimed at formulating a climate change mitigation and adaptation strategy for the Basilicata Region. Workshop participants utilized the tool to determine the optimal allocation of financial resources sourced from various funding programs, including the Regional Operating Programs (RPs)—namely the European Regional Development Fund (ERDF) and the European Social Fund Plus (ESF +)—as well as Rural Development Funds (RDC), which encompass the European Agricultural Guarantee Fund (EAGF), the European Agricultural Rural Development Fund (EARDF), and additional national and regional contributions. The total budget available across four programming cycles was €3,703.2 million (€925.8 million per cycle), with €3,680.2 million allocated, equating to a utilization rate of 99.4%.

Cumulative expenditures by domain were allocated as follows: €803.8 million for Agriculture, €473.1 million for Forestry, €285.0 million for Water, €101.0 million for the Marine Environment, €587.7 million for Transportation, €738.6 million for Energy, €401.4 million for Urban areas, and €289.7 million for Industry (See Fig. 3 and Table 1).

By 2050, the selected actions are projected to result in an annual reduction of greenhouse gas emissions amounting to 3.21 million metric tons of CO_2 equivalent—representing a 55.33% decrease from the 2022 baseline level of 5.806 $MtCO_2e$. The sectors contributing most significantly to this reduction are Transportation (60.6%), Energy (16.6%), and Agriculture (10.4%) (See Table 1 and Fig. 4).

Among individual measures, optimizing transport logistics—specifically through increasing load factors and maximizing vehicle capacity—emerges as the option with the highest cost-benefit ratio, due to a mitigation factor of 18 tCO_2 per vehicle per year at a cost of €226.24 per vehicle. In the Energy sector, Bioenergy with Carbon Capture and Storage (BECCS) contributes 0.264 $MtCO_2e$ per year to the cumulative mitigation outcome. BECCS combines biomass-based energy production with carbon capture and storage technologies. Despite offering a significant mitigation factor (5 $MtCO_2$ per year), this solution involves a high marginal abatement cost of €140 per ton of CO_2. Furthermore, BECCS is expected to reach technological maturity by 2050. Consequently, a limited share (5%) of the energy sector's budget is allocated to BECCS

