Research Paper

Envisioning the Rural Metropolis:
"Ethanol Urbanism" for Ecological and Social Sustainability in the Near-Collapse Scenario for the Year 2074

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Abstract

According to the Near Collapse scenario, which is part of a Harvard Graduate School of Design academic study, Cova da Beira, Portugal, will have robust urban design strategies by 2074. The research, which emphasizes ecological self-sufficiency, social integration, and dynamic equilibrium with ecosystems, is impacted by "sci-fi urbanism." 2312 by Kim Stanley Robinson and Pedro Gadanho's ideas on sustainable urbanism both work in a similar way. Under extreme environmental stress, it uses scenario thinking to explain responses to food, energy, and societal crises. Important strategies include creating closed-loop energy and food systems, integrating agriculture into urban areas, advocating for social justice, and designing infrastructure to coexist with natural ecosystems. The report provides a framework for future crises that urban planners and policymakers may utilize to advance sustainable urban expansion and environmental justice.

Keywords

resilient urban design, ecological self-sufficiency, sci-fi urbanism, environmental justice, social integration, adaptive infrastructure

1. From Sci-fi urbanism to contemporary ecological challenges

1.1. Sci-Fi Urbanism And Ecological Insights

For a long time, authors of science fiction have envisioned how people may react to the ecological constraints of Earth. Kim Stanley Robinson imagines a future in which environmental concerns drive human colonization of the solar system in his book *2312*. His inventive "sci-fi urbanism" includes amazing adaptations such as creating cities that run around Mercury's equator to avoid its blazing sun and protecting Earth's threatened biomes inside hollowed-out asteroids (Robinson, 2012). Though intriguing, these images highlight an important point: we must handle urgent issues on Earth before we can dream

about colonizing other planets.Our knowledge of resource constraints underwent a sea change in the wake of the 1973 oil crisis. William Catton and other environmental experts started drawing attention to the fact that throughout the past four centuries, humankind's remarkable expansion has depended on using resources that the planet can't naturally produce. "Borrowing" from other countries, seas, fossil resources, and even future generations was necessary for this expansion (Catton, 1982). With humankind's combined resource usage now equaling that of two Earths, glaring global disparities and pressing environmental justice issues are brought to light. Robinson's futuristic vision, in which humans colonize distant planets and space stations, is both a cautionary tale and an inspiration. His innovative solutions force us to reconsider how we handle Earth's current environmental problems, even though space colonization is still only a speculative idea (Gadanho, 2024). The creativity displayed in conceiving off-world solutions may be more useful to us in resolving domestic issues.

1.2. Applying Scenario Planning for Regional Climate Adaptation

Scenario planning is the cornerstone of sci-fi urbanism's approach to imagining future cities (Gadanho, 2024). This strategic tool has a fascinating history, having been developed for military forecasting in the 1950s by Herman Kahn of the RAND Corporation. It later found wider applications in business strategy and public policy (Schwartz, 1991). Kahn developed the approach of creating detailed "future narratives" or scenarios, which gained popularity through institutions such as the Hudson Institute and the Stanford Research Institute (Kahn, 1965). By the 1970s, major corporations such as Shell and DHL had implemented scenario planning to cope with uncertain futures (Chermack, Lynham, and Ruona, 2001). The current climate catastrophe has made scenario planning even more important. One part of the challenge is predicting the effects of climate change; another is communicating complex adaptation alternatives to a variety of audiences, such as lawmakers, designers, and local residents (Harvard Graduate School of Design, 2024). Kira, a climate design researcher, offers an innovative method called place-based scenario planning. This approach situates false climate projections into the familiar context of local infrastructure, cultural institutions, and landscapes. By focusing on specific communities while recognizing shared regional features, such as urban centers, water bodies, rural highlands, and critical infrastructure, planners may develop more inclusive and relevant adaptation strategies.As we look to 2074, a significant year that will mark both the 100th anniversary of Portugal's democratic revolution and the anticipated 10 billion-person global population peak, our effort is divided into two stages. We start by creating thorough scenarios of potential futures. Next, we develop adaption strategies based on regional requirements. The goal of this systematic approach is to develop a framework that is adaptable to the specific climate issues faced by communities around the world (Town Green 2025, n.d.).

2. Rural Metropolis and its ecological prospect

2.1. The Model of Rural Metropolis

In many places, the surge in urbanization around the world results in population reduction, ecological harm, and economic degradation (Pallagst et al., 2009). For example, as more individuals from rural areas have moved to cities, the "emptying" of rural towns has gotten worse (Lei, 2009). This scenario involves "the whole migration of abandoned houses, hollow villages, abandoned settlements, the trend of pre-empty waste of remote settlements caused by urbanization, empty waste and empty waste development of public construction land, empty waste of agricultural production facilities, the phenomenon of agricultural homes and abandoned development of traditional dwellings" (Lei, 2002). These phenomena affect people's

quality of life and threaten the balance of the local ecology in addition to wasting land resources and building antiquated infrastructure (Koolhaas and AMO, 2020).

