DCARE: Drones for Climate Action and Resilience Exchange: Academic Capacity Building and Climate-Focused UAV Applications

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***Abstract*—Pakistan's climate vulnerabilities, manifest through 2022's catastrophic floods, chronic droughts, and coastal erosion, necessitate indigenous expertise in UAV-based environmental monitoring and resilience strategies. To meet this critical need, the Drones for Climate Action and Resilience Exchange (DCARE), a British Council–funded Transnational Education (TNE) partnership between Ulster University (UU) and MUET, works systematically to strengthen academic capacity through targeted initiatives. DCARE embodies the core purpose of TNE, delivering locally relevant education that empowers Pakistani communities through indigenous capacity building in climate resilience technologies. Our objectives encompassed postgraduate curriculum development in sensing technologies, communication protocols, and AI-driven climate applications; and faculty expertise enhancement via structured workshops. Hands-on training was conducted through UU made in FALCON educational kits for foundational assembly and programming skills, alongside DJI commercial platforms for operational applications in precision agriculture, disaster assessment, and coastal surveillance. Reciprocal field visits between institutions facilitated technology transfer and pedagogical alignment. Outcomes include MUET-tailored STEM modules, sustainable training infrastructure, and formalized postgraduate courses addressing Pakistan-specific SDGs. DCARE exemplifies TNE's transformative potential, positioning MUET as Pakistan's pioneer in drone-enabled climate adaptation while strengthening enduring UK-Pakistan academic partnerships.**

***Index Terms*—Drones, TNE, UAV, Climate Resilience, Education Capacity Building, Pakistan.**

I. INTRODUCTION

Pakistan stands as one of the world's most climate-vulnerable countries, a reality now visible in the everyday lives of its people as much as in statistical records [1]–[3]. Rural and urban communities alike are increasingly exposed to heatwaves, longer dry spells, and intense rainfall events, with observational analyses showing clear upward trends in consecutive dry days and heavy precipitation across Pakistan's main climatic zones [4]. The 2010 super-floods and the unprecedented 2022 monsoon floods together displaced tens of millions, destroyed homes and livelihoods, and caused economic losses estimated in the tens of billions of dollars, while hitting already marginalized populations the hardest [5]–[7]. These climate shocks interact with high poverty, limited public services, and fragile local institutions, deepening vulnerability and threatening food security, health, and long-term development prospects [8]–[10]. In this context, better climate information is not just a technical requirement but a human necessity for safer housing, more resilient farming, and timely evacuation and relief. Unmanned Aerial Vehicles (UAVs), or drones, offer an emerging way to generate locally relevant, high-resolution environmental data for applications such as flood mapping, damage assessment, and precision agriculture, complementing GIS and satellite-based approaches already recommended in the Pakistani context [5], [11]–[13]. Yet, despite this potential, the country largely remains a consumer of imported drone systems, with limited local research and development, few context-specific applications, and a notable absence of structured academic pathways to train engineers and practitioners who can adapt these tools to community needs [14]–[18]. Addressing this gap requires more than procuring equipment; it calls for building an ecosystem of people, practices, and institutions. Transnational Education (TNE) partnerships provide one route to such capacity building by enabling joint curriculum design, staff development, and shared experimentation between institutions in the Global North and South [19]. The Drones for Climate Action and Resilience Exchange (DCARE) project is one such TNE initiative between Ulster University (UU), UK, and Mehran University of Engineering and Technology (MUET), Pakistan. It is designed to respond directly to documented climate vulnerabilities, including Climate Change Vulnerability Index (CCVI) scores as high as 0.81 for agricultural communities by strengthening local educational and technical capacity [20]. DCARE embodies the broader vision of TNE, providing Pakistan's local engineers and learners with education tailored to community needs and national climate challenges. This paper examines DCARE as an integrated intervention model, focusing on its co-developed postgraduate curricula, dedicated drone laboratory, and dual-platform teaching strategy that combines the UU FALCON kit for exploratory work with commercial DJI systems for applied field activities. Through analysis of workshops, reciprocal visits, and academic integration processes, the study argues that DCARE offers a practical and replicable blueprint for developing a locally grounded, human-centred drone education ecosystem that supports Pakistan's transition from passive technology use to active, context-specific innovation.

