Darwin Initiative Innovation: Final Report

To be completed with reference to the "Project Reporting Information Note": (https://www.darwininitiative.org.uk/resources/information-notes/).

It is expected that this report will be a **maximum of 20 pages** in length, excluding annexes.

Submission Deadline: no later than 3 months after agreed end date.

Submit to: BCF-Reports@niras.com including your project ref in the subject line.

Darwin Initiative Project Information

Project reference	DARNV014
Project title	Pioneering approaches for drone use in biodiversity conservation - Madagascar
Country(ies)	Madagascar
Lead Organisation	Durrell Wildlife Conservation Trust
Project partner(s)	Liverpool John Moores University (LJMU) Madagascar National Parks (MNP)
Darwin Initiative grant value	£197,959
Start/end dates of project	01/03/2023 - 30/06/2025
Project Leader's name	Andriatsitohaina Rakotozoely (Tsito)
Project website/blog/social media	
Report author(s) and date	Andriatsitohaina Rakotozoely (Tsito)

1 Project Summary

Our project has combined drone technology, artificial intelligence (AI), and community engagement to tackle pressing environmental and developmental challenges in Madagascar. By integrating semi-automated monitoring systems into biodiversity protection efforts, the project represents a pioneering move toward scalable and data-driven conservation in a region where such technology has been underutilized. The project deployed drones equipped with high-resolution imagery, LiDAR, and infrared sensors, alongside open-source AI tools, to:

- Monitor deforestation, tree survival and tree growth rate under the National Reforestation Program.
- Detect and survey populations of Critically Endangered species, particularly the Alatroan gentle lemur (*Hapalemur alaotrensis*) in Lake Alaotra.
- Establish a semi-automated tree detection pipeline and an AI-driven species monitoring protocol for highland and mangrove area with difficult access.
- Implement a drone deterrence protocol to reduce illegal activities such as logging and fires within protected areas.

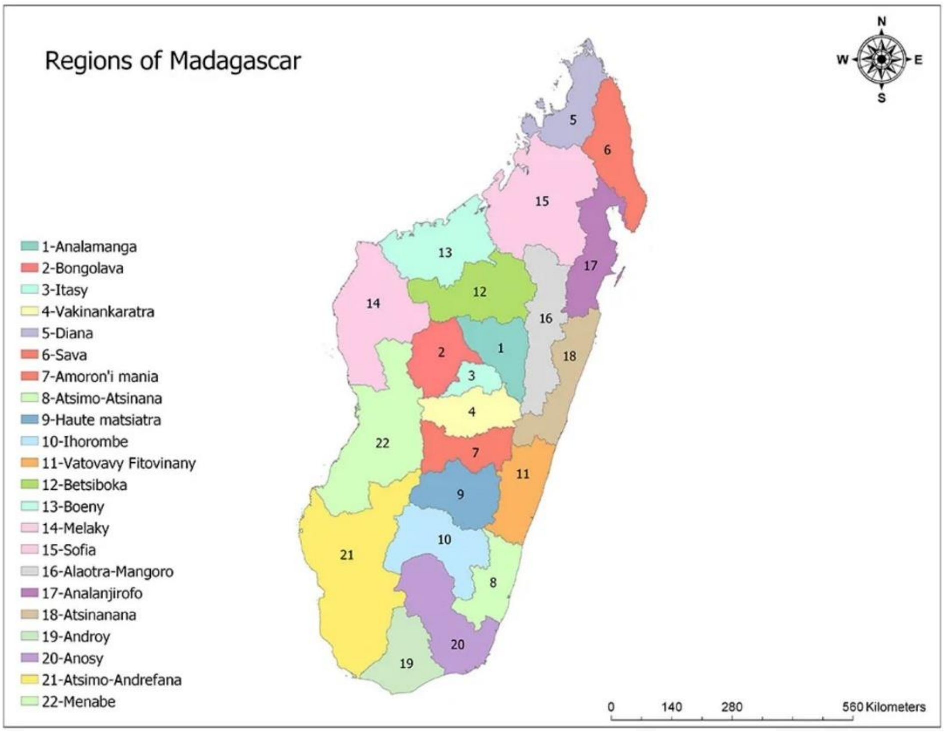
Project activities spanned several critical biodiversity regions:

- Lake Alaotra (region 16 below) – lemur monitoring, wetland surveys, and reforestation tracking.
- Menabe Antimena Protected Area (region 22 below) – fire detection and habitat threat surveillance.
- Nationwide engagement – including drone training hubs in Antananarivo, Diego Suarez, Fianarantsoa, Tulear, Toamasina, and Majunga.

Community empowerment and capacity building:

- Trained 240 new drone pilots across 19 regions and 6 provinces, with an emphasis on youth involvement and gender equity.
- Created the Madagascar Conservation Drone Community (MCDC), now linked to the International Conservation Drones Network, to promote cross-border knowledge sharing.
- Partnered with local NGOs, universities, and the Ministry of Environment (MEDD) to ensure relevance and sustainability of the training and technologies.

The results are expected to inform national conservation policy, establish best practices for drone use in biodiversity and support Madagascar's long-term goals in climate resilience, sustainable development, and ecosystem restoration.



2 Project Partnerships

This project was conceived and executed through a collaborative and participatory framework, bringing together key institutions and local actors to address Madagascar's environmental and biodiversity challenges using drone-based technology and artificial intelligence.

The initiative was shaped through initial consultations and ongoing collaboration with:

- Ministry of Environment and Sustainable Development (MEDD): Provided strategic leadership and policy support, including the minister's endorsement of drone-based monitoring strategies.
- Madagascar National Parks (MNP): Integrated drone methods into protected area management; more than 30 staff were trained in drone use and data analysis.