By guiding 17 communities and towns in Portugal's eastern core to apply for the 2027 European Capital of Culture, Pedro Gadanho, a professor at Harvard University, proposed the "rural metropolis" model as a solution to these issues and as a prime location for future climate migration. This approach seeks to achieve rural self-sufficiency through socioeconomic measures, energy structural reform, and ecological restoration (Gadanho, 2024).

Numerous European nations have established systems to address comparable rural issues. For instance, France encourages organic farming and agrotourism while bolstering ecological and environmental protection in an effort to boost the rural economy. Germany encourages rural residents to participate in community planning and management through the "village revitalization plan," which aims to improve the area's attractiveness and quality of life; Italy encourages sustainable rural development through the restoration of traditional agriculture, the preservation of cultural heritage, and the growth of rural tourism (Koolhaas and AMO, 2020). Gadanho's "rural metropolis" concept is particularly good because it encompasses not only agricultural development but also decarbonization, energy mobility, food security, water management, resource extraction, biodiversity conservation, and cross-species mobility. These national programs have produced impressive results in their respective contexts. Utilizing a range of renewable energy sources is preferred in order to accomplish energy recycling and self-sufficiency, lessen regional reliance on outside energy sources, and improve the resilience of rural communities (Harvard Graduate School of Design, 2024). This study looks at Portugal's "rural metropolis" ecological approach and its implications for rural regeneration around the world.

2.2. Portugal's Rural Metropolis Concept and its Ecological Prospects

Only 3 million people live in the interior of Portugal, whereas 7 million live in a 30-kilometer-wide coastal area. The rural eastern hinterlands have been severely depopulated as a result of this coastal focus, and by 2100, they are predicted to be almost completely deserted. Nevertheless, despite this population reduction, eastern Portugal has a wealth of natural resources, such as farms, rivers, and woods, which make it the perfect place for a "rural metropolis" approach. As Portugal's digital transformation and EU infrastructure improvements create opportunities for low-density urbanization in rural regions, the COVID-19 pandemic and climate change may reverse population emigration. In order to revitalize the eastern countryside, Gadanho suggested using eco-migration and rural regeneration to draw in skilled workers, migrants, returning locals, newcomers, and digital nomads. This would stimulate social,economic, and ecological redevelopment.

Low-density development near nature that makes use of abundant natural and cultural resources is part of the concept of a "rural metropolis." These rural metropolises could be centers of ecologically beneficial societal change as Europe moves toward decarbonization under the Green New Deal. Because locals attend activities in other municipalities, small villages in the area are already culturally integrated. Better intercity public transportation, including electric bikes and ecological microbuses, might strengthen these ties in places like Cova da Beira and promote sustainable movement between urban nodes.

"Business as usual," "managed degrowth," and "near-collapse" were the three future scenarios that interdisciplinary teams investigated for Cova da Beira in 2074 as part of a research experiment that Gadanho started at Harvard GSD in 2024 to further this plan. For sustainable development, luring climate

migrants, and ecological self-sufficiency, each team created creative plans. According to the "business as usual" scenario, economic development will continue while decarbonization targets are postponed. The "managed degrowth" scenario envisions the EU establishing a test area for sustainable urban development and the circular economy. The "near-collapse" scenario concludes by discussing the preparations for food, energy, and societal issues. By demonstrating how rural metropolises could adapt to severe ecological and social challenges, these scenarios help Portugal's interior regions become more resilient and experience sustainable growth.

3. Regional Planning Strategies for a "Rural Metropolis"

3.1. Timeline and Regional Analysis

The "Near Collapse" initiative envisions potential reactions from the Cova da Beira regional administration in the form of time nodes and outcome triggers throughout the 2024–2074 time frame in awareness of the growing dangers of food, energy, and social collapse. For instance, the region needs to guarantee food security beforehand because the drought in Europe is expected to result in famine in 2042. Alternative energy sources need to be identified beforehand in case of a gas crisis in 2060. By foreseeing and creating plans to make the area environmentally balanced and nearly self-sufficient while embracing and integrating 120,000 locals and climate migrants, the initiative seeks to attain ecological stability and dynamic balance. Economic systems and land usage that support food, energy, and social self-sufficiency are taken into account in the design in the wake of environmental disasters and deglobalization.

