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Advancing Sustainability Education and Research at AUB: The Role of ESDU

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Abstract. The Environment and Sustainable Development Unit (ESDU) at the American University of Beirut (AUB) has been instrumental in shaping sustainability education through research, interdisciplinary collaboration, and community-driven initiatives. Emerging from an effort to integrate research with real-world development challenges, ESDU fosters partnerships and promotes an applied, participatory approach to learning within and beyond the campus walls. ESDU with other AUB partners has fostered the development of pioneering undergraduate and graduate programs addressing environmental sustainability and management, rural community development, sustainable agriculture, food production, and food security. In addition to these academic programs that prepare university students to address pressing sustainability challenges through innovative and practical solutions, the ESDU serves as the community engagement arm of the Faculty of Agricultural and Food Sciences (FAFS) with a major role in capacity building, continuing education and outreach to the community at large with tailored educational and training tools for promoting socioeconomic as well as environmental sustainability at the University and beyond. The ESDU has established a campus-based sustainability show-case, The Urban Oasis; combining top of the line smart technology with traditional material and design it serves as community hub, living-lab in sustainability and an engagement and educational. The role of the ESDU complements the University's effort towards a more sustainable management of the Institution including collaboration for campus greening and improved waste management. The AUB's overall sustainability efforts are documented and reported by the Environmental Health, Safety, and Risk Management (EHSRM) department, contributing alongside other university departments to advance institutional sustainability goals).

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1. Introduction

1.1. Brief Institutional Overview

The American University of Beirut (AUB) was founded in 1866 as a private teaching-centered research university chartered under the State of New York and based on the American liberal arts model of higher education. AUB is one of the oldest and most respected higher education institutions in the Middle East and North Africa (MENA) region. The Faculty of Agriculture, now the Faculty of Agricultural and Food Sciences (FAFS), opened its doors in 1952, and in 1953, the 100-hectare Advancing Research, Enabling Communities (AREC) facility was acquired. Located in Lebanon's Bekaa Valley, AREC became a model center for agricultural research, education, and community engagement.

Fostered by a supportive institutional environment, a group of like-minded researchers from different disciplines came together under an International Development Research Centre (IDRC–Canada) funded project to address rural development and the socio-economic challenges of post-war Lebanon[1]. Following the success of this pioneering initiative, the Environment and Sustainable Development Unit (ESDU) was established in 2001 within FAFS as an interdisciplinary research and development center specializing in participatory community development and sustainable agriculture.

Over the past two decades, ESDU has evolved into a dynamic unit that demonstrates the transformative potential of academia when directly connected to the needs and aspirations of marginalized communities. Through more than 100 development projects, collaborations with international organizations, and tailored education programs, ESDU has helped shape Lebanon's sustainability discourse while delivering tangible benefits to thousands of individuals.

Higher education institutions (HEIs) are becoming more widely acknowledged as important players in promoting sustainable transitions through community involvement, governance, education, and research. Universities are increasingly expected to serve as living labs and innovation hubs that promote climate resilience, sustainability-oriented learning, and participatory governance in addition to their conventional academic role. According to recent research, campus living labs and experiential learning settings are becoming increasingly important for fostering interdisciplinary cooperation and workable sustainability solutions both on and off university campuses. Simultaneously, HEIs' sustainable governance frameworks place a greater emphasis on institutional integration, stakeholder involvement, and alignment with the Sustainable Development Goals (SDGs), especially in areas with social, economic, and environmental vulnerabilities[2].

1.2. Sustainability Paradigms and Assessment

Project-based research and development (R&D) in agriculture has long struggled with a lack of strategic support, which often threatens its continuity[1]. Large interdisciplinary projects generate critical data and policy insights that bridge gaps between fragmented research tracks; however, most are limited to three- to five-year implementation periods. As a result, successful outcomes often fade after project completion and funding cessation, leaving communities vulnerable to setbacks.

In developing countries, agricultural R&D is inherently multidimensional, addressing environmental, social, and economic sustainability amid scarce natural, financial, and human resources. Yet, the R&D–education–community engagement nexus is rarely evaluated from a sustainability perspective, which makes it prone to discontinuity

and short-lived impacts.

Ensuring the sustainability of a university unit, or of the institution as a whole, is therefore a pressing concern. Although "sustainability" increasingly encompasses environmental, social, and economic dimensions, HEIs vary in their adoption of this triple bottom line concept[3, 4]. Literature on HEI sustainability tends to emphasize environmental dimensions, particularly "greening the campus" and reducing the institutional ecological footprint[5]. However, more comprehensive approaches are emerging through assessment tools such as the UI Green Metric World University System[7], the Unit-Based Sustainability Assessment Tool (USAT) for African universities[8], and the Times Higher Education Impact Rankings[9].

The establishment of the SDGs, with a 2030 target, has further encouraged universities to assess and report their sustainability achievements. The 17 SDGs provide a universal framework for evaluating environmental, social, and economic outcomes across disciplines and scales. Caputo et al. (2021) highlighted the dual role of universities: contributing to SDGs through teaching and research while advancing them through institutional strategies[10]. Recent studies suggest that most HEIs report on SDG 4 (Quality Education), alongside others related to health, industry, responsible consumption and production, climate action, and partnerships[9–11]. Alcántara-Rubio et al. (2022)[11] observed that integrating SDG education within curricula remains the most common institutional action, while partnerships (SDG 17) are frequently identified as key areas for improvement.

Even while the amount of research on sustainability in HEIs is expanding, the majority of studies concentrate on environmental performance metrics, sustainability rankings, or campus greening efforts. Integrated sustainability approaches, which integrate research, education, community involvement, and participatory development under a single institutional framework, have received relatively less attention, especially at universities working in resource-constrained and crisis-affected environments. There are still a few studies in the MENA region that look at university-based living laboratories and sustainability governance systems, particularly those that connect sustainability teaching with long-term stakeholder involvement and practical community-oriented research. This emphasizes the necessity for more context-specific case studies that look at how universities might support sustainability transitions while addressing regional environmental and socioeconomic issues[12].

The ESDU of AUB is presented in this paper as an interdisciplinary sustainability model that integrates research, education, community engagement, and participatory development to address these gaps. The Urban Oasis (UO) initiative, a campus-based living laboratory that combines community-centered learning, climate-smart technologies, and sustainability teaching, receives special emphasis. The study's objective is to evaluate ESDU's alignment with the SDGs and the TBL sustainability dimensions while analyzing its contribution to sustainability through its Research, Development, and Engagement (R&D+E) framework. The paper adds to the growing conversations about resilience-oriented sustainability models in HEIs in the Global South by describing this experience in light of Lebanon's socioeconomic and environmental issues.