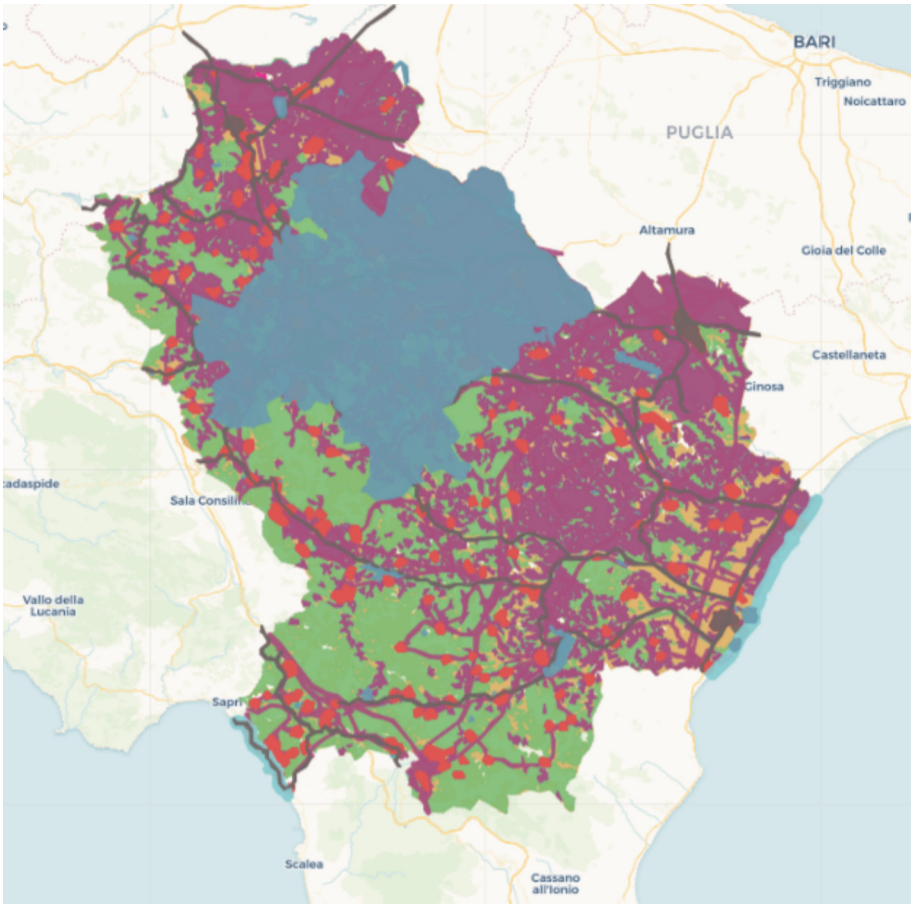

Fig. 2. Strategic design developed by Basilicata Workshop participants

during the first three cycles, with an increase to 15% in the fourth cycle. As a result, the cumulative abatement attributed to BECCS by 2050 corresponds to just 4.5% of the region's annual CO_2 emissions.

Lastly, concerning options relevant to the agriculture domain, leaving crop residue on the soil surface contributes to mitigation outcomes by 0.163 $MtCO_2$ per year, and represents 58.1% of the mitigation outcome generated by the agricultural sector. This option presents a positive cost-benefit ratio, as resulting from a significant mitigation factor of 1.16tCO_2 ha^{-1} per year and a minimal cost of 20.4€ ha^{-1} per year. Its implementation extends to 20.8% of agricultural land, indicating a relevant potential for landscape-scale implementation.

Regarding the remaining sectors, water reuse and protection and restoration of wetlands contributes by 59.3% and 37.9% respectively to the mitigation outcome generated by the water sector over the four cycles, which amounts to 0.034 MtCO2e per year (1.1% of the cumulative mitigation outcome).

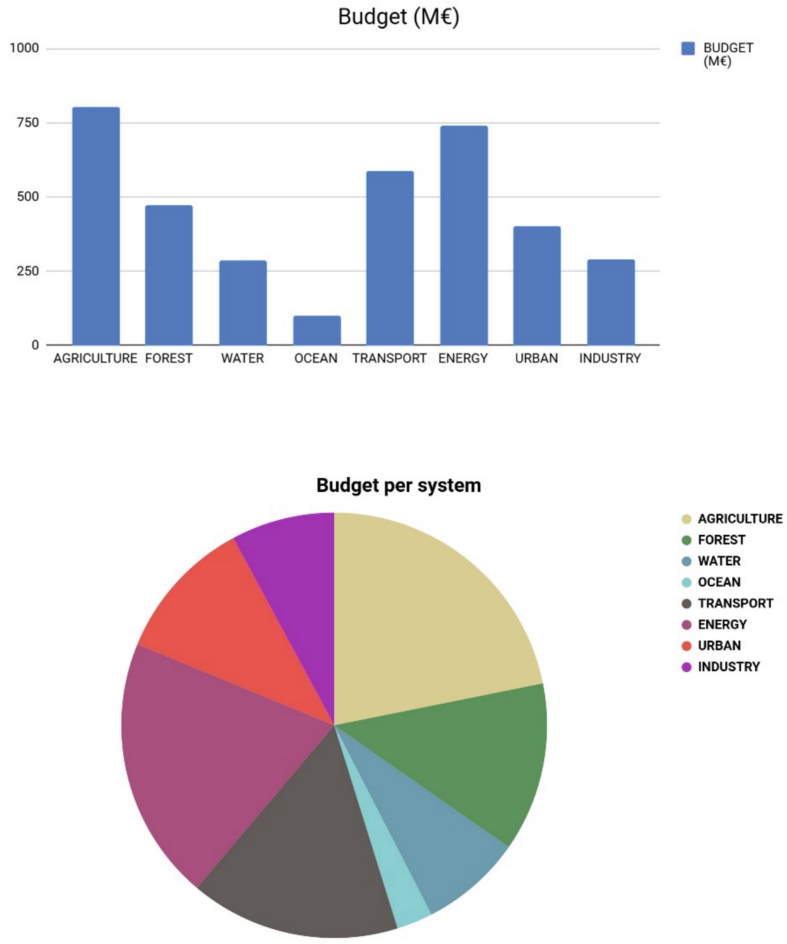

Fig. 3. Allocation of the Fundings among the selected domains

Planning and management of areas close to marine protected areas contributes by 83.9% to the mitigation benefits resulting from the marine Environment sector, over the four cycles. The actions related to the marine environment sector constitute a marginal portion of the cumulative mitigation output, amounting to only 0.7%. Co-located Housing and Jobs and Mixed Land Use, and avoiding, minimizing, and recycling waste contributes by 57.3% and 20.4%, respectively, to the mitigation benefits resulting from mitigation and adaptation actions of urbanized areas.