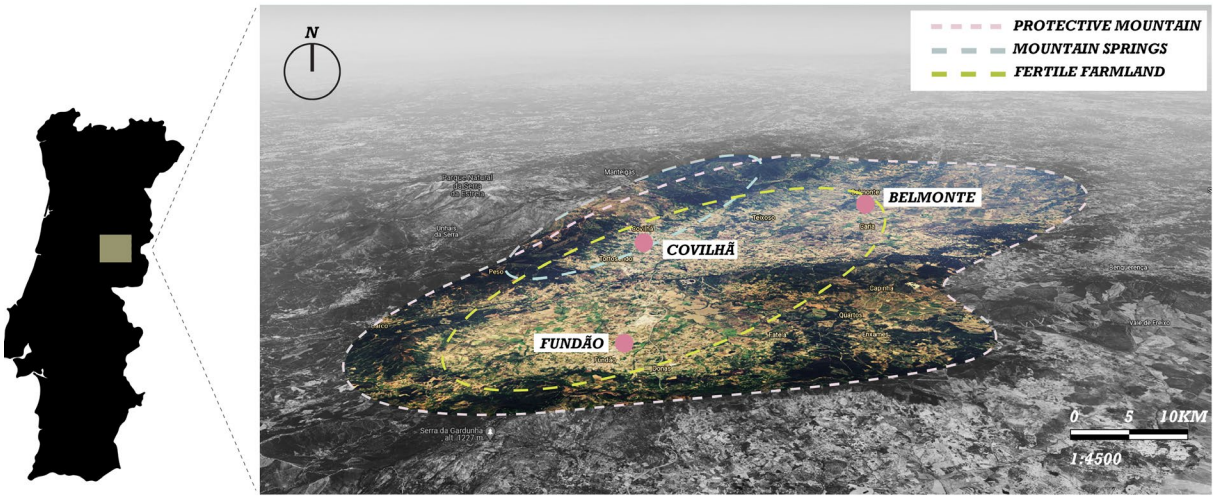

Figure 1. Aerial view of the Cova da Beira area. Source: Authors.

In the middle of the Iberian Peninsula, between Lisbon and Madrid, sits the Cova da Beira region. It is primarily an agricultural valley with a total area of roughly 1,000 square kilometers (Figure 1). The area is home to several minor towns and villages in addition to the three major cities of Covilha, Fundao, and Belmonte. A river flows across the valley from north to south, and there are other mountain streams that

supply drinking water. The area maintains a strong connection to nature in spite of the environmental and climate crises: it has been largely spared from industrialization, has no major sources of pollution, has fertile land and intriguing natural landscapes, and is far from scenarios of desertification and water scarcity (Harvard Graduate School of Design, 2024). The project team believes that achieving self-sufficiency in energy, food, and ecosystems is the key to success in the "near collapse" scenario.

3.2. Energy Independence and Circular Economy

The "Near Collapse" project has implemented a novel ethanol energy system in order to achieve energy independence (Figure 2). Due to its low startup costs, easy access to resources, and limitless availability, ethanol is the ideal option because many fossil fuel substitutes depend on internationally traded resources and have substantial entry barriers (Boyle and Open University, 2012). Ethanol is renewable yet less efficient than gas and oil. To guarantee energy recycling and self-sufficiency, the system operates in a closed-loop mode (Lin and Tanaka, 2006). In contrast to traditional ethanol production, which blends cattle and corn, the system selects chicken and cacti due to their high yield efficiency and minimal water requirements. Cacti are drought-tolerant, low water requirements, easy to cultivate, and highly efficient at producing ethanol (Alencar et al., 2022). In addition to producing more manure that can be utilized to make ethanol, poultry use less water (Getahun et al., 2013). The ethanol generated can be used to power generators, public transit, and local vineyards, boosting revenue.