This paper presents a comprehensive case study of ESDU's evolving sustainability model. It draws upon institutional documentation, project reports, and academic programs co-developed by ESDU. The analysis employs a qualitative, systems-based approach supported by triangulation of institutional documents, project evaluations, and educational materials to ensure data validity and reliability. It aligns with the

environmental, economic, and social dimensions of sustainability, while identifying and mapping the targeted SDGs linked to ESDU's research, education, and engagement activities.

2. Methodology

2.1. Research Design

This study uses a qualitative institutional case-study methodology to investigate how ESDU advances sustainability through collaborations, research, education, and engagement. Through the prism of the Triple Bottom Line (TBL) sustainability framework and the SDGs, the study evaluates ESDU's activities and outputs using both descriptive and analytical assessment techniques. In a setting with limited resources and a crisis, a systems-based approach was used to examine the relationships between institutional operations, community involvement, and sustainability-focused educational and development programs.

2.2. ESDU's R&D + E Operation

Building on the sustainability paradigms outlined earlier, this study conceptualizes the ESDU as an R&D + E entity, where "E" stands for both Engagement and Education. This framing reflects ESDU's dual mission of generating applied research and fostering community-based learning, aligning with emerging sustainability-driven research and development frameworks in higher-education institutions.

ESDU's foundation lies in a participatory, human-centered approach that elevates the voices of local stakeholders in co-creating development initiatives[5, 6]. Unlike top-down academic models, ESDU integrates local knowledge systems, traditional practices, and continuous feedback loops to ensure that its projects and educational programs remain relevant and effective. Communities, including smallholder farmers, women's cooperatives, youth groups, and refugee populations, are engaged throughout the project lifecycle, from needs assessment to planning, implementation, and evaluation. The unit's most impactful initiatives are those developed and implemented with and for the community through genuine participatory action.

ESDU's operations span four interconnected domains: research, education, engagement, and development.

The research and development agenda follows an applied, interdisciplinary, and participatory approach that addresses global challenges through locally adapted solutions focused on agroecology, circular economy, local food systems, and climate resilience. Research outcomes inform project design and policy recommendations, which are then translated into pilot initiatives, value-chain enhancements, alternative-energy systems, and sustainable-agriculture models.

The education and engagement dimension transforms community needs into targeted higher-education programs, specialized courses, and capacity-building initiatives. These include technical training for farmers, youth, and cooperatives, ensuring that academic output remains grounded in real-world applications.

The partnership network—connecting faculty, students, rural communities, cooperatives, NGOs, municipalities, ministries, and private actors catalyzes co-creating sustainable solutions and advancing multiple SDGs.

Through this R&D + E framework, ESDU operates simultaneously as an academic

hub and a practical engine for sustainable transformation, ensuring that community engagement continuously informs education and research within a feedback-driven system. Figure 1 illustrates the proposed theory-of-change framework underlying ESDU's R&D+E sustainability model and its linkage to the SDGs.

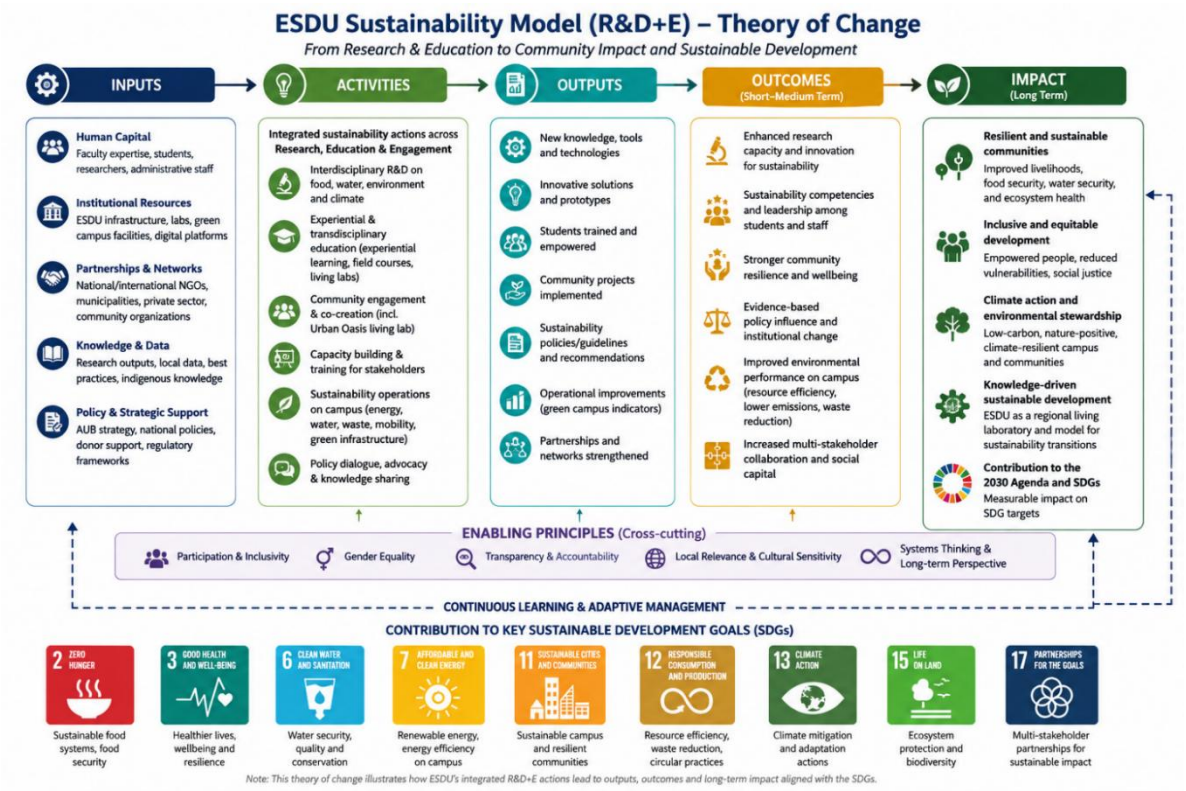

Figure 1. Theory of change framework of ESDU's R&D+ E sustainability model and its contribution to the SDGs

2.3. Data Sources and Collection

The study's primary methods for evaluating ESDU's sustainability-related initiatives and results were document analysis and institutional evaluation. Strategic plans, institutional reports, project reports and evaluations, training and capacity-building modules, educational curriculum, partnership records, and operational paperwork on the UO program were the sources of supporting data. Internal academic and administrative resources created by ESDU and the Faculty of Agricultural and Food Sciences (FAFS) provided more information. In order to identify the relationships between research, education, engagement, and development activities within the ESDU framework, the gathered data were examined and combined. Although no official interviews were done for this study, observational and operational insights from the execution and tracking of ESDU efforts throughout time were included in the analysis

2.4. Analytical Framework and Assessment Approach

This section outlines the methodological framework used to assess ESDU's major outputs and contributions, focusing on R&D, education, engagement, and partnerships as key pillars. The outputs are first mapped according to the TBL dimensions of sustainability—environmental, social, and economic and subsequently analyzed through

the SDGs framework.

