MULTI-CRITERIA SPATIAL ANALYSIS FOR URBAN LAND-BASED SOLUTIONS SUITABILITY MAPS IN THE CONTEXT OF RETHINKACTION PROJECT

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ABSTRACT

A multi-criteria spatial analysis within the context of the Horizon 2020 RethinkAction project is presented. RethinkAction is aligned with the EU Green Deal and the Paris Agreement that focuses on the important role of land use planning in achieving long-term climate mitigation and adaptation goals. To that end, the project employs a cross-sectoral planning decision-making platform to empower citizens and decision-makers in fostering climate action across Europe. Focused on the establishment and maintenance of green urban ecosystems and limiting urban sprawl, methods proposed in this paper employs techniques to develop suitability maps for urban land-based adaptation and mitigation solutions, such as establishment and maintenance of green urban ecosystems (GUE) and limiting the urban sprawl (LUS). The methodology, suitability factors applied, and results for each Land-based Adaptation Measure (LAMS), shedding light on the intricate relationship between urban planning and climate action are described.

Index Terms—Land-use, urban, climate, multi-criteria spatial analysis, land-based climate solutions, suitability factors, GIS

1. INTRODUCTION

The objectives of the RethinkAction project (https://rethinkaction.eu/), funded under Horizon 2020, are aligned with European Union's Green Deal, championing the imperative of sustainable land use planning to meet the objectives of the Paris Agreement. With a strong emphasis on citizen and decision-makers involvement, the project endeavors to create a cross-sectoral planning decision-making platform that transcends geographical boundaries within Europe. Central to this endeavor is the integration of multi-criteria spatial analysis, a powerful tool that enables the development of suitability maps for urban land-based solutions. Urban landscapes, being both contributors to, and mitigators of climate change, require innovative approaches for sustainable development [1-3].

Urban growth refers to the rate at which the population, land area, or significant land-use increases. The causes are multiple, including the natural increase in population, migration, industrialization, commercialization, advancement of transport and communication, availability of educational and recreational facilities, urban planning policies, and topographical factors. Growth in urban populations presents a wide range of societal, environmental, and economic consequences [1], [3]. The 11th item in the United Nations' Sustainable Development Goals (SDGs) pledges to "*make cities and human settlements inclusive, safe, resilient and sustainable*" and the associated 2030 objectives have spurred cities to introduce a variety of initiatives—in areas such as housing, transportation, public health, and environmental protection [4].

Urban growth is linked to two distinct issues: (i) the replacement of natural materials with artificial ones that result in the development of the Urban Heat Island (UHI) phenomenon where the temperature of the dense city centre is higher than its surrounding rural and suburban areas [2]; and (ii) the urban sprawl, a form of unplanned urban and suburban development that takes place over a large area and creates a low-density environment with a high segregation between residential and commercial areas.

In the framework of RethinkAction, several Land use-based Adaptation and Mitigation Solutions (LAMS) address the above two issues. These LAMS are grouped in two broad categories, namely "Establishment and maintenance of green urban ecosystems" and "Limiting Urban Sprawl"—henceforth referred to as GUE and LUS, respectively. The former focuses on the establishment and maintenance of green urban ecosystems and counteracting the UHI effect by improving the city green infrastructure (e.g., green roofs, trees, and other vegetation in public spaces [2], [5], [6]), while the latter on limiting urban sprawl by promoting more compact ways of development (increase urban density), redeveloping brownfields, and preserving natural resources [7]. For each selected LAMS, dedicated suitability maps will be created that will help answer two key questions: "how big an area is actually suitable for conversion and where can one intervene?". In this work, the method used for creating the GUE and LUS suitability maps and a set of preliminary results are presented.