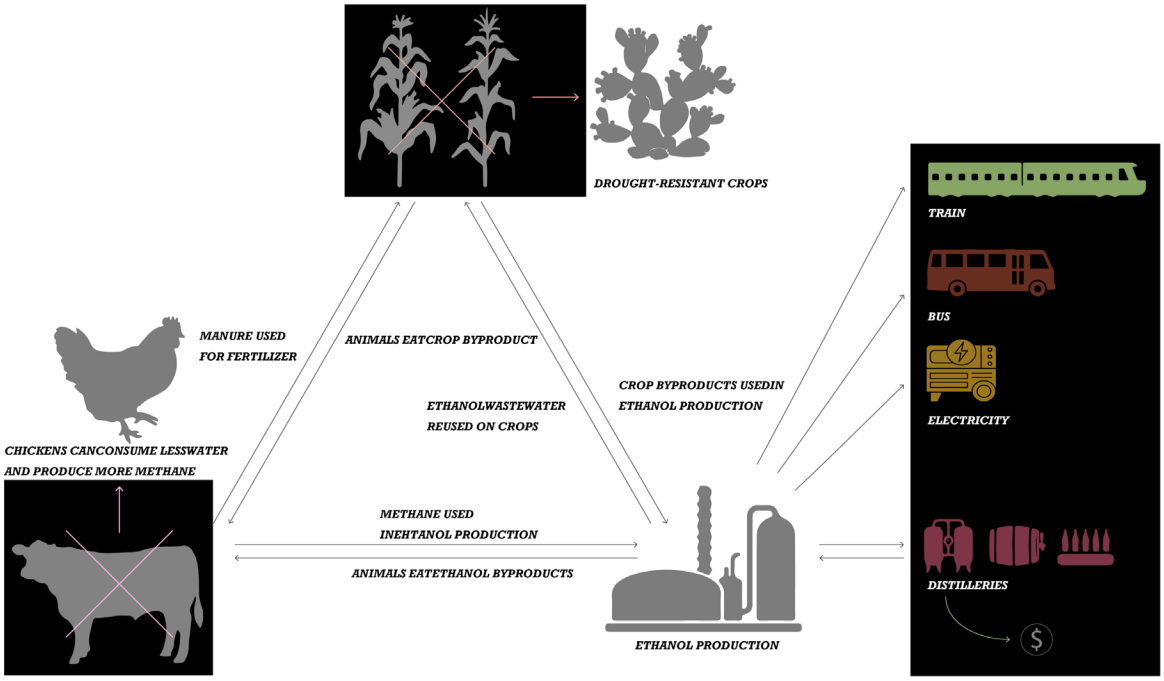

Figure 2. Diagram of ethanol circulation system based on cactus and poultry. Source: Authors.

Utilizing Portugal's wealth of natural resources, the project also incorporates a number of additional renewable energy sources, including geothermal and hydropower, to guarantee a sustainable energy

supply (Figure 3). Stable power can be generated from nearby mountain streams, rivers, and micro-dams using hydropower, which is simple to maintain (Kurtagić et al., 2022). The new strategy intends to continue using hydropower for the manufacturing of ethanol, in addition to the region's long-standing legacy of using it for the textile sector. Similarly, hydropower and ethanol can be effectively supplemented by geothermal energy, which comes from deep under the mountains and uses subterranean heat to produce heating and cooling. A green energy transition can be achieved by encouraging the use of renewable energy sources and decreasing reliance on fossil fuels. In addition to increasing rural communities' energy self-sufficiency, this strategy lowers carbon emissions, which benefits sustainable development and environmental preservation.

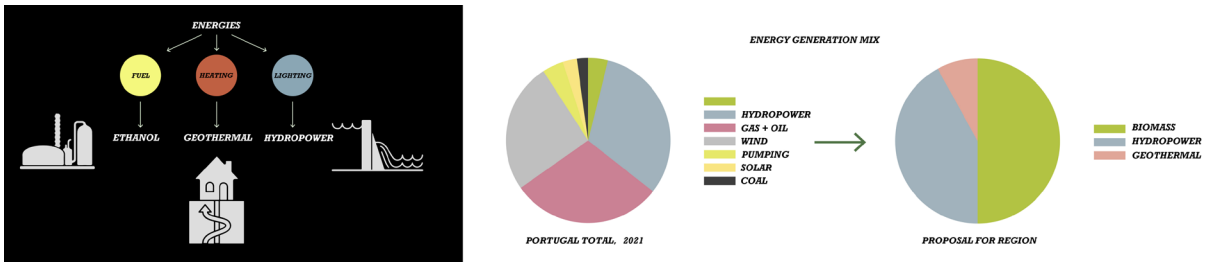

Figure 3. Renewable energy systems composed of ethanol, hydropower and geothermal. Source: Authors.

3.3. Ecological Interventions, Water Management, and Social Sustainability

Achieving self-sufficiency and safeguarding the entire area are the goals of the ecological intervention. In addition to the ecological corridor created by reforestation to link the region's existing dispersed patch forests, the "Near Collapse" project planted an agave defense belt and a fire forest belt at the regional border. At the same time, reforestation was planted around the city to create a buffer zone and stop the spread of the fire forest (Figure 4). During energy crises and severe weather, these actions safeguard communities from alien populations and forest fires while promoting the production of ethanol. Furthermore, by promoting carbon sinks and lowering carbon emissions, these ecological interventions aid in the achievement of rural decarbonization objectives.