Supporting data were derived from strategic plans, project reports and evaluations, educational curricula, and capacity-building modules. A qualitative, systems-based analysis was applied to synthesize findings across these sources, enabling triangulation between institutional documentation, field-level outcomes, and academic content to ensure data reliability and validity.

For the research dimension, major ESDU projects with budgets exceeding USD 100,000 were included. Each project was mapped to the SDGs based on its thematic focus and activities, and a frequency diagram illustrates the SDGs most frequently addressed.

For the education dimension, a total of 23 graduate courses across the Master's in Food Security, Master's in Rural Community Development, and the Diploma in Food Security were analyzed. Each course was mapped according to its primary SDG alignment. A similar mapping was conducted for the undergraduate Agriculture program, which includes more than 50 courses across multiple disciplines. SDG 4 (Quality Education) was inherently considered applicable to all courses. Separate frequency diagrams visualize the distribution of SDGs across graduate and undergraduate programs.

For the engagement component, the UO serves as a flagship case study exemplifying ESDU's outreach and participatory-engagement model. The facility's design and operation are mapped to both the TBL sustainability dimensions and the SDGs.

Finally, the partnerships are analyzed qualitatively, with emphasis on their diversity, strategic function, and contribution to ESDU's overall sustainability. Given the complexity of partnership structures, explicit SDG mapping was not conducted; instead, the analysis highlights their enabling role in achieving sustainability outcomes.

2.5. Limitations

The institutional documentation, project records, instructional materials, and internal operational data about ESDU and the UO program are the main sources of information used in this qualitative study. The lack of standardized quantitative sustainability indicators and longitudinal impact assessment tools limits the analysis, even though the adopted systems-based and SDG-oriented approach offers insightful information about the relationships between research, education, engagement, and sustainability outcomes. Furthermore, the study's focus on a single institutional scenario inside a particular socioeconomic and environmental setting may restrict the findings' direct applicability to other institutions of higher learning. However, in HEIs functioning in crisis-affected areas, the case-study approach provides significant context-specific insights into sustainability-oriented methods and participatory development models.

3. Results

3.1 Mapping of ESDU's Outputs Following the Triple Bottom Line Sustainability Framework

Figure 1 shows a general mapping of ESDU's main outputs to the sustainability dimensions. The figure illustrates an overall balance between the different output types across the three sustainability dimensions. It is worth noting that a clear separation among these dimensions is impossible, since many outputs address two or all three simultaneously. This will be further detailed when each output type is presented separately and mapped according to the SDGs below.

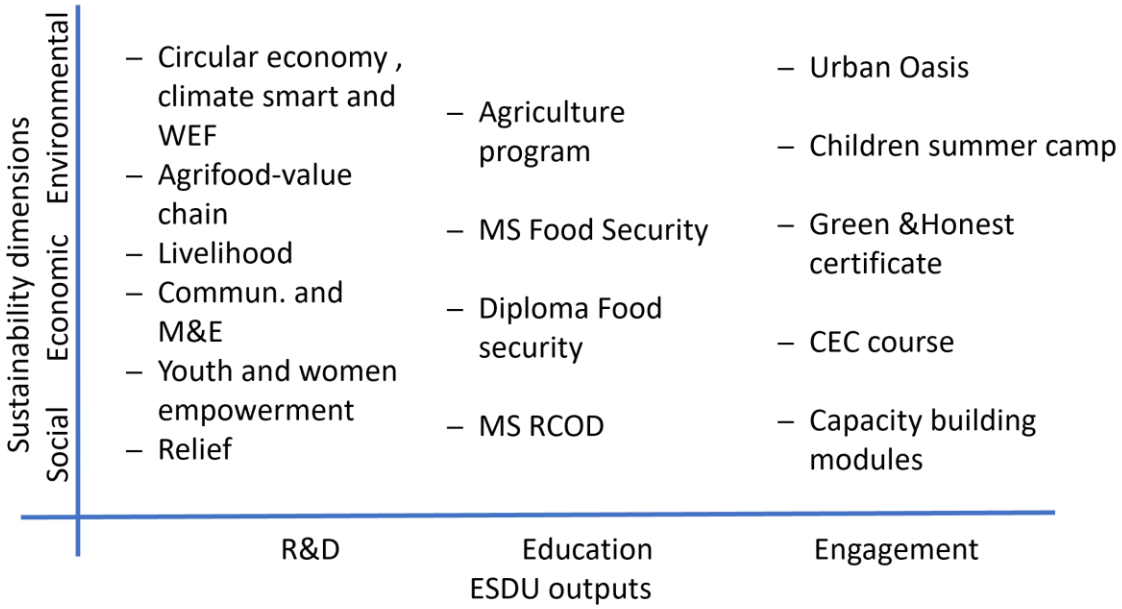

Figure 2. Mapping of major ESDU outputs to the three sustainability dimensions

The themes of ESDU's R&D projects represent a wide range from highly technical climate-smart research to relief projects responding to the multiple crises that have affected Lebanon. ESDU aims to enhance environmental sustainability through projects embracing the circular economy, agroecology, the Water–Energy–Food–Health (WEFH) nexus, and climate-smart technologies and solutions.

In 2020–2021, more than 200 farmers and 10 SMEs were technically supported and trained on alternative energy and sustainable production solutions, including solar panels, hydroponic units, adapted seeds and seedlings, and composting systems. In addition, research on integrated olive–small ruminant systems, improved root–soil symbiosis in wheat, dairy food chain assessment, and the evaluation of by-products were among the topics under study.

Social sustainability lies at the core of ESDU's people-centered approach. ESDU's project beneficiaries and participants include marginalized groups such as vulnerable communities and refugees, with particular attention given to ensuring equal opportunities for women and youth participation.

In a country that has suffered repeated cycles of political, security, and financial turmoil, economic sustainability remains particularly fragile. ESDU has strived to preserve the livelihoods of the most affected populations. Livelihood projects have adopted the principle of "teaching them how to fish"—training and supporting smallholders and vulnerable communities to sustain and grow their income sources. In 2020–2021 alone, more than 10,000 beneficiaries participated in livelihood projects focused on capacity building and training. However, in times of extreme need, direct assistance and relief were also provided. During the same period, which marked a time of severe financial crisis, more than 8,500 vulnerable households received hot meals. A similar number was also supported during the 2024 war, which left thousands internally displaced.