II. DCARE: A TNE Framework for Capacity Building in Drone-Based Climate Resilience

The DCARE project was established as a targeted intervention to address Pakistan's climate vulnerability and technical capacity gaps. It is a formal TNE collaboration between UU and MUET, Pakistan, funded by a British Council grant. Figure 1 presents the DCARE Project Structure, a transnational education partnership between UU and MUET for systematic capacity building in sensing, communications, and AI-Driven drone technology. The project operates on the premise that

Fig. 1. DCARE TNE Framework: UU-MUET Collaboration Addressing Pakistan's Climate Vulnerability Through Drone Technology Capacity Building.

long-term climate resilience depends on indigenous technological competence, blending climate action with academic exchange. The core objective of DCARE is to systematically build human and institutional capacity at MUET, and by extension, within Pakistan's higher education sector, specifically in the development and application of drone systems for climate resilience monitoring. By embedding these competencies in the local academic system, DCARE extends the benefits of TNE beyond university boundaries, equipping local educators, students, and practitioners with the knowledge to apply drone technologies for community-level environmental management and resilience. Moving beyond one-off equipment donations or generic training, DCARE is structured to cultivate a self-sustaining academic ecosystem. This is achieved through three interlinked pillars: the co-development of postgraduate-level curriculum, the establishment of dedicated drone research and teaching laboratories at MUET, and the delivery of immersive, hands-on training for faculty and students [1]. The project's technical and academic focus is strategically organized around three critical domains essential for effective drone-based environmental monitoring:

- Sensing: Covers sensor selection, calibration, and integration for tailored applications such as crop health assessment or flood mapping.
- Communications: Addresses reliable data transmission and telemetry in remote or rugged terrain typical of Pakistan.
- Artificial Intelligence and Data Analytics: Focuses on processing aerial data into actionable insights through machine learning and computer vision [12].

Mastering this spectrum enables a shift from merely operating drones to engineering customized solutions for specific local challenges, such as designing sensors for salinity monitoring in the Indus Delta or building AI models to assess drought impacts in Thar. The expected outcomes of DCARE are both immediate and long-term. Nationally, the project helps build the expertise needed to deploy adaptable drone systems for climate monitoring, supporting Sustainable Development Goals on climate action (SDG 13) and innovation (SDG 9) [21]. Academically, it will integrate drone technology into MUET's postgraduate curriculum, establish a functional UAV lab, and train a cohort of local faculty as resource persons.

III. DCARE as a Model for Strategic Transnational Education

The TNE refers to partnerships where educational programs are co-designed and delivered across borders. In the context of Pakistan and the UK, TNE offers a vital channel for accelerating human capital development in high-tech fields. For Pakistan, it provides access to international pedagogical standards and research practices; for UK institutions, it represents an opportunity to apply expertise to globally significant challenges while enriching their own research through international collaboration.

A. DCARE as a Successful TNE Model

DCARE embodies the core principles of a successful, equity-focused TNE model. It is characterized by co-creation, contextual adaptation, and a clear pathway to local sustainability. Unlike transactional models of training, DCARE was structured from the outset as a collaborative development process. The gap analysis, joint curriculum design, and bidirectional workshop model (where MUET researchers presented their work in Belfast and Ulster experts trained on-site in Jamshoro) ensure that the partnership is a dialogue, not a monologue. This approach respects and integrates the local context of MUET, ensuring that the developed competencies are directly applicable to Pakistan's specific climate monitoring needs. The impact of this approach can be observed in several key areas:

- **Enhancing Academic Standards:** DCARE integrates globally benchmarked curricula and lab practices to strengthen MUET's academic quality and align with international UAV and environmental data science trends.
- **Building Sustainable Capacity:** By training MUET faculty as local instructors and lab managers, DCARE ensures lasting in-country expertise and continued skill transfer to future cohorts.
- **Producing Joint Outputs:** The co-developed Climate Action Curriculum and Lab Manual combine Ulster's technical expertise with MUET's local context, fostering long-term collaboration.