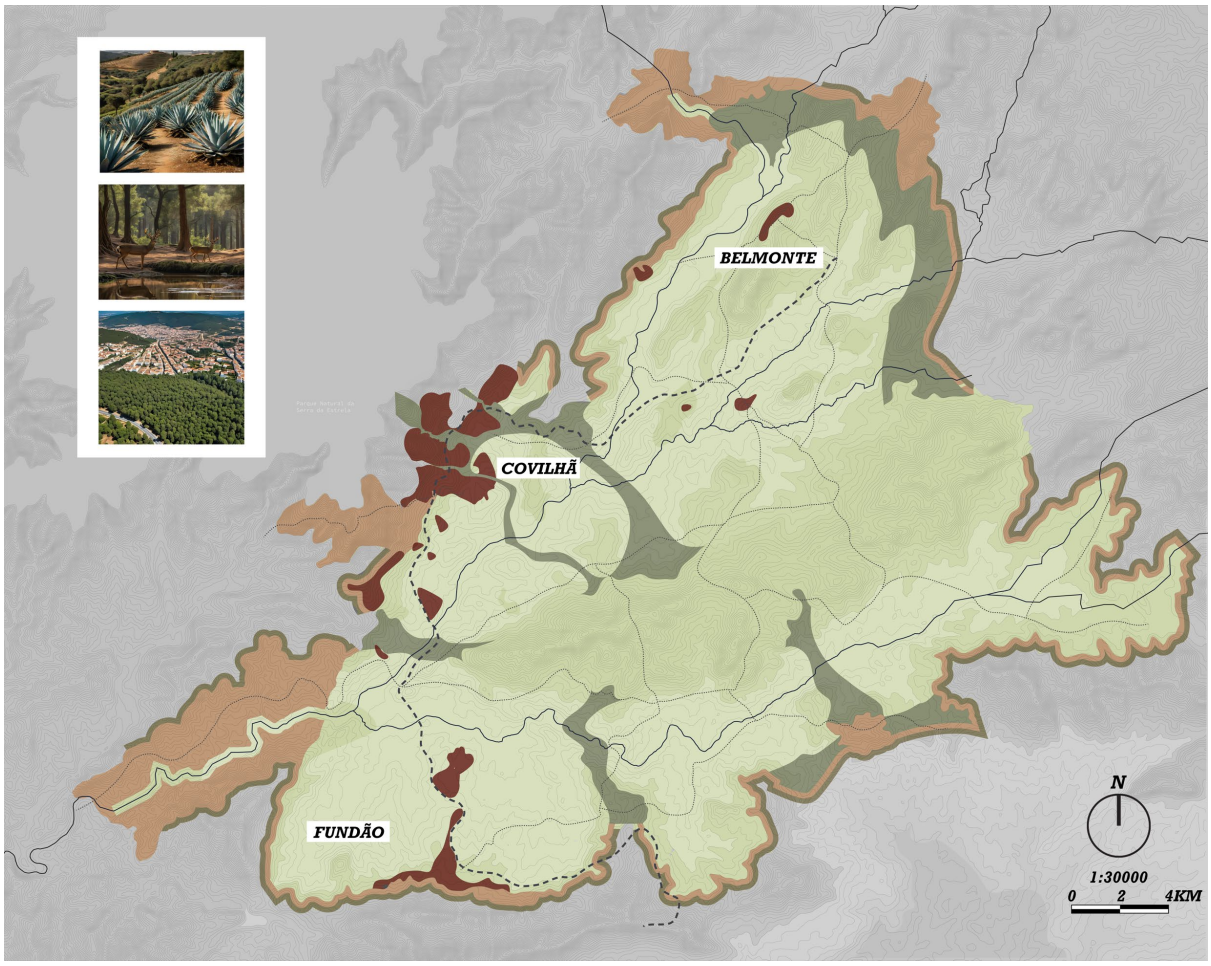

Figure 4. Agave borders, reforestation ecological corridors and urban peri-buffer zones. Source: Authors.

The majority of the land in the area will be used for agricultural in order to raise the population by 50%. In order to prevent cattle from using a significant amount of space for food production, the project suggests switching to a nearly vegetarian diet consisting of a variety of plants, home-raised livestock, and occasionally hunting in the forest. Agroforestry zones serve as a transition between forests and agricultural areas (Figure 5), facilitating wildlife mobility and connecting natural corridors. Ecological buffer zones preserve the environment and produce a wealth of agricultural goods by growing a variety of crops and trees. The people of the dispersed villages in the eastern portion of the area were incorporated into the western metropolis to aid in population control, and the old villages were converted into work camps and maintenance stations for forestry and agriculture. Numerous abandoned Urban farms, greenhouses, and vertical agriculture are examples of spaces that can be transformed into food producing areas in urban environments. The study concentrated on passive thermal techniques to lower heating usage. In the winter, the ground floor is heated by the thermal energy of the donkeys and hens that use it as a source of food and transportation.