Moving to education outputs, ESDU has partnered over the years with multiple AUB and FAFS entities to develop academic programs responding to community and regional needs. In 2013, the Master's in Rural Community Development program was successfully launched, hosted by ESDU with an interdisciplinary supervisory committee. The program

remains one of its kind in the region and has attracted students from Africa to the Americas. Its well-balanced curriculum offers students a deep understanding of sustainability from the perspectives of diverse experts in the field.

In collaboration with FAFS and other AUB units, ESDU also contributed to the development of the Master's in Food Security program, followed by the Graduate Online Diploma in Food Security. Based on FAO's identification of the four basic pillars of food security, availability, access, utilization, and stability[11], it is evident that sustainability in all its dimensions is essential. In fact, FAO later adopted sustainability and agency as the fifth and sixth pillars of food security[14].

Within FAFS, and under the leadership of the Department of Agriculture, ESDU contributed to the revision and update of the Bachelor of Science in Agriculture program. This four-year program was modernized with a new concentration track in sustainable agriculture, emphasizing experiential learning and community engagement throughout the academic journey and across its diverse disciplinary courses.

Engagement represents a critical dimension for bridging the gap between academia, scientific research, and the community. ESDU has consistently played this role in a country where public extension services are largely absent[14]. Since 2019, ESDU has been officially designated as the engagement arm of FAFS, reinforcing its outreach mandate.

This role was further strengthened through the establishment of the Khalifa Palm Award Urban Oasis (UO), a campus-based facility serving as a community engagement center open to AUB faculty, students, and the wider public. The UO is not merely a meeting place; it functions as a living laboratory for all aspects of sustainability. It integrates traditional building materials, smart water and energy technologies, a green roof, and urban gardens that serve as spaces for awareness, training, research, and engagement.

Among the UO's major activities to date is the Youth Summer Camp, launched in 2024, designed to introduce children aged 8–12 to sustainable agriculture and AI. A three-week program was developed and completed, receiving positive feedback from participants and their parents.

ESDU's engagement outputs also extend to the AUB community through the development of a Community Course on Sustainable Farming, in cooperation with the Continuing Education Center. This course, the first of its kind at AUB, addresses the basics of sustainable agriculture with practical training sessions. Its launch was delayed due to the recent conflict, but is expected to proceed soon.

Beyond the university walls, ESDU has consistently prioritized capacity building as a cornerstone of its community projects. The numerous training modules developed and delivered cover a wide range of environmental and technical themes, from alternative energy and water resource management to best practices in crop and livestock production.

Additionally, ESDU's outreach activities include fostering entrepreneurship and strengthening economic and financial sustainability, especially for small and medium enterprises (SMEs), while empowering women and youth toward sustainable livelihoods. Social cohesion is equally prioritized by engaging communities of diverse backgrounds in shared learning environments that promote respect, tolerance, and collective progress.

Within its engagement initiatives supporting sustainability education and practice, ESDU launched the Keepers of the Land Campaign. Two main components are of interest in this study.

The *Keepers of the Land Prize Awards* for FAFS graduating students, recognizing

outstanding projects aligned with ESDU's sustainability vision; and the *Community Keepers of the Land Awards*, which honor community members who play leading roles as custodians of cultural and environmental heritage.

Women Keepers of the Land were celebrated during ESDU's 15th Anniversary and continue to be recognized. Although this campaign primarily promotes social impact, it also fosters economic sustainability by enhancing visibility and awareness within both student and community circles.

ESDU's community engagement further extends through digital media. In addition to its social media presence, ESDU manages Karianet, a multilingual Knowledge Sharing and Management Platform targeting Arab communities. Karianet features updated resources, training materials, and information on sustainable agriculture and food systems. The platform serves as a sustainable engagement outlet, ensuring open access to knowledge and equal learning opportunities across the Arab region.

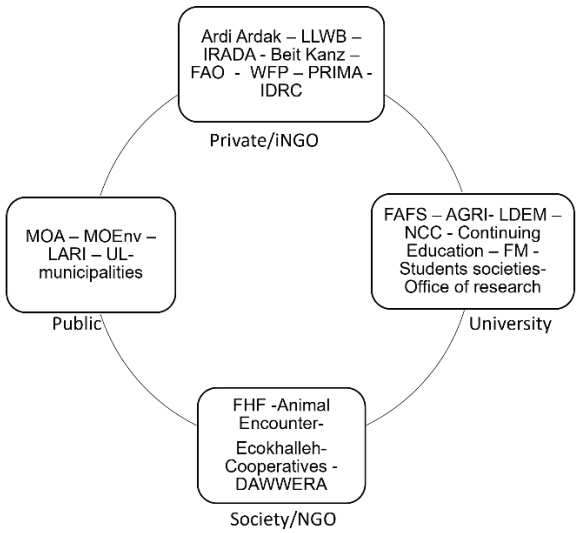

Figure 3. Representation of the ESDU's main partners' network

Reflecting on ESDU's network of partners (Figure 3), it is challenging to map it precisely across the sustainability dimensions. However, a closer look is needed to assess the level of contribution and active participation of the different entities. An initial review shows a strong reliance on the University and Society domains.

The university's rich alliances are reflected in the previously discussed educational outputs, which span the three sustainability dimensions. In addition, the institutional framework itself is a key factor in enabling meaningful research. ESDU's alignment with AUB's sustainability agenda, particularly in improving campus operations through initiatives such as waste sorting and recycling, further reinforces this institutional connection.

The society partners are, in many ways, the raison d'être of ESDU. They are both the source of inspiration and the primary beneficiaries of its activities. Of particular importance within this domain is ESDU's sister NGO, the Food Heritage Foundation (FHF), established in 2007 as an independent organization. Partnership with FHF has allowed many ESDU projects to continue beyond their initial funding cycles. FHF supports project beneficiaries by providing marketing channels and a recognized label for their products. In this sense, the ESDU–FHF partnership effectively encompasses the three sustainability dimensions, since the beneficiaries are trained participants in ESDU's

projects who apply sustainable practices in production and marketing.

Linkages with the public sector are equally significant. However, agriculture and environmental programs in Lebanon receive minimal governmental budgetary support despite their economic and social importance to rural households[14]. Of particular relevance to ESDU's mission are the strong partnerships developed with municipalities over the years. These relationships reflect the unit's community-centered approach and the strategic advantage of working through local authorities to ensure project continuity and sustainability, rather than focusing exclusively on central policymakers. This approach aligns with the literature emphasizing the role of decentralization in effectively addressing waste management and other environmental challenges[15].