The latter amounts to 0,094 $MtCO_2$ e per year and represents a marginal proportion (2.9%) of the cumulative mitigation outcome. The modest impact of actions related to urbanized areas is determined by a moderate cost-benefit ratio. In particular, Mixed Land Use targets 22.7% of people residing in the Basilicata Region with a modest mitigation factor of $0.500tCO_2e\ inh^{-1}$ per year. Conversely, avoiding, minimizing and recycling waste, despite a significant mitigation factor (1.400 tCO2/tPO), presents a cost factor of

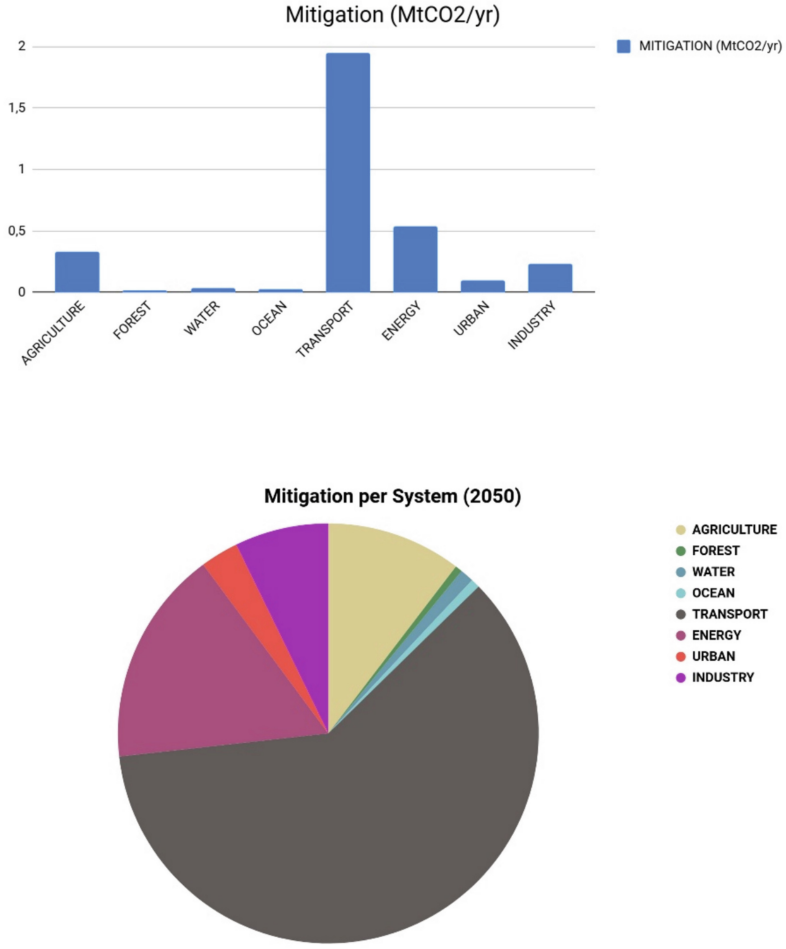

Fig. 4. Contribution of individual sectors to the total Mitigation output

5000 €/tPO, which limits its impact on the total production of municipal waste in the Basilicata Region, given the budget constraints. A significant impact on forest areas can result from the implementation of actions related to Sustainable/ Adaptive management of forests and Restoration of riparian buffers. Given a budget of 473.1 M€ over the four cycles, 77730,14 ha of forest lands could be targeted by the proposed interventions, producing a cumulative mitigation outcome of 0,017 Mt per year of equivalent carbon dioxide sequestered.