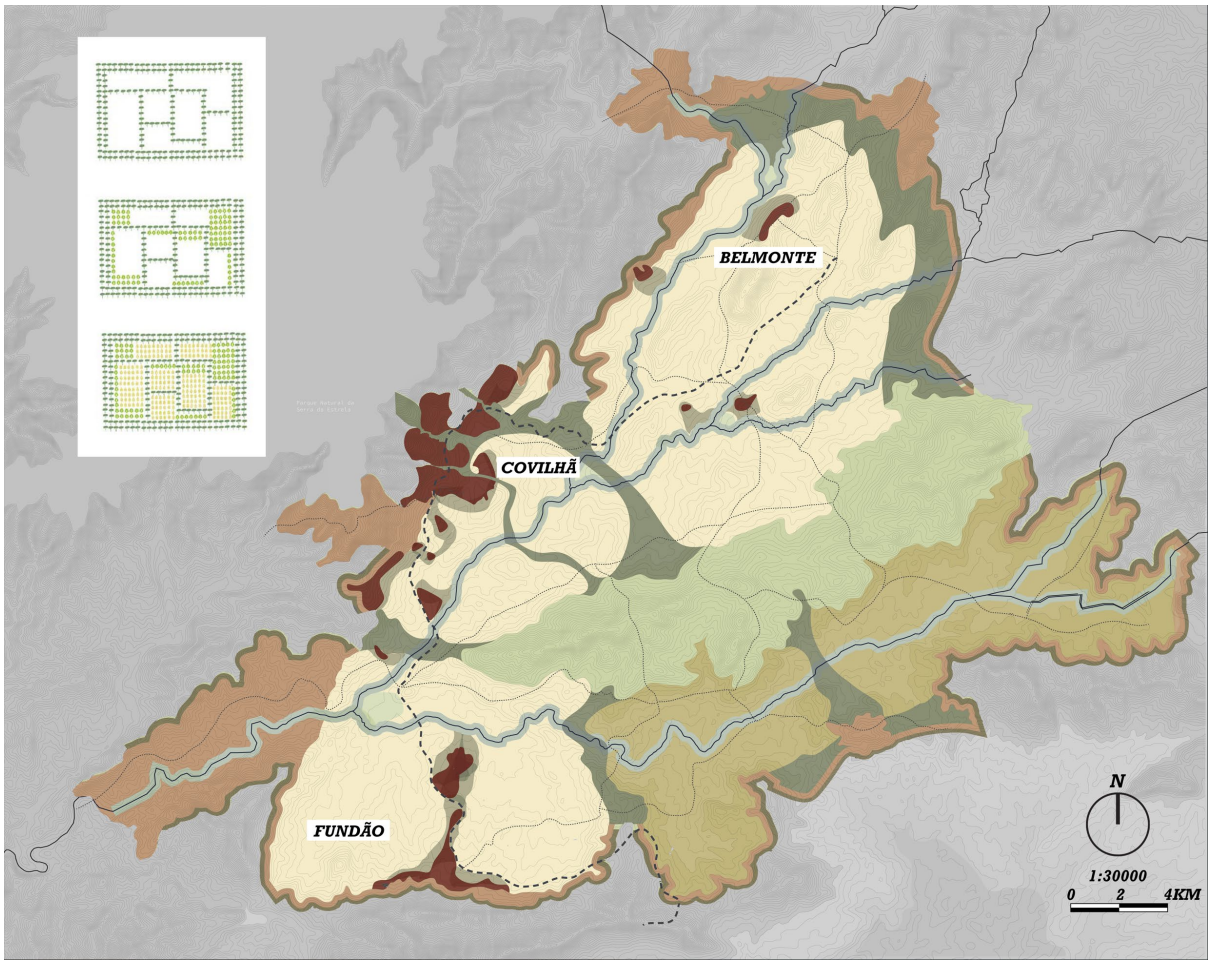

Figure 5. Distribution map of agricultural and agroforestry area. Source: Authors.

Micro-dams and reservoirs are constructed at river confluence in conjunction with topographic advantages to extend river water bodies in order to guarantee a year-round supply of water in hot and arid regions (Unami et al., 2013) (Figure 6). Micro-dams maintain agricultural output by controlling water flow, preventing flooding, and storing water during dry seasons. In order to supply irrigation water and integrate into the environment, the reservoir combines ecological and landscape purposes. To maximize water use, develop drip irrigation systems, encourage the adoption of drought-tolerant cereals and vegetables, and practice excellent agricultural management. Along the enlarged main river channel, ecological buffer zones were created to provide recreational opportunities while shielding it from agricultural activity.