The private sector and international NGOs (iNGOs) represent one of the most dynamic domains within ESDU's partnership network. On one hand, iNGO funding and technical support are essential for the implementation of large-scale, high-impact projects. On the other hand, funding gaps during "dry spells" pose ongoing challenges to the unit's financial sustainability. To mitigate this, ESDU has actively engaged local private partners to maintain a diversified and stable portfolio of input streams.

A notable example is Ardi Ardak, a recently established organization formed in cooperation with prominent Lebanese businesswomen and men. It serves as a platform offering the wider community expert services, delivered primarily through ESDU, across a range of agricultural and environmental topics. Other key private partners have also contributed to sustaining ESDU's educational mission, particularly through the sponsorship of student prizes, such as the Beit Kanz Foundation.

3.2 Mapping of Projects and Courses to the SDGs

Figure 4 presents the mapping of ESDU's major R&D project themes against the SDGs. As noted earlier, only the major projects were considered for this analysis, a total of 23, while ESDU's full portfolio includes more than twice this number of smaller projects that also address a wide range of SDGs.

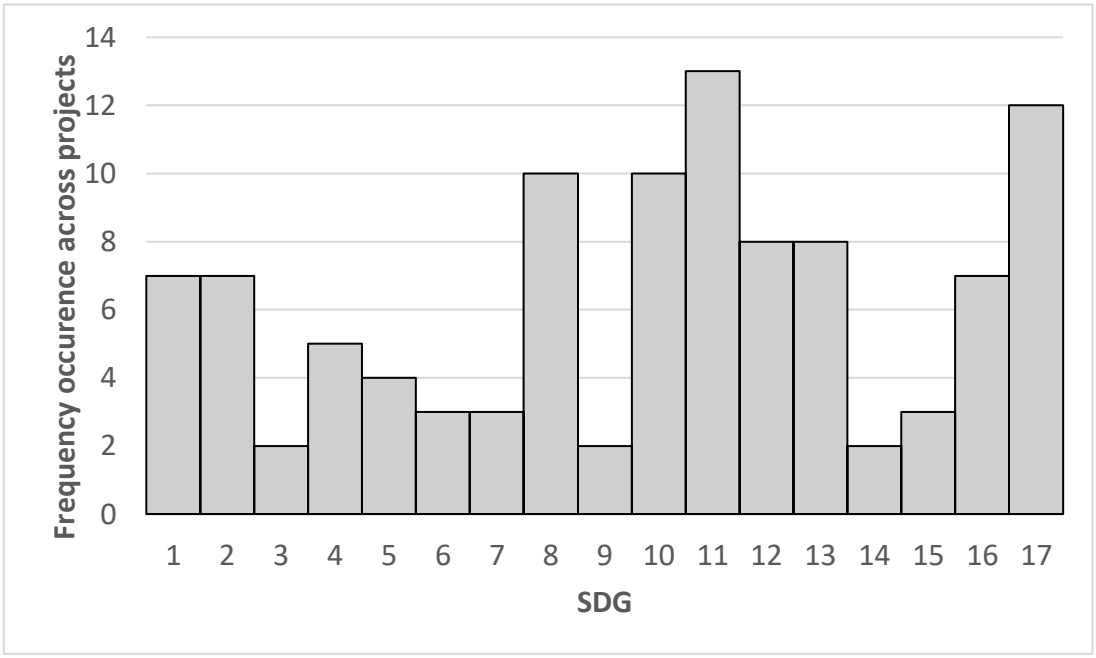

Figure 4. Mapping of frequency of occurrence of SDGs across the thematic areas of ESDU's major R&D projects

The figure highlights a clear emphasis on SDG 11 (Sustainable Cities and Communities) as an overarching umbrella theme, which is consistent with ESDU's mission and areas of work. Another dominant goal is SDG 17 (Partnerships for the Goals), reflecting ESDU's participatory approach in which most projects involve multiple stakeholders drawn from its extensive network of partners. Conversely, a few SDGs appear less represented within the major projects. This is expected, as these goals may be better covered through smaller initiatives not included in the current analysis. A notable example is ESDU's pioneering work in establishing and promoting community kitchens across Lebanon through small grants implemented in response to the Syrian crisis and the influx of refugees. That line of work is closely aligned with SDG 2 (Zero Hunger), which is not strongly reflected in the present graph.

This observation also points to a limitation of the current approach in assessing ESDU's contribution to the SDGs. At present, the model lacks standardized quantitative indicators within the SDG framework that would enable more precise measurement of contribution levels across projects.

