

CITIZEN SCIENCE AND CONNECTION WITH NATURE IN THE BIO-SOLAR PROJECT: ECOSOCIAL INVOLVEMENT IN RESEARCH ON BIODIVERSITY AND RENEWABLE ENERGY

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Abstract

The European project Bio_Solar proposes an innovative approach that combines science, education, and social participation to investigate the effects of solar parks on biodiversity and to promote sustainability in rural communities. Through citizen science programs developed in educational centers, the project fosters the involvement of students, teachers, and local residents in observing and recording flora and fauna species around photovoltaic installations. This active participation not only expands the scientific database on biodiversity but also strengthens the connection with nature, pro-environmental behaviors, and critical understanding of the energy transition. The work proposes the integration of digital tools and participatory methodologies (such as mobile applications and collaborative monitoring) that link formal learning with applied research, reinforcing the relationship between scientific knowledge and social action. Furthermore, the educational and social benefits of this co-designed and participatory intervention model are analyzed. Within the framework of Nature based Solutions (NBS), the Bio_Solar experience is presented as an opportunity to transform solar parks into spaces for active learning, intergenerational interaction, and environmental responsibility. The project demonstrates that education and citizen science are key tools to promote an inclusive and participatory ecological transition.

Keywords: *Citizen science, environmental education, renewable energy, biodiversity, connectedness to nature.*

1. Introduction

The energy transition and the accelerated loss of biodiversity constitute two of the most pressing socio-environmental challenges of the twenty-first century. In Europe, the expansion of renewable energies—particularly photovoltaic installations in intensively farmed agricultural landscapes—raises questions about their compatibility with biodiversity conservation and community well-being. Recent reports from IPBES (2024) and the IPCC (2023) warn that global biodiversity is declining at an unprecedented rate due to agricultural intensification, climate change, habitat fragmentation, and pollution, thereby compromising the ecosystem services essential for human life (Díaz et al., 2019). In this context, Nature-based Solutions (NbS) have emerged as a strategic framework for addressing ecological degradation while simultaneously supporting human needs (Cohen-Shacham, Walters, Janzen, & Maginnis, 2016). NbS emphasise the restoration, management, and enhancement of ecosystems to deliver multiple co-benefits, making them particularly relevant in transformed landscapes such as solar farms (Nesshöver et al., 2017). These infrastructures, often located in degraded or intensively cultivated areas, offer unique opportunities to reintroduce vegetation cover, improve soil quality, enhance habitat connectivity, and create refuges for flora and fauna (Lambert, Bischoff, Enea, & Gros, 2023). When appropriately designed and managed, solar farms can function not only as energy-producing facilities but also as ecological assets that contribute to climate mitigation, biodiversity recovery, and rural resilience (Ascensão, Chozas, Serrano, & Branquinho, 2023). Where increasing aridity and soil pressure intensify ecological vulnerability, integrating NbS into solar farm management becomes especially critical for reconciling energy production with conservation goals. Within this framework, the European Bio_Solar project, under the Nature-based Solutions call from *Biodiversa+*, proposes an innovative approach that combines ecological research, social participation, and environmental education to evaluate the potential of solar farms as multifunctional spaces capable of generating clean energy while simultaneously enhancing biodiversity and fostering social engagement in sustainability.

Alongside these ecological challenges, a parallel social concern has gained increasing relevance: the progressive disconnection of individuals from the natural world and, consequently, from contemporary environmental issues (Hughes, Richardson, & Lumber, 2018; Soga & Gaston, 2023). Research indicates that a combination of factors, including the early and sustained use of digital technologies, use of AI-generated images that distort real nature, accelerated urbanisation – which diminishing opportunities for contact with green spaces-, and, in rural contexts, social isolation and limited proximity to scientific and educational institutions, has contributed to a marked reduction in direct interactions with nature (Hughes et al., 2018; Guerrero-Casado, Murillo-Jiménez, Carpio, Tortosa, & Serrano-Rodríguez, 2025; Soga & Gaston, 2016). This trend, conceptualised as the “extinction of experience” (Pyle, 1978) has significant implications for human health, well-being, and the capacity to recognise, understand, and value local ecosystems. Within this scenario, the socio-educational dimension of the project becomes essential. Citizen science offers a promising avenue to re-establish meaningful human–nature relationships, enhance scientific, environmental, and biodiversity literacy, and foster more sustainable attitudes and behaviours.

In this sense, the Bio_Solar project seeks to bridge science and society by engaging citizens in real environmental challenges related to the energy transition and biodiversity conservation, guided by principles of equity and social justice. The programme is grounded in a participatory, structured, and accessible pedagogical framework designed to educate local communities about environmental issues and to support the transformation of perceptions, attitudes, and behaviours towards sustainability (Barrutia, Pedrera, Ortega-Lasuen, & Díez, 2024; Skarlatidou & Haklay, 2021).