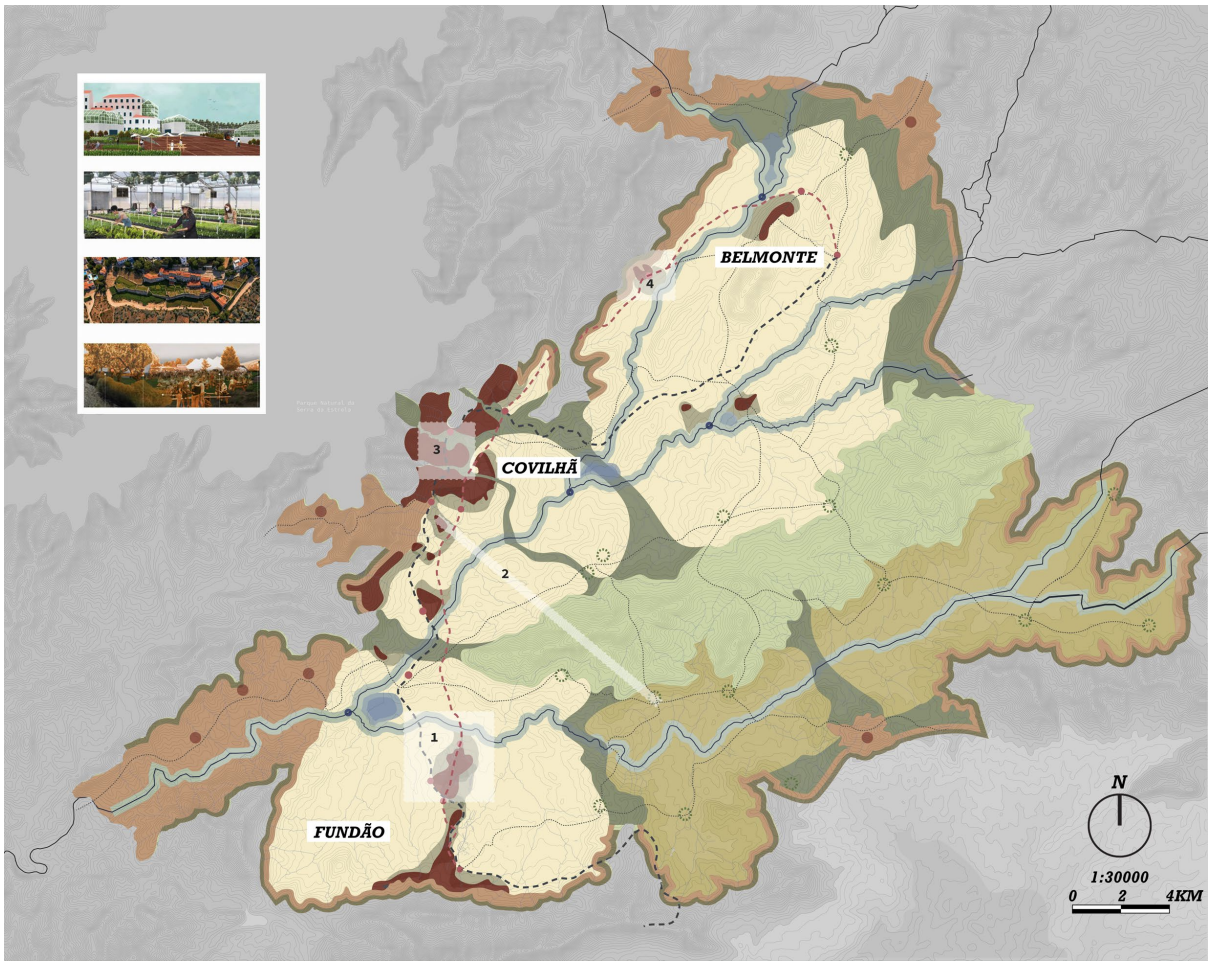

Figure 6. Ecoregional water resources management planning map. Source: Authors.

Data indicates that the EU has incentives to fund regional initiatives that aim to achieve food security, shelter, and energy independence (European Commission, 2024). The goal of the "Near Collapse" project was to create a Community Land Trust (CLT) that would unite all of the small towns and villages in the area, manage food production, develop agricultural plans, provide housing subsidies for new immigrants, and support businesses such as restaurants, wineries, and agriculture (Davis, 2010). A self-sufficiency cycle is created when farms supply food for restaurants, wineries supply alcohol, and restaurants supply compost for agriculture.

The public and private sectors of food production and distribution are connected by community land trusts, which also guarantee the land's sustainable use and long-term protection while encouraging community members to work together and share benefits. The land trust will oversee the production and distribution of 70% of the food, grow food for 120,000 people in public spaces, and harvest food from private family gardens for their personal consumption. Everyone works equally hard and receives the same quantity of food. Currently, 80% of the population gets their food from farmland; the remaining 20% comes from urban and vertical farming, which lowers the carbon impact of conventional agriculture.

3.4. Broader Project Impact and Future Development

The applicability of Portugal's "rural metropolis" ecological transformation model could be tested in different types of villages wordwide, especially in China. It needs to be comprehensively considered in combination with geographical, climatic and economic conditions. The rural terrain of eastern Portugal is diverse, which is similar to the mountainous areas of Yunnan and Guizhou in China and the North China Plain. Its Mediterranean Sea and Marine climate are similar to the southern and eastern coastal areas of China. The economy is relatively backward, relying on agriculture and handicrafts, which is highly consistent with the characteristics of many rural areas in China. This model has provided many useful experiences for China's rural revitalization, especially in coping with climate change, enhancing ecological resilience and promoting economic revitalization. In the future, through the joint efforts of policy support, technological innovation and community cooperation, China's rural areas are expected to achieve a dynamic balance between ecological protection and economic prosperity, showing higher sustainable development potential.

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4. References

Alencar, B., Medeiros, N., Lira, C., Torres Sales, A., Damilano, E., Sampaio, E.V.D.S., Menezes, R. & Júnior, M. (2022) 'Bioethanol production from cactus cladode biomass: considerations of harvesting time, dry matter concentrations, and enzymatic hydrolysis', *Biomass Conversion and Biorefinery*, 12. doi: 10.1007/s13399-020-00960-2.

Boyle, G. and Open University (2012) *Renewable Energy: Power for a Sustainable Future*. 3rd edn. Oxford: Oxford University Press in association with the Open University.