The DCARE project demonstrates that TNE, when designed as a genuine partnership focused on co-creation and capacity retention, is a powerful mechanism for addressing systemic educational gaps. It provides a viable blueprint for how UK-Pakistan academic collaborations can effectively translate global expertise into local innovation capacity, directly contributing to national priorities such as climate resilience and STEM development. Crucially, DCARE demonstrates how TNE can democratize advanced technical education, enabling local learners and institutions to translate global expertise into solutions that improve community resilience and livelihoods.

IV. Key Academic Activities: Implementation, Outputs, and Evolving Collaboration

The DCARE project's strategic framework is being operationalised through a sequence of interconnected activities, generating concrete outputs while adaptively planning future phases. This section highlights progress across its three core pillars, analyzing initial results and the project's iterative development path.

A. Curriculum and Knowledge Resource Development

The curriculum development process is foundational, evidence-based, and collaborative. It was initiated with a systematic gap analysis conducted through regular project meetings between Ulster and MUET faculty. These sessions audited the existing postgraduate programmes in engineering and computing at MUET against the competencies required for drone-based climate monitoring, identifying critical gaps in practical UAV systems engineering, sensor integration, and environmental data science. Informed by this analysis, the project adopted a resource-first, phased approach. The primary initial output is the comprehensive "Climate Action Lab Manual," a detailed instructional guide for drone assembly, programming, and application development. This manual serves as the core pedagogical text to enable immediate hands-on learning. Concurrently, the structure for a formal Drone-based Climate Action Curriculum is being designed. This curriculum, built around the lab manual and structured across the three pillars of Sensing, Communications, and AI, is being tailored for seamless integration into MUET's local academic system, adhering to its credit hour requirements and approval processes to ensure long-term institutionalization beyond the project timeline.

B. Facility Establishment

The establishment of dedicated physical infrastructure is critical for translating curriculum into practical competence. This component involves a two-stage exposure and implementation model. The first stage involves planned exposure visits by the MUET team to UU. Scheduled for October 2025, these visits are designed to provide MUET faculty and technical staff with firsthand insight into the layout, safety protocols, and advanced research workflows of an operational UAV facility, informing the setup at MUET. The second, concurrent stage is the establishment of the research and training laboratories at MUET. This process involves the procurement, installation, and calibration of a suite of equipment, including UU FALCON development kits, DJI commercial platforms, sensor payloads, and data processing workstations. Ulster-MUET teams coordinate remotely and onsite to create a pedagogically integrated drone lab supporting the new curriculum.

C. Workshops, Field Visits and Educational Impact

The most tangible and transformative elements of the DCARE project were the in-person workshops and field visits, which translated theoretical plans into practical skills and collaborative relationships. These activities, particularly the on-site engagement in Pakistan, served as the critical catalyst for capacity building and had a direct, measurable impact on STEM-oriented teaching at MUET. Figures 2 and 3 demonstrate a DCARE Workshop at MUET Jamshoro (Pakistan) and UU, Belfast, led by Dr. Usman Hadi, demonstrating hands-on drone training.

1) On-Site Engagement: The MUET Residency Workshop: A pivotal component of the project was the dedicated residency workshop conducted at MUET, Jamshoro. For this activity, the project lead from UU, Dr. Usman Hadi, travelled to Pakistan to lead an intensive, hands-on training program. This on-ground presence was instrumental in contextualizing the training and fostering direct mentor-mentee relationships.

Fig. 2. DCARE Workshops and Drone Training Sessions at MUET, Pakistan.