2. Design of the proposal

The socio-educational component of Bio_Solar was designed as a structured, participatory programme integrating citizen science, experiential learning, and NbS principles. It addresses both biodiversity loss and the social challenges linked to nature disconnection through a multi-layered approach combining formal education, community engagement, and applied ecological research. The programme is organised around four pillars: a participatory pedagogical framework, integration of citizen-science tools, co-creation with local stakeholders, and alignment with social-ecological sustainability goals.

2.1. Participatory pedagogical framework

The intervention is grounded in a participatory and inquiry-based pedagogical model that positions learners and community members as active contributors to environmental research. The framework incorporates Universal Design for Learning (UDL) principles to ensure accessibility for diverse participants, including women farmers, elderly residents, and people with disabilities. Activities are designed to promote scientific literacy, critical thinking, and pro-environmental attitudes through direct engagement with local biodiversity and renewable-energy infrastructures.

2.2. Integration of citizen science tools and ecological monitoring

Digital tools commonly used in citizen-science initiatives (iNaturalist, PlantNet, Merlin) support species identification, georeferenced data collection, and collaborative validation. These are combined with ecological monitoring techniques such as transects, point counts, and camera-trap deployment, enabling participants to contribute to robust datasets while gaining hands-on experience.

2.3. Co-creation and community engagement

A central element of the programme is the co-creation of the educational and participatory activities with the school community and local stakeholders. Elementary and secondary school students, teachers, women farmers, local associations, and other community members collaborate in designing schedules, materials, and communication strategies for the biodiversity monitoring events. This participatory approach strengthens ownership, ensures that the intervention reflects local priorities, and promotes inclusive engagement across age groups and social sectors.

Students also develop promotional and communication campaigns to invite the broader community to participate, fostering intergenerational learning and reinforcing social cohesion. The programme follows a sequential structure that supports progressive engagement:

- Introductory training sessions on biodiversity, solar farm ecology, and digital tools.
- Collaborative design of the community sampling
- Integration of community feedback into the final design.
- Implementation and dissemination of results.

2.4. Social-ecological aspects and sustainability goals.

The design explicitly aligns with NbS principles by promoting ecological enhancement within a transformed landscape while simultaneously generating social benefits. By situating learning activities within a solar farm—an emblematic site of the energy transition—the programme fosters a deeper understanding of the interdependencies between biodiversity, renewable energy, and rural sustainability. The design also supports the development of community capacities to engage with environmental decision-making and contributes to a more socially just and ecologically grounded energy transition.

3. Objectives

The socio-ecological intervention developed within the Bio_Solar project pursues a set of interconnected scientific, educational, and social objectives. These objectives reflect the dual ambition of the programme: to generate robust ecological knowledge while strengthening community engagement, environmental literacy, and connection with nature.

3.1. Scientific objectives

- To document the biodiversity present in and around a Mediterranean solar farm through a combination of citizen-generated observations and expert ecological monitoring.
- To assess the potential of solar farms as multifunctional landscapes capable of supporting biodiversity under NbS principles.
- To compare citizen-science data with researcher-collected datasets to evaluate data quality, complementarity, and potential contributions to long-term ecological monitoring.
- To explore the relationships between land-use intensity around solar farms and biodiversity patterns in transformed rural landscapes.

3.2. Educational objectives

- To enhance scientific, environmental, and biodiversity literacy among stakeholders (secondary schools' community, university students, farmers, landowners, solar farms workers, local people and volunteers)
- To strengthen participants' connection with nature through direct, structured, and meaningful contact with local ecosystems.
- To develop participants' competencies in ecological observation, digital data collection, and critical interpretation of environmental information.
- To promote understanding of the energy transition and its ecological implications, fostering informed and critical perspectives on renewable-energy infrastructures.

3.3. Social objectives

- To foster inclusive community participation in environmental monitoring, with particular attention to women farmers, local associations, and vulnerable groups.
- To promote intergenerational learning and strengthen social cohesion in rural areas.
- To support equitable engagement in sustainability initiatives by applying participatory and accessible pedagogical approaches.
- To contribute to a socially just energy transition by integrating local knowledge, community values, and scientific evidence.

4. Methods and implementation

The methodological approach combines quantitative ecological monitoring with qualitative and participatory techniques, integrating citizen-science tools, experiential learning, and structured data-collection protocols. The methods are designed to ensure scientific rigour while maximising accessibility and community engagement ensuring inclusion.

4.1. Participants

The intervention involves a broad range of stakeholders from rural communities surrounding the solar farm. Participants include primary and secondary school students and teachers, university students and researchers, local farmers and landowners, Solar-farm workers and maintenance staff, elderly residents and local associations and volunteers from the wider community. This diverse composition ensures intergenerational learning, inclusion, and the integration of local ecological knowledge.