Catton, W.R. (1982) *Overshoot: The Ecological Basis of Revolutionary Change*. Urbana/Chicago: University of Chicago Press.

Chermack, T.J., Lynham, S.A. and Ruona, W.E.A. (2001) 'A Review of Scenario Planning Literature', *Futures Research Quarterly*, 7(2), pp. 7-32.

Davis, J.E. (2010) *Community Land Trust Reader*. Cambridge, MA: Lincoln Institute of Land Policy.

European Commission (2024) 'Portugal's Recovery and Resilience Plan' [online]. Available at: https://commission.europa.eu/strategy-and-policy/recovery-and-resilience-plan-portugal_en (Accessed: 23 October 2024).

Eurostat (2023) *Demography of Europe – 2023 edition* [online]. Available at: https://ec.europa.eu/eurostat/web/interactive-publications/demography-2023#expandable-example-content (Accessed: 23 October 2024).

Forman, R.T.T. (2008) *Urban Regions: Ecology and Planning Beyond City*. Cambridge, Massachusetts: Cambridge University Press.

Gadanho, P. (2024) 'Ecological Stress Test: On the Awes and Wonders of Sci-Fi Urbanism' [online]. Available at: https://weirdeconomies.com/contributions/ecological-stress-test (Accessed: 23 October 2024).

Getahun, T., Adila, M., Gabbiye, N. and Abera, S. (2013) 'Bio-ethanol Production from Poultry Manure at Bonga Poultry Farm in Ethiopia', *Research Journal of Chemical Sciences*, 3(12), pp. 11-17. Available at: https://www.researchgate.net/publication/262312722_Bio-ethanol_production_from_poultry_manure_at_Bonga_Poultry_Farm_in_Ethiopia.

Grammarly (2025) *Grammarly [AI software]*. Available at: https://www.grammarly.com (Accessed: 18 January 2025).

Harvard Graduate School of Design (2025) 'Place-Based Scenario Planning for the Climate Emergency: Spring 2025' [online]. Available at: https://www.gsd.harvard.edu/course/place-based-scenario-planning-for-the-climate-emergency-spring-2025/ (Accessed: 23 October 2024).

Harvard Graduate School of Design (2024) *Envisioning the Rural Metropolis: Syllabus* [online]. Available at: https://www.gsd.harvard.edu/course/envisioning-the-rural-metropolis-spring-2024/ (Accessed: 23 October 2024).

Kahn, H. (1965) *Thinking About the Unthinkable*. New York: Horizon Press.

Koolhaas, R. and AMO (2020) *Countryside: A Report*. Cologne: Taschen.

Kurtagić, S., Trožić-Borovac, S., Bijelić, B., and Hadziahmetovic, H. (2022) 'Sustainability Assessment of Small Hydropower Plants', *DAAAM International Scientific Book*, pp. 0123-0132. doi: 10.2507/33rd.daaam.proceedings.018.

Lei, Z.D. (2002) 'Concept of Rural Settlement Vacancy and its Quantitative Analysis Model', *Journal of Northwest University Natural Science Edition*, 32(4), pp. 421.

Lei, Z.D. (2009) *Integration and Reconstruction: A Study on the Transformation of Guanzhong Village Settlements*. Nanjing: Southeast University Press.

Lin, Y. and Tanaka, S. (2006) 'Ethanol Fermentation from Biomass Resources: Current State and Prospects', *Applied Microbiology and Biotechnology*, 69(6), pp. 627-642. doi: 10.1007/s00253-005-0229-x.

OpenAI (2025) *ChatGPT (Jan 2025 version) [AI software]*. Available at: https://www.openai.com (Accessed: 18 January 2025).

Pallagst, K., Aber, J., Audirac, I., Cunningham-Sabot, E., Fol, S., Martinez-Fernandez, C., Moraes, S., Mulligan, H., Vargas-Hernandez, J., Wiechmann, T., Wu, T. and Rich, J. (eds.) (2009) *The Future of Shrinking Cities: Problems, Patterns and Strategies of Urban Transformation in a Global Context* [online]. eScholarship. Available at: https://escholarship.org/uc/item/7zz6s7bm (Accessed: 23 October 2024).

Robinson, K.S. (2012) *2312*. London/New York: Orbit.

Schwartz, P. (1991) *The Art of the Long View: Planning for the Future in an Uncertain World*. New York: Currency Doubleday.

Town Green 2025 (n.d.) 'HU CACC Research Proposal' [online]. Available at: https://towngreen2025.org/perch/resources/hucaccresearchproposal.pdf (Accessed: 23 October 2024).

Unami, K., Yangyuoru, M., Alam, A.H.M.B. and Kranjac-Berisavljevic, G. (2013) 'Stochastic Control of a Micro-Dam Irrigation Scheme for Dry Season Farming', *Stochastic Environmental Research and Risk Assessment*, 27(1), pp. 77-89. doi: 10.1007/s00477-012-0555-3.