Finally, concerning the options identified for the industrial sector, which accounts for 7.2% of the cumulative mitigation outcome, Reduced Venting and Electrification in upstream oil and gas production contribute the most to emission reductions in the Basilicata Region. More precisely, reduced venting presents a mitigation factor of 0.002 tCO_2 per Barrel of oil equivalent (BOE), at a modest cost of 0.75€/BOE. As a result, its

Table 1. Cumulative Mitigation outcome for the selected domains

	AGRICULTURE	FOREST	WATER	OCEAN	TRANSPORT	ENERGY	URBAN	INDUSTRY
Budget (M€)	803,8	473,1	285,0	101,0	587,7	738,6	401,4	289,7
N_Actions	8	2	7	7	6	8	8	16
Mitigation (Mtco2/Yr)	0,333	0,017	0,034	0,022	1,946	0,534	0,094	0,232
ADAPTATION IMPACT								
ha	39,65%	19,84%	122,69%	98,76%	0,00%	0,00%	31,64%	0,00%
tPO	0,00%	0,00%	0,00%	124,59%	0,00%	15,93%	27,30%	41,34%
BOE	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	86,88%
inh	0,00%	0,00%	34,71%	0,00%	28,72%	0,00%	24,46%	0,00%
Veh	0,00%	0,00%	0,00%	0,00%	60,49%	0,00%	0,00%	0,00%
Km	0,00%	0,00%	0,00%	0,00%	2,12%	0,00%	0,00%	0,00%
MWh	0,00%	0,00%	0,00%	0,00%	0,00%	22,26%	0,00%	0,00%
tCO2	0,00%	0,00%	0,00%	0,00%	0,00%	4,57%	0,00%	0,00%
	BASELINE (MtCO2/yr)	2050 (MtCO2/yr)	VARIATION (%)					
	5,806	2,593	–55,33%					

implementation, over the four cycles could target the production of 9655333.33 BOE per year and could reduce equivalent carbon dioxide emissions by 19117.56 metric tons per year, equal to 8.6% of the mitigation outcome of the industry sector under the considered scenario.

Electrification of drilling rigs presents a significant mitigation factor of 0.011 tCO_2 per BOE at a cost of 1,92€/BOE. Its implementation, given an investment of 32.6 M€ over the four cycles could target the production of 7543229.17 BOEand reduce equivalent carbon dioxide emissions by 79203.91 metric tons per year, equal to 35.5% of the industrial sector's cumulative mitigation outcome.

4 Conclusions

This research demonstrates how spatialized, participatory, and evidence-based approaches can play a pivotal role in translating national climate adaptation and mitigation strategies into coherent regional actions. Within the broader framework defined by the SNAC and PNACC, the GD-CURE project in Basilicata has successfully showcased the potential of Geodesign methodology [18, 29], to support multi-level governance and spatial decision-making. By combining land suitability analysis with collaborative scenario planning, the project has enabled a deeper understanding of how climate challenges manifest at the territorial scale and how targeted, domain-specific responses can be developed accordingly.

The integration of the GeodesignHub platform together with tailored analytical tools such as the impact model and the climate action handbook, facilitated a structured, informed, and participatory process that engaged a wide spectrum of stakeholders—from technical professionals and researchers to local administrators and civil society organizations [3, 30]. This not only enhanced the legitimacy and feasibility of the proposed measures, but also contributed to the creation of a shared adaptation culture grounded in spatial and scientific awareness [31, 32].

The land suitability maps proved to be key instruments in spatializing the strategic objectives of climate mitigation and adaptation on specific territorial targets. They provided clear, data-driven guidance on where and how to implement actions across various critical sectors—Energy, Agriculture, Forests, Marine and Coastal areas, Settlements, Industry, Transportation, and Water Resources. Such spatial delineation supports more efficient resource allocation, reduces implementation uncertainty, and helps anticipate trade-offs between competing land uses increasing the feasibility assessment of a regional scale complex strategy.

Ultimately, the Basilicata Geodesign Workshop highlighted how regionally adapted tools and processes can reinforce resilience planning and promote sustainable development in vulnerable contexts[33]. The findings underscore the value of spatially explicit approaches in addressing the complexity of climate governance, especially when combined with multi-actor collaboration and system thinking [34–37]. These outcomes offer relevant insights for replicating similar initiatives in other Italian regions and contribute to building a robust foundation for integrated territorial climate strategies at national and European levels.

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