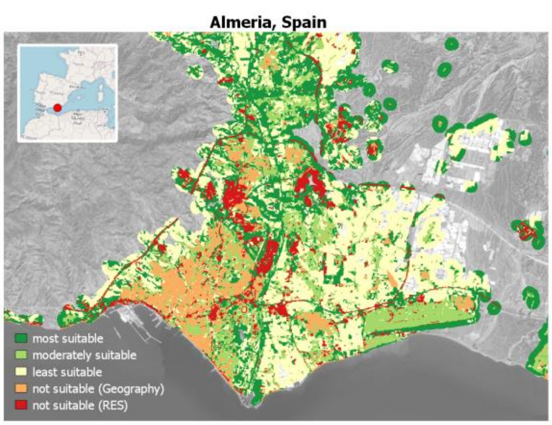
2. DATA & METHODS

The urban environment is traditionally examined with the finest spatial resolution available, often provided by datasets such as Urban Atlas, which offer detailed information at the building block level, including tree layers and building heights. These datasets, part of the Copernicus programme by the European Environment Agency (EEA), are accessible through the Copernicus Land Monitoring Service (CLMS). The high resolution (10 m) land use maps generated within the framework of RethinkAction project is used. They are based on Sentinel-2 data and the aforementioned CLMS high resolution layers for the project case studies: Gotland, Sweden; Tarn-et-Garonne, France; Bács-Kiskun County, Hungary; Aosta Valley, Italy; Almería Province, Spain; and the Autonomous Region of the Azores, Portugal.

The methodology employed in this study is rooted in the principles of multi-criteria spatial analysis, a technique that considers various factors simultaneously to make informed decisions about spatial distribution. Our research design integrates diverse datasets, encompassing urban infrastructure, environmental factors, and socio-economic indicators. Geographic Information Systems (GIS) serve as the backbone of our methodology, allowing for the synthesis of complex spatial information. Through a systematic approach, the suitable areas for urban land-based solutions are identified and prioritized based on a range of criteria, including climate vulnerability, existing infrastructure, and community needs. The transparency and replicability of our research design ensure its applicability across diverse urban landscapes, offering a scalable solution for climate-conscious land use planning.

For each LAMS, specific suitability factors are considered, providing a detailed understanding of their impact on urban sustainability. For GUE, the significance of factors like urban forestation, and water bodies are explored. Similarly, the analysis of strategies to LUS involves examining the ecological, economic, and social consequences of applied policies.

For each 10-meter high-resolution land cover map provided by the RethinkAction project, we delineated potential suitable areas by excluding urban pixels within the Functional Urban Area (FUA), which encompasses European cities with populations exceeding 100,000. This methodology was applied to all six case studies of RethinkAction, resulting in five FUA polygons (three for Case Study 3 in Hungary, one for Case Study 5 in Spain, and one for Case Study 6 in the Azores, specifically one of the islands).



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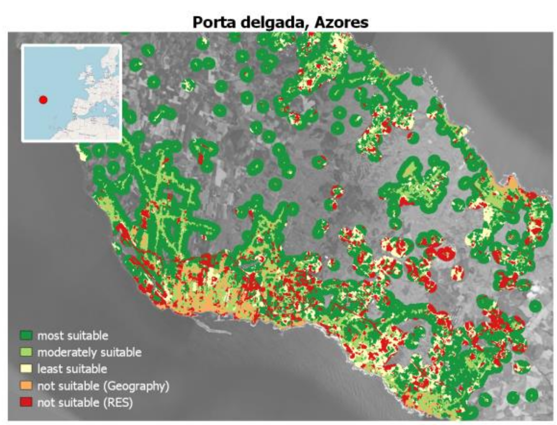


(b)

Fig. 1. The suitability maps for the "Limiting Urban Sprawl" (LUS) LAMS for (a) Almeria, Spain; and (b) Porta delgada, Autonomous Region of the Azores, Portugal.

Subsequently, a suitable-per-urban-LAMS buffer zone was established around Continuous and Discontinuous Urban Land. Pixels located outside this buffer were classified as non-suitable.

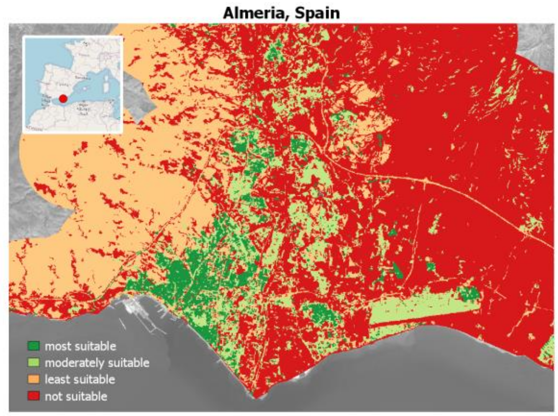
Within the designated area, each pixel was evaluated against a set of predefined criteria to determine its suitability level, categorizing them as most favorable, moderately suitable, or least suitable, or identifying reasons for non-suitability, such as geographical or regulatory constraints. The final output of this process is a raster file (geoTIFF) that depicts these suitability levels, accompanied by a table to inform the dynamic model (WILIAM).