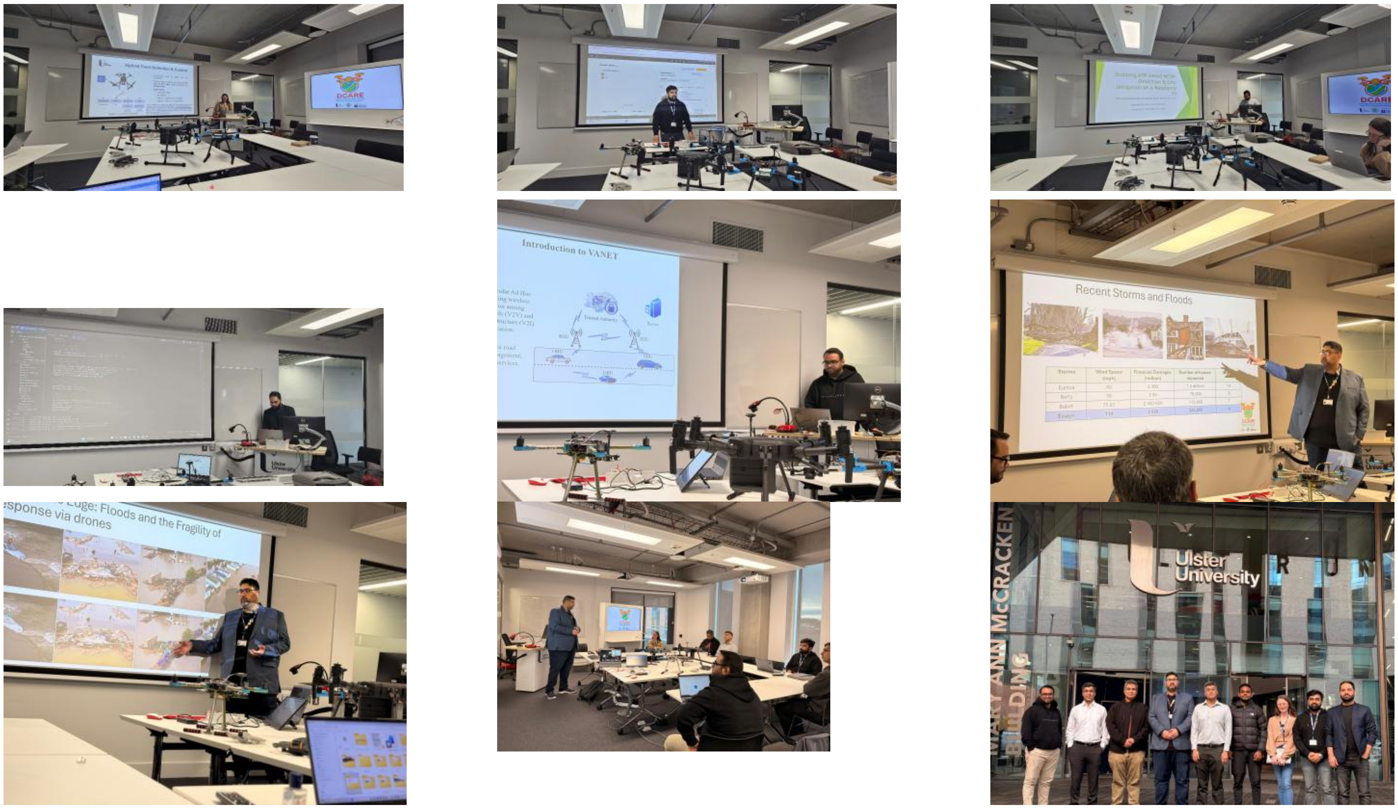


Fig. 3. DCARE Workshops and Drone Training Sessions at Ulster University.

2) Workshop Activities and Training Modules: The workshop employed a practice-intensive curriculum structured around core competency modules essential for UAV-based climate work:

- Fundamentals of UAV Systems and Safety: Sessions covered Pakistani airspace regulations, mission risk assessment, and pre-flight check protocols, grounding the technology in local operational realities.
- Hands-On Assembly and Programming (UU FALCON Kit): Participants engaged in the complete assembly of FALCON educational drones, wiring flight controllers (Pixhawk), calibrating sensors, and programming autonomous flight missions using QGroundControl software. This module demystified the drone's internal architecture.
- Professional Field Operations: Trainees conducted practical flights with DJI Mavic and Matrice series drones. They planned and executed photogrammetry grid missions to create 2D orthomosaics and 3D models of campus areas, simulating mapping for flood assessment or land use change.
- Sensor Application and Data Acquisition: Using integrated thermal and multispectral sensors, participants collected data for specific applications, such as identifying heat signatures and calculating vegetation indices for crop health analysis.
- Geospatial Data Processing and Analysis: This module trained participants in processing captured imagery using software like Pix4Dmapper and QGIS, transforming raw data into actionable maps, volumetric calculations, and analytical reports.