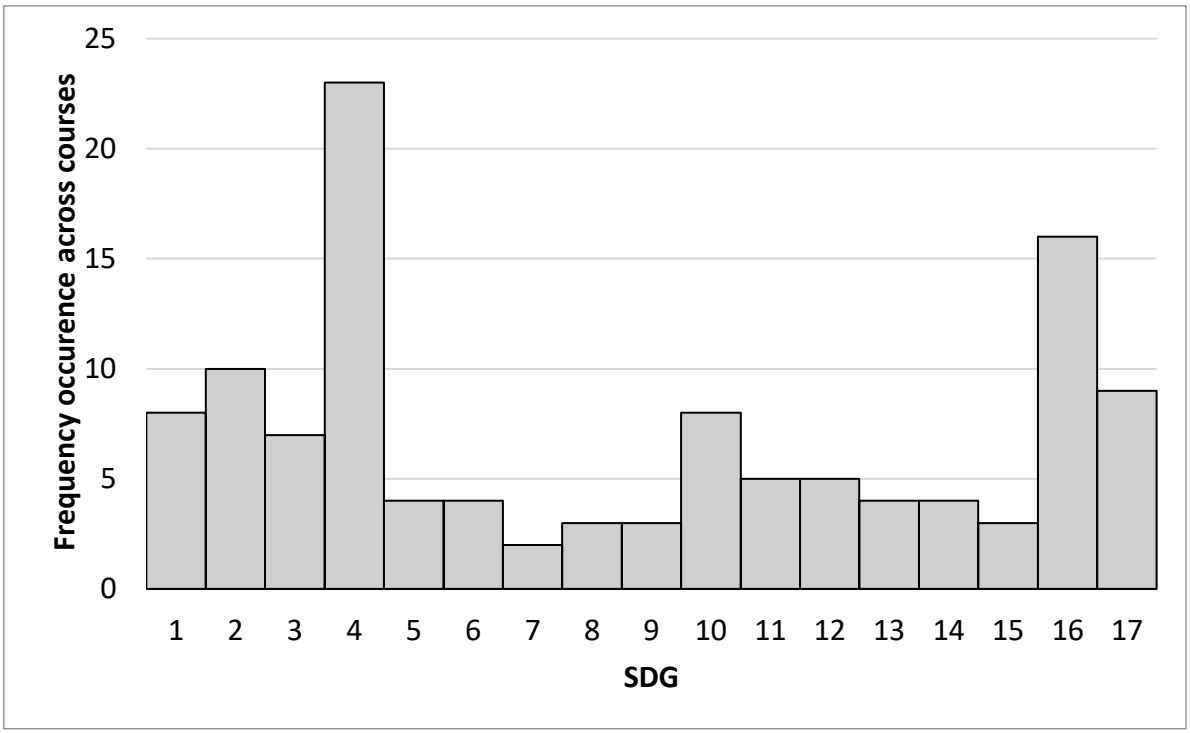

Figure 5. Mapping of frequency of occurrence of SDGs across the thematic areas of ESDU related graduate courses.

Moving to the graduate courses (Figure 5), and as previously mentioned, SDG 4 (Quality Education) is inherently addressed in any formal academic curriculum. However, the mapping also highlights a strong emphasis on SDG 16 (Peace, Justice, and Strong Institutions), reflecting the nature of ESDU-related programs that extend beyond technical domains. These programs prepare students to address food security and rural community development through holistic and systems-based approaches. Viewed from this perspective, it is understandable to observe the prominence of SDG 16 within the curriculum.

Equally noteworthy is the relevance of SDG 2 (Zero Hunger), given that many of the courses are closely related to food and nutritional security. In total, 23 major courses were

mapped within these graduate programs. It is, however, important to note that students are required to complete only a selection of these courses, with flexibility to choose electives according to their degree requirements. Consequently, the combination of courses selected by each student will ultimately result in variations in the frequency and range of SDGs addressed.

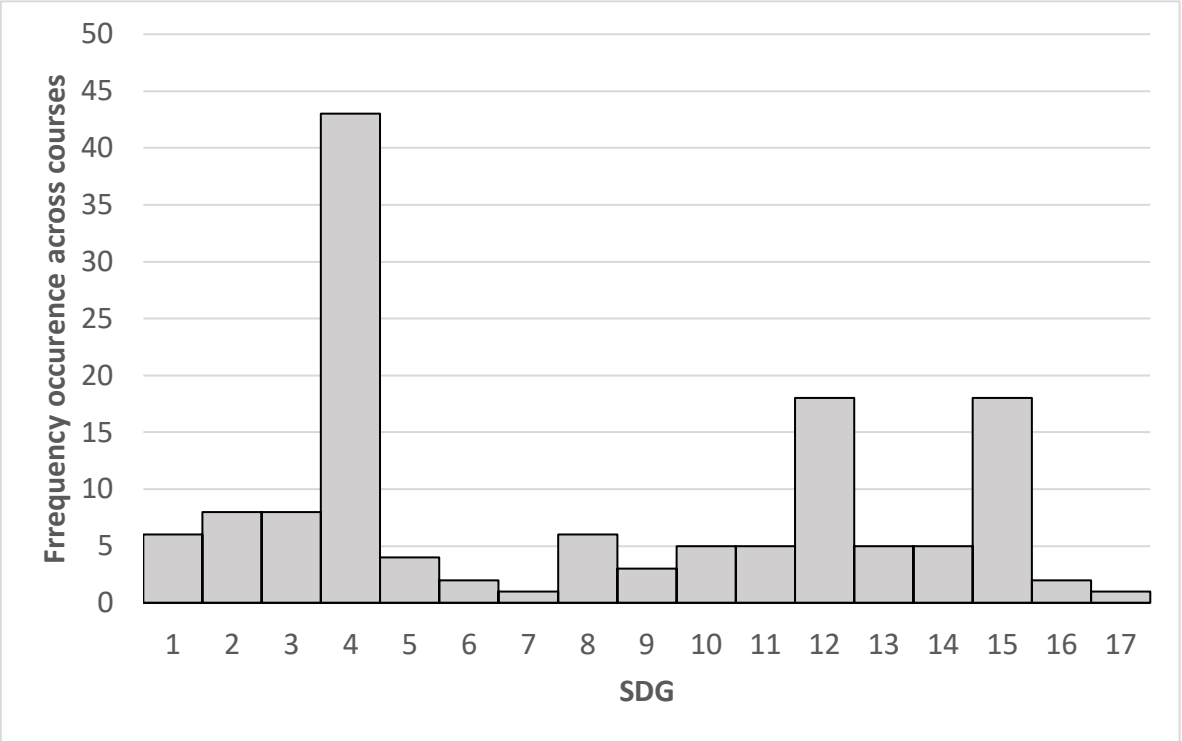

Figure 6. Mapping of frequency of occurrence of SDGs across the thematic areas of ESDU related undergraduate courses

Comparatively, undergraduate students (Figure 6) follow a relatively uniform curriculum with minimal variation across cohorts. As a professional degree, the Bachelor of Science in Agriculture program places a stronger emphasis on the natural and applied sciences. Accordingly, the figure shows a high frequency of SDG 15 (Life on Land), which is inherently linked to agricultural activity and discourse.

Similarly, as previously noted, the program aims to equip students with knowledge and skills in sustainable agriculture, a core component of SDG 12 (Responsible Consumption and Production).

In contrast to the graduate programs, lower emphasis is observed on SDGs 16 (Peace, Justice, and Strong Institutions) and 17 (Partnerships for the Goals). This difference does not imply reduced importance; rather, it reflects the technical nature of the undergraduate curriculum and the need to prioritize essential scientific and professional competencies within the degree structure.

3.3 Mapping of Engagement and Partnership Network to the SDGs

3.3.1. Case of the Urban Oasis

In 2020, the ESDU won the Khalifa International Award for Date Palm and Agricultural Innovation for implementing a pioneering project on climate-smart livelihoods (funded by GFZ/WFP). Following the award, ESDU dedicated most of the

funds to establishing a facility that would both enhance its engagement role and serve as a living showcase of applied sustainability, integrating the Water– Energy–Food (WEF) nexus and circular economy frameworks.

The table below (Table 1) summarizes the design, operation, and functional elements of the UO and illustrates how each contributes to the Sustainability Dimensions and the SDGs.

Table 1. Mapping of ESDU's Urban Oasis engagement center features to the sustainability dimensions and the SDGs.