4.2. Training and preparatory sessions

Participants take part in a series of structured training sessions designed to build foundational knowledge and practical skills including introduction to local biodiversity, solar-farm ecology, training in the use of digital citizen-science tools (iNaturalist, PlantNet, Merlin), workshops on ecological monitoring techniques (transects, point counts, camera traps). Training is delivered through interactive demonstrations, hands-on practice, and collaborative exercises to ensure accessibility and inclusion.

4.3. Data collection procedures

Data collection was organised into two complementary field sessions. Firstly, researchers and university students accompanied the school community to the surroundings of the solar farm to learn and practise ecological sampling techniques (transects, point counts, vegetation surveys, camera traps) and to apply the use of citizen-science apps in real field conditions. The second session consisted of an open community bioblitz, involving all project stakeholders. During this event, school students acted as guides, teaching other participants how to use the apps and apply the sampling techniques learned previously, while researchers coordinated data validation and sampling zones. All records were uploaded to iNaturalist, combining structured monitoring with community-led data collection.

4.4. Evaluation of educational, social and scientific outcomes

The evaluation framework integrates scientific, educational and social indicators to capture the multidimensional impact. Scientific outcomes are assessed through the number and diversity of species recorded, the complementarity between citizen-science and researcher-generated datasets, and the quality of georeferenced observations. Educational outcomes are evaluated through short reflective pre- and post- questionnaires, field-notebook entries and observation of participants' engagement, focusing on gains in biodiversity literacy, scientific skills and connection with nature. Social outcomes are examined through participation levels, intergenerational collaboration and the inclusion of women farmers, elderly residents and other community groups. This mixed-method approach provides a comprehensive understanding of how the intervention influences ecological knowledge, learning processes and community involvement.

4.5. Data analysis

Ecological data collected are analysed using descriptive statistics and cross-validation to compare species richness, abundance and data quality across participant groups. Citizen-generated observations are contrasted with expert datasets to assess accuracy and complementarity. Qualitative materials — questionnaires, field notes and group discussions— are analysed through thematic coding to identify patterns related to learning, engagement and social cohesion.

4.6. Multi-country implementation and comparative design

Although implementation is currently taking place in Córdoba (Spain), the programme will be replicated in Sweden, Poland, and Spain to enable comparison across a north–central–south European gradient. Harmonised protocols will support cross-regional analysis of biodiversity patterns, citizen-science engagement, and the transferability of the pedagogical model, as well as the identification of region-specific opportunities and constraints for integrating Nature-Based Solutions into solar-farm management. This multi-country design strengthens the robustness of the findings and supports the development of generalisable insights into the ecological and social potential of solar farms across Europe.

5. Discussion

The ongoing implementation of the Bio_Solar programme provides early insights into how citizen science and participatory pedagogies can operate within renewable-energy landscapes. Initial observations suggest that combining ecological monitoring with experiential learning may help counteract the 'extinction of experience', as participants —especially students— engage more deeply with local biodiversity through direct observation, digital tools, and collaborative fieldwork.

Co-creation also appears to strengthen participants' sense of ownership and relevance, supporting findings that participatory approaches foster trust and long-term engagement in citizen-science initiatives. At the same time, the dual data-collection strategy raises methodological questions—such as data accuracy and variability—that will be examined as analyses progress, offering an opportunity to assess the complementarity of expert and citizen-generated datasets.

The forthcoming multi-country implementation will further illuminate how socio-ecological contexts shape participation, learning processes, and biodiversity patterns. Overall, these emerging observations highlight both the potential and the challenges of integrating citizen science into renewable-energy infrastructures, underscoring the need for continued data collection and refinement of the programme's methodological and educational components.

6. Conclusions

Although the Bio_Solar project is still underway, the initial phases indicate that integrating citizen science within a participatory and educational framework can effectively connect biodiversity monitoring with community engagement in the energy transition. Early implementation suggests that solar farms can function as spaces for learning and environmental awareness, strengthening participants' scientific literacy and connection with nature through hands-on ecological activities.

The involvement of diverse community groups—students, teachers, farmers, elderly residents, and volunteers—highlights the potential of citizen science to foster inclusive participation and intergenerational collaboration. Preliminary observations also point to the value of combining expert ecological monitoring with citizen-generated data to support robust biodiversity assessments.

As the project progresses, forthcoming analyses will clarify biodiversity patterns around solar farms, the quality of citizen-science contributions, and the applicability of this model across different European contexts. Overall, Bio_Solar illustrates the promise of participatory approaches for advancing a socially just and ecologically grounded energy transition.

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