D. Existing Commercial Drone Assets Management

Beyond training on purpose-built educational platforms, the workshop also emphasized the optimal use of existing commercial drone assets already available within the UU, UK. Dedicated sessions guided participants on assessing payload compatibility, performing firmware updates, and extending operational life of currently owned DJI and Parrot drones. Demonstrations showcased how these platforms can be repurposed for environmental monitoring tasks such as floodplain mapping and infrastructure inspection. This component highlighted sustainability by ensuring that institutional investments in earlier drone procurements directly contribute to climate resilience education and applied research. Figure 4 illustrates one such training session using existing UU drone units.

E. Participant Outcomes and Immediate Impact

The workshop directly engaged a cohort of 15 MUET faculty members and postgraduate researchers from electrical, mechanical, and computer engineering departments. Post-workshop feedback and assessment revealed significant outcomes:

- For Faculty: Participants transitioned from a theoretical understanding of drones to practical, operational confidence. They gained the proficiency to independently

Fig. 4. Training session on the utilization of existing commercial drones for climate data collection at UU, Belfats, UK.

set up, operate, and troubleshoot both educational (FALCON) and commercial (DJI) platforms. This equipped them to become the ”local tutors” central to the project’s sustainability model, enabling them to lead practical lab sessions for students in the newly developed curriculum.

- For Students: The students acquired cutting-edge technical skills highly relevant to their theses and future careers. They reported an enhanced ability to conceptualize and design research projects utilizing UAVs for environmental monitoring, directly linking their academic work to applied national challenges.

V. UAV Platforms and Hands-on Training: A Dual-Pillar Pedagogical Approach

A key aspect of the DCARE project’s teaching strategy is its dual platform training model, which uses two complementary types of UAVs: the UU FALCON educational kit and commercial DJI drones. This approach is designed to build a complete skillset, from foundational engineering to professional field operations directly applicable to climate resilience work. Figure 4 presents a DCARE training platform educational drone kit and commercial UAV system.

A. UU FALCON Kit: Foundational Systems Engineering

The UU FALCON kit serves as the platform for deep, hands-on learning of UAV fundamentals. Unlike ready-to-fly commercial drones, the FALCON requires trainees to assemble, configure, and program the aircraft themselves, demystifying the underlying technology. Participants work directly with components such as flight controllers (Pixhawk), motors, ESCs, and telemetry systems, building a practical understanding of aerodynamics, avionics, and safety mechanisms. Programming autonomous missions with software like Mission Planner or QGroundControl further develops embedded systems and robotics skills. The FALCON also makes it ideal for STEM education and applied research. Students and faculty can modify hardware, integrate custom sensors, such as low-cost air quality monitors, and develop new algorithms for flight control or data processing. This fosters innovation and allows MUET researchers to prototype tailored solutions for local challenges, such as designing drones for methane leak detection or optimizing endurance for agricultural surveys.

B. DJI Commercial Drones: Applied Field Operations

Complementing the UU FALCON kit, commercial DJI drones (e.g., Mavic 3 Enterprise, Matrice series) are used to train students in professional, real-world applications. These platforms represent industry standards for reliability, ease of use, and integrated sensor capabilities in fields like mapping and inspection. Training on DJI systems focuses on operational proficiency and data acquisition. This includes planning photogrammetry missions, executing automated flights to create orthomosaics and digital elevation models, and operating specialized payloads like thermal and multispectral cameras. These skills translate directly to climate-related tasks: precise flood mapping, volumetric analysis of water bodies, crop health monitoring using NDVI, and post-disaster damage assessment. The two platforms play synergistic roles: while FALCON teaches how drones are built and programmed, DJI training teaches how to deploy them effectively in the field to collect professional data. This ensures graduates are both innovators capable of modifying technology and skilled operators ready to contribute to applied projects.