UO feature	**Sustainability dimension**	**SDGs**
Design and structures		4, 11, 17
Designed through student competition	Social	
Traditional material (mud wall)	Environmental	11,13
Recycled structural material	Environmental	11,13
Solar power	Environmental	7, 11,13
Green roof	Environmental	11, 13
Water harvesting	Environmental	6, 11, 13
Composting unit	Environmental	11, 12, 13
Urban garden	Environmental	11, 12
Small coop	Environmental	11, 12
Gathering space	Social	11, 17
Operation		
AI and smart control of water and energy	Environmental	6, 7, 9, 11, 13
Drip irrigation	Environmental	6, 11, 13
Waste sorting	Environmental	11, 12, 13
Organic waste composting	Environmental	11, 12, 13
Plant and animal production (small amount for sale)	Environmental, Economic	11, 12
Function		
Community meetings	Social	17
Children summer camp	Social, Economic	4, 17
Research and internships	Environmental, Social	4, 5, 11, 17
Living Lab (continuous learning and training on the implemented climate-smart technologies	Environmental, Social	4, 11, 12, 17
Periodic farmers' market	Environmental, Social, Economic	8, 11, 12, 17
Healthy snack outlet	Environmental, Social, Economic	2, 3, 12

The case of the UO clearly illustrates the variation in insights that emerge when applying different sustainability assessment frameworks. The TBL framework emphasizes the environmental dimension, with economic aspects appearing less dominant, whereas SDG mapping provides a broader, integrative perspective. In particular, the UO aligns strongly with SDGs 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), and 13 (Climate Action), a reflection of its

multidimensional sustainability outcomes.

The two frameworks are not contradictory but rather complementary, each highlighting different nuances. Together, they confirm that the UO encompasses most sustainability dimensions, a promising indication for ESDU's future strategies in engagement and education.

Beyond its sustainable features and physical architecture, the UO is a campus-based living laboratory that combines applied sustainability techniques, experiential learning, and participatory engagement into a unified operating framework. The project serves as a platform for interdisciplinary education and community engagement in addition to serving as a demonstration site for the circular economy and climate-smart technology. The UO enhances the relationship between academic knowledge and practical sustainability issues by connecting research activities with outreach, teaching, and training. This strategy is in line with new research that highlights how university living labs support resilience-focused innovation, stakeholder collaboration, and sustainability transitions in higher education. The UO further illustrates how centralized and community-centered sustainability initiatives can support institutional resilience, adaptive learning, and sustainability governance beyond traditional campus greening approaches in the context of Lebanon's socioeconomic and environmental challenges.

3.4 Partnership Assessment

Assessing partnerships, however, remains a more complex task. As discussed in Figure 3, ESDU's network encompasses a diverse range of partners and stakeholders. These relationships vary significantly in duration, type of collaboration, and level of engagement, making direct mapping to specific SDGs less meaningful without further qualitative detail.

The field of partnership assessment itself is still evolving. In 2022, the Food and Agriculture Organization (FAO) released the first edition of its Guidelines on Building High-Impact Multi-Stakeholder Partnerships for the SDGs[17]. This reference provides valuable direction for both evaluating and strengthening partnerships while highlighting the dynamic and adaptive nature of local and global collaborations toward SDG achievement.

It is also noteworthy that AUB, ESDU's parent institution, has been developing a framework for tracking and reporting contributions to the SDGs. This effort is managed by the Environmental Health, Safety, and Risk Management (EHSRM) department, with input from various faculties and units across the university. The alignment between ESDU's engagement activities and AUB's institutional sustainability reporting reinforces their shared commitment to measurable, community-driven contributions toward sustainable development.

4. Discussions

A review of the literature on sustainability assessment and reporting in universities reveals a wide range of approaches and tools, indicating that further refinement is needed to achieve a unified assessment methodology. These approaches often diverge in their calculations, with weighted metrics developed for selected sets of indicators, such as the STARS framework[3,6,18,19]. Such tools typically address the social, environmental, and economic dimensions of sustainability, while some expand to include additional domains such as education, governance, and management—centered around the university or unit

itself.

Sustainability assessment in higher education remains largely an internal exercise focused on performance tracking. However, it is gradually evolving into a more standardized and regulated practice, with some countries introducing national reporting guidelines for HEIs, as noted by Huber and Bassen[20] for the case of Germany. These developments also highlight the growing role of sustainability assessment in supporting institutional decision-making[19].

In contrast, literature on R&D sustainability assessment for business-linked units suggests more sophisticated frameworks that guide decision-making and strategic implementation. Examples include the Data Envelopment Analysis (DEA) approach for R&D portfolio management[21] and the Sustainability Balanced Scorecard model[5, 22]. Given that agricultural R&D lies at the intersection of research, education, community engagement, and innovation, hybrid assessment tools may need to be designed to reflect this integrated function and ensure long-term impact tracking. Gutiérrez Cano et al. (2023)[23] highlighted similar challenges in assessing Agricultural Innovation Systems (AIS) given the interconnection between training, research and development, ICTs, sustainability, and extension services as pillars for agricultural transformation. Through a literature review approach, they identified the systemic barriers, limited coordination, insufficient capacities, and weak policy support that hinder effective innovation in global agriculture. In comparison, the ESDU experience represents a contextual and operational translation of these same principles. While the Gutiérrez Cano et al. (2023)[22] review remains primarily analytical and policy-oriented, ESDU demonstrates how AIS concepts can be institutionally embedded within a university setting through participatory R&D, experiential learning, and multi-stakeholder engagement. Both converge on the importance of inclusive knowledge systems, yet ESDU advances the discussion by operationalizing innovation within fragile, community-based contexts, bridging the gap between theory and field practice.

The ESDU model integrates research, education, community engagement, and sustainability experimentation within a university setting, much like sustainability-oriented initiatives implemented at several HEIs across the MENA region, including sustainability and innovation platforms developed by institutions such as KAUST in Saudi Arabia and UM6P in Morocco. The emphasis on multidisciplinary cooperation, experiential learning, and stakeholder involvement as essential elements of sustainability transitions in HEIs is growing in these projects. However, the ESDU and UO model operates in a crisis-affected setting with limited institutional resources, environmental challenges, and economic volatility, in contrast to many sustainability efforts that operate in relatively resource-stable situations. In addition to emphasizing the possible role of HEIs in assisting localized sustainability transitions in the Global South, this setting reinforces the importance of resilience, adaptation, and participatory governance within ESDU's sustainability paradigm[24-26].