4. RESULTS

To demonstrate the results of the proposed method, Fig. 1 and Fig. 2 are presented showing the LUS and GUE suitability maps, for selected cities in RethinkAction's case study areas. The suitability maps of Fig.1 present with yellow and green colors the areas that are suitable (least to most) for implementing land-use adaptation and mitigation solutions that aim to establish new green urban ecosystems or to maintain and enhance existing ones. With orange and red colors, the areas that are not suitable, either due to geographic (e.g., topography, distance from roads) or other regulatory criteria (e.g., protected areas), are shown. Fig. 2 presents the suitability maps for the GUE LAMS for the same two urban areas and also for the cities of Szeged, Kecskemet, and Bekescsaba in Hungary. In these maps, the areas where the urban area can be expanded are shown with green colors and the areas that are not suitable for further expansion with red colors. The results of the employed multi-criteria spatial analysis reveal intricate patterns of suitability for urban land-based adaptation and mitigation solutions. By considering diverse criteria, areas where adaptation action can be most effectively implemented are unveiled, considering the unique characteristics and challenges of each urban landscape. The maps presented in Fig. 1 and 2 corroborate each other well, indicating that the regions suitable for the application of GUE solutions outnumber those suitable for LUS. These maps also highlight regions where both solutions can be implemented in parallel, offering a versatile approach to implementing land use adaptation and mitigation actions. This dual implementation could potentially lead to synergistic effects, enhancing the overall impact of these solutions.

5. CONCLUDING REMARKS

The methodology proposed in this article, based on a multi-criteria spatial analysis, is of great interest and relevance for the quantification and evaluation of suitability maps based on the territory's capacity to accommodate the deployment of urban LAMS. The results obtained are crucial for implementing functional models at the case study level, which will be key within the RethinkAction platform. The platform will be centered on land use as a key to sustain life



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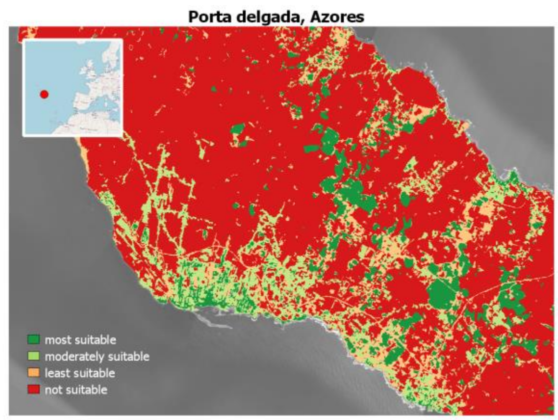

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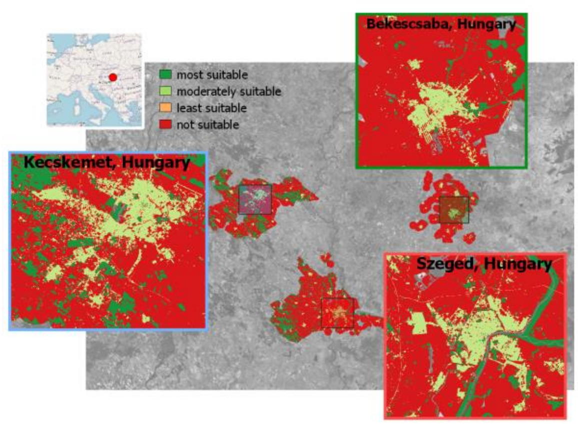

(c)

Fig. 2. The suitability maps for the "Establishment and maintenance of green urban ecosystems" (GUE) LAMS for (a) Almeria, Spain; (b) Porta delgada, Autonomous Region of the Azores, Portugal; and Szeged, Kecskemet, and Bekescsaba, Hungary.

and reach objectives in the context of climate change and will allow users to access solutions linking local, European and global scales, based on the comprehension of the suitability maps as the one shown here presenting the feasible areas to implement each specific LAMS.

7. ACKNOWLEDGMENTS

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