C. Synthesis of the Dual-Pillar Model

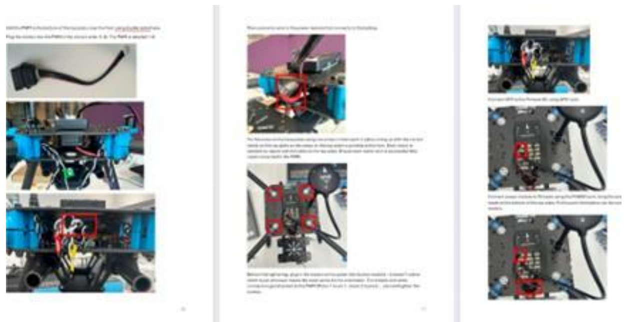
Together, this dual-pillar model ensures a comprehensive skill set. The UU FALCON kit builds engineering and R&D capacity for long-term adaptation and innovation. DJI training builds immediate operational capacity for reliable data collection in real-world conditions. By combining both, DCARE prepares participants to be not only users of drone technology but also creators of localized solutions, equipping them to advance climate resilience in Pakistan from conceptual research to deployed application.

VI. Academic and National Impact: Building a Foundation for Resilience

The DCARE project is designed as a catalytic intervention, with impacts unfolding across immediate academic horizons and longer-term national development trajectories. Its success is measured not only by the skills transferred but by its capacity to seed a self-sustaining ecosystem for innovation and application.

A. Academic Impact: Institutionalizing a New Competency

The primary academic impact lies in the systematic integration of UAV technology into the formal engineering education structure at MUET, with anticipated ripple effects across Pakistan’s higher education sector. This institutionalization is realized through several key outcomes. The co-developed



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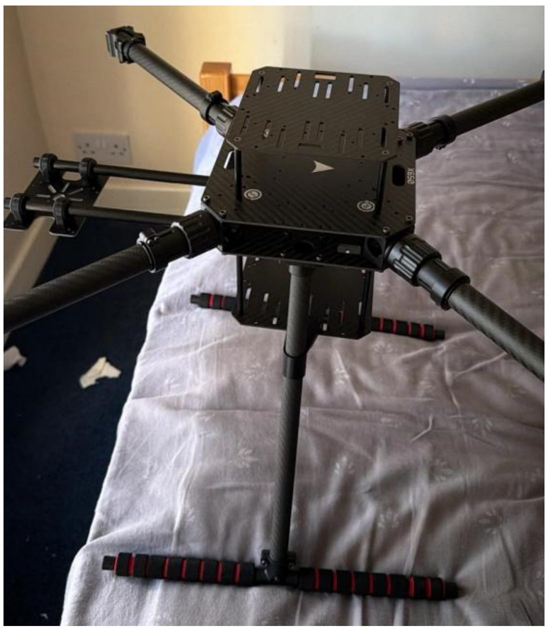

(b)

Fig. 5. DCARE Dual Training Platforms: Educational Drone Kit and Professional UAV.

Drone-based Climate Action Curriculum and its foundational Climate Action Lab Manual introduce formally accredited, specialized courses into MUET's postgraduate engineering programmes, filling a critical gap and providing a structured academic pathway into this high-demand field. Concurrently, the establishment of a dedicated UAV research laboratory, equipped with both UU FALCON kits for prototyping and DJI platforms for data collection, fundamentally transforms MUET's research potential. Faculty and students now possess the tools to design and execute applied research on topics such as developing low-cost sensor packages for local environmental monitoring or creating AI models for automated land degradation assessment. Furthermore, this laboratory serves as a permanent hub for experiential learning, enabling a pedagogical shift from theory-heavy instruction to the hands-on, project-based learning essential for modern engineering education, thereby directly improving graduate employability and technical proficiency. Perhaps the most significant sustainable outcome is the creation of a cohort of trained MUET faculty who now act as "local tutors." This internalization of expertise ensures the programme's continuity and independence, transforming these individuals into ambassadors capable of supporting other institutions in Pakistan and thereby amplifying the project's initial investment [4].