Transitioning from the TBL framework to an assessment of contributions toward the SDGs is not straightforward. As mentioned earlier, most current sustainability assessments are institution-centered, motivated by the desire to demonstrate internal sustainability performance. Shifting toward SDG-based assessment requires an adjustment of the system boundaries of the organization being evaluated. An example can be drawn from Table 1, which highlights the children's summer camp activity. Under the TBL framework, this initiative is linked to economic sustainability, as the revenue contributes to the unit's financial well-being. However, when mapped to the SDGs, this

economic aspect becomes secondary to the activity's educational and social dimensions, specifically SDG 4 (Quality Education) and SDG 17 (Partnerships for the Goals). This comparison illustrates the complexity of assigning specific contributions and the challenge of maintaining consistency across frameworks.

Despite these challenges, the qualitative analysis presented here provides an initial step toward evaluating ESDU's contribution to the SDGs. Caputo et al. (2021)[10] discussed how HEIs can integrate SDG reporting by linking existing sustainability indicators, such as those from the Global Reporting Initiative (GRI), to relevant SDGs based on the SDG Compass Guide (GRI, UNGC, WBCSD, 2015)[23]. This reinforces the importance of preliminary thematic mapping of institutional units, activities, and outputs, as applied in this study.

However, achieving quantitative assessment requires the adoption of a clear and consistent scoring methodology. Alawneh et al. (2021)[8] explored such an approach by adapting the UI Green Metric reporting framework for measuring contributions to SDGs. Although this methodology is applied at the institutional level, it may be adaptable to sub-unit contexts such as ESDU. Nonetheless, careful attention must be given to the distinct balance between research, development, and engagement (R&D+E) functions within ESDU, which differ from those of the broader university.

Equally important is the inclusion of partnership networks in any sustainability assessment approach. The ESDU case demonstrates the vital role that partnerships play in participatory, multi-stakeholder initiatives. Since "Partnerships for the Goals" (SDG 17) is itself a distinct SDG, it deserves both qualitative and quantitative evaluation. The FAO SDG Partnership Guide (2022)[17] offers an important foundation for such analysis, helping capture dynamic interactions among local, regional, and international partners. Within this context, ESDU's collaboration with AUB aligns strongly with institutional efforts toward campus greening, sustainable management, and collective SDG reporting.

Beyond the methodological challenges of assessment, ESDU also faces practical challenges during implementation, such as ensuring continuity of funding, maintaining stakeholder engagement, and balancing academic objectives with community needs. These factors directly affect long-term sustainability outcomes. Nevertheless, the structured approach proposed in this study enables the identification of critical gaps and supports the formulation of targeted solutions.

Maintaining long-term institutional and operational sustainability is nevertheless difficult, especially in crisis-affected countries like Lebanon, despite the opportunities offered by participatory sustainability models. The experience of ESDU shows how crucial it is to maintain research and community-focused projects over time through ongoing funding, stakeholder participation, institutional coordination, and flexible governance systems. The literature on sustainability transitions has noted similar issues, especially with relation to the sustainability of living-lab projects and the difficulties of converting short-term project results into long-term institutional transformation. These limitations highlight the necessity of adaptable sustainability frameworks that can retain significant stakeholder participation while adjusting to shifting environmental and socioeconomic situations[27].

Ultimately, achieving sustainability at both the unit and institutional levels remains an evolving process. Given the dynamic context in which ESDU operates, a flexible and adaptive framework, one that allows for continuous refinement and learning, is essential. Further effort should be directed toward establishing a quantitative yet context-sensitive assessment model that captures both immediate impacts and long-term sustainability

performance.

The ESDU experience has wider ramifications for universities looking to improve community involvement and sustainability-focused instruction in settings with limited resources. Universities looking to assist localized sustainability transitions while bolstering institutional resilience and stakeholder collaboration may find a transferable framework in the integration of experiential learning, campus-based living laboratories, and participatory research[28].The results indicate that sustainability programs in higher education can progress beyond campus management toward more integrated and community-responsive governance models, even though implementation tactics are still context-dependent.

5. Conclusions and Future Perspectives

In conclusion, the ESDU remains firmly committed to sustainability at all levels, in alignment with its vision and in coordination with AUB and FAFS. Sustainability assessment tools offer valuable guidance for shaping the way forward by identifying critical areas for improvement and highlighting the "bottom line." Even the preliminary mapping conducted in this study serves as an effective gap analysis, revealing where strengths and weaknesses lie across the different sustainability dimensions.

ESDU's research portfolio is diverse and well aligned with its sustainability mission. Likewise, the academic programs to which ESDU has contributed demonstrate strong alignment with the SDGs, maintaining a complementary balance between undergraduate and graduate courses. The UO, as a model for engagement and applied sustainability, reflects the Unit's capacity to integrate environmental and social dimensions while showing promising potential for economic sustainability through its various functions.

Finally, partnerships continue to represent a dual-natured element, serving as essential assets that foster collaboration and innovation yet also posing challenges that must be addressed to enhance long-term sustainability performance and progress toward the SDGs.

Even with the advancements made possible by ESDU's integrated sustainability approach, several operational and institutional issues still exist. Sustained financial resources, long-term stakeholder engagement, and adaptable governance procedures are necessary to ensure the continuation of sustainability-oriented programs within HEIs functioning in crisis-affected areas. The long-term scalability and continuity of sustainability interventions may be impacted by reliance on outside project-based funding, changing socioeconomic conditions, and the difficulty of coordinating transdisciplinary and multi-stakeholder initiatives[29].These difficulties show how crucial it is to improve institutional integration, create more organized methods for assessing sustainability, and enhance strategic alliances that can assist long-term resilience and sustainability transitions.

Looking ahead, the findings of this study emphasize the importance of continuous reflection, adaptive planning, and long-term monitoring to maintain and strengthen ESDU's impact. Future efforts should build upon the insights of this preliminary assessment, refining sustainability evaluation methods and promoting more integrated approaches that ensure resilience, inclusivity, and sustained alignment with both institutional and global sustainability goals.

Future studies should concentrate on creating more thorough and quantitative frameworks for sustainability assessment that can gauge the long-term effects of living laboratories and university-based sustainability programs. Understanding of sustainability governance and participatory engagement models in higher education may be further strengthened by comparative studies conducted across higher education institutions in various socioeconomic and regional contexts. Strengthening data-driven sustainability monitoring systems, increasing interdisciplinary collaboration, and improving the scalability and transferability of community-oriented sustainability practices both on and off university campuses should all receive more attention from an implementation standpoint[30].

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Authors Contribution

All authors contributed substantially to the work. **L.J.** conceived the research idea and drafted the manuscript. **C.BH**. contributed to the methodology, data analysis and manuscript revision. **D.M**. carried out the data collection and manuscript revision. **S.H.** provided senior supervision, coordination and critical revision. All authors reviewed and approved the final version of the manuscript.

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