B. National Impact: Enabling Data-Driven Climate Resilience

By constructing this academic foundation, DCARE directly contributes to Pakistan's capacity to address its most pressing environmental challenges through technology. The project enables the practical application of UAVs for critical national monitoring needs across multiple sectors. UAVs provide the high-resolution, temporal data essential for tracking climate change indicators, such as glacial retreat in the north or shifting river courses in the plains, directly informing the implementation of the National Climate Change Policy. The skills cultivated at MUET are designed to feed into numerous applied fields essential for national resilience. In agriculture, multispectral drones can monitor crop health, optimize irrigation, and assess yield, supporting precision agriculture and food security initiatives. For environmental conservation, regular aerial surveys enable accurate deforestation tracking and afforestation audits, while repeated coastal surveys can quantify erosion rates to inform management strategies in vulnerable regions like Sindh and Balochistan. In disaster management, as demonstrated during the 2022 floods, UAVs are indispensable for rapid damage assessment, search and rescue planning, and post-disaster reconstruction monitoring; trained local operators can deploy immediately in future crises. Additionally, UAVs offer a non-invasive method for wildlife observation and habitat mapping, supporting the conservation of sensitive ecosystems such as the Indus Delta mangroves [6], [20].

VII. Challenges and Future Directions

While the DCARE project establishes a vital academic foundation, its long-term success and the broader maturation of Pakistan's drone ecosystem face systemic challenges. Key among these are restrictive regulatory frameworks, import dependencies, a lack of standardized professional certification, and weak linkages between academia and industry. These constraints hinder practical deployment, increase costs, and limit the commercial translation of research. To move forward, a multi-stakeholder approach is required. Priorities must include advocating for enabling policies, such as streamlined flight permissions and research "sandboxes," and scaling the TNE model to other institutions and sectors. Furthermore, strengthening academia-industry-government partnerships through applied research centers and internship programs is essential to align R&D with national needs. Building on DCARE's curriculum, there is significant potential to develop a local certification ecosystem in collaboration with bodies such as the Pakistan Civil Aviation Authority and the Pakistan Engineering Council, professionalizing the UAV workforce. Ultimately, the foundational skills cultivated through hands-on training with platforms like the UU FALCON kit provide a basis for an even more ambitious goal: fostering local manufacturing and assembly of drone components. Starting with simpler parts and moving toward specialized designs for Pakistani conditions, this would reduce costs, enhance sovereignty, and spur innovation.

VIII. CONCLUSION

This paper has analyzed the DCARE project as a strategic model for building technical capacity in drone technology for climate resilience. Facing Pakistan's severe vulnerability to climate impacts and a critical shortage of local expertise, the partnership between UU and MUET sought to establish a sustainable academic ecosystem for UAV education and research. Key outcomes of the project are concrete: the co-development of a Drone-based Climate Action Curriculum, the creation of a practical Climate Action Lab Manual, and the setup of a dedicated UAV research lab at MUET. By combining hands-on training with UU FALCON kits for systems engineering and DJI platforms for applied fieldwork, DCARE has cultivated a group of local faculty who are now equipped to independently train future engineers. This capacity is directly relevant to Pakistan's climate resilience. Locally skilled professionals can deploy drones to generate timely, high-resolution environmental data for agriculture monitoring, flood mapping, deforestation tracking, and disaster response, turning academic training into practical adaptation. The project demonstrates the value of TNE when built on co-creation and local ownership, moving beyond one-off training to foster lasting institutional change. It further highlights the social dimension of TNE, ensuring that advanced education and technological know-how reach local students, educators, and practitioners who can directly apply these skills to serve community needs. For Pakistan's drone ecosystem to fully mature, the academic foundation laid by DCARE must now be coupled with supportive policy, stronger industry-academia links, and steps toward local manufacturing. With continued investment, such initiatives can help transition Pakistan from a technology importer to an innovator, building long-term resilience from within.

IX. ACKNOWLEDGMENT

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