- Madagascar Civil Aviation Authority (ACM): Co-organized national workshops and helped draft updated drone regulations, ensuring safe and legal drone operations in conservation.
- Liverpool John Moores University (LJMU): Offered expert support in drone deployment, AI improvement, and led machine learning workshops.
- British Embassy: Promoted environmental protection and endorsed project events such as World Environment Day and national drone workshops.

The stakeholder network expanded to year 2 to include:

- Regional departments of MEDD and MNP.
- A wide array of NGOs and civil society organizations across all provinces.
- Local university students involved in data collection and algorithm development (Annex 13).
- Community-based organizations, many of which joined the Madagascar Conservation Drone Community (MCDC) for long-term engagement.

Each partner contributed through a "train, share, and apply" model:

- Training more than 50 MEDD representatives in drone and AI use.
- Developing legal drone curricula and registration procedures in collaboration with ACM.
- Conducting post-training evaluations, debriefs, and structured feedback sessions to fine-tune project activities.

A landmark achievement was the joint formulation and presentation of Madagascar's updated national drone regulations, thanks to collaborative efforts between ACM, MEDD, MNP, and international partners. This strengthened institutional capacity and paved the way for continued safe drone usage. The project effectively bridged technical innovation with institutional policymaking, demonstrating the power of interdisciplinary collaboration. Operational challenges, such as coordinating multi-sector timelines during election periods, were managed through shared calendars and flexible task ownership.

Partnerships formed during the project are positioned for long-term collaboration:

- LJMU and Durrell are exploring future research opportunities.
- MNP has embedded drone protocols into their operational toolkit.
- MEDD and ACM are actively working to enhance national training frameworks for drone-based conservation and environmental monitoring.

3 Project Achievements

3.1 Outputs

Output 1: Techniques established for semi-automated reforestation monitoring using drones

Output indicator 1.1 Three reforestation plots surveyed by drones in both dry and rainy season by the end of Y1

Drone flights over Alaotra reforestation plots (≈200 ha) were completed in the dry and rainy seasons, using identical flight plans to allow six-month comparative analysis. Same plots have been surveyed using LiDAR for data completion and accuracy, as this provides better RGB resolution and allows for more accurate tree body and leaves imaging. These additional flights also include new reforestation plots after the bushfire in Ambohidavakely which destroyed the first reference plot. To avoid risks of references lost due to forest fire or bushfire, more flights and data collection have been conducted in Lac Alaotra reforestation sites like: Vohibola, Morarano, Vohimena Be and Vohimena Kely (July 2023, November 2024, April 2025).

In Menabe PA, 2 flights with the LIDAR sensor have been conducted to collect data samples on forest loss assessment and are contributing to the deterrence flights with bigger drone with longer flight time and flight range.

Output indicator 1.2 Three reforestation plots surveyed for ground truthing in both dry and rainy season by end of Y1

Ground truthing followed each flight in three plots, recording each tree's GPS position and manually measuring young trees to validate aerial data. Reference points and marking of young trees was carried out to be used for the next flights and improve accuracy. Data was then integrated into AI to verify height accuracy data.

Field surveys confirmed tree survival rates and supported AI height verification. This step was only feasible with point cloud delivered by the LiDAR drone and photogrammetry licenced software which provide detailed data and under canopy reflection.

Following the bushfire that destroyed the Ambohidavakely reference plot in Year 1, three new reforestation plots were selected to ensure continuity of monitoring. New ground reference data were collected and integrated into the AI pipeline to support growth rate estimation and survival analysis. The updated algorithm now provides centimetre-level measurement accuracy, enabling precise comparison between historical and newly established plots.

Output indicator 1.3 Technique developed for the processing of drone imagery to track individual survival of trees in reforestation plots allowing carbon sequestration to be accurately tracked, alongside correlates of tree survival

A semi-automated pipeline for young tree detection was developed in Python with university students and supported by LJMU professors using RGB imagery and photogrammetry, with datasets from Vohibola, Morarano, Vohimena Be and Vohimena Kely used to train the initial machine learning model. The pipeline was developed to recognize young trees, assess survival and growth rates (Annex 14).

It was further enhanced with the arrival of LiDAR equipment in September 2024, enabling comparative analysis and improved classification accuracy. A first version of the working pipeline was issued during the last knowledge-sharing workshop.

Python is the main language used for the pipeline, but more open sources software and web-based tools have been also used like Google Colab, label studio, Open CV and Visual Studio Code. All codes are shared on collaborative platform to ensure progression and contribution by other researcher, partners and students, and a web-based interface makes it user-friendly, meaning that it can be used by people who do not have a coding or programming background.

Output indicator 1.4 AI based system developed to accurately detect tree species and coverage in reforestation plots to enable post-hoc monitoring of reforestation plots

A dedicated trainee began working in October 2023 on the semi-automated tree species and coverage detection algorithm. Datasets from Lake Alaotra reforestation plots have been used in the first range and additional data have been added after LiDAR Point cloud data collection which provide higher resolution images. Manual sample measurements and aerial data were integrated into a training database to calibrate AI models. For each plot, vegetation and soil condition are different requiring more dataset to be integrated into the AI model.

Initial testing in January 2024 guided model refinement using real-world imagery and ground data. Difference between standard RGB sensor and high-resolution LiDAR provide more accuracy and allow the algorithm to work and think deeper. The first tests have been based on object detection using YOLOv8 and improvements have been added by including colour detection to refine the young tree structure and identification. This is still being tested and refined to make species detection accurate.

Output indicator 1.5 One training session delivered to new working group on standardising drone-based reforestation monitoring in Madagascar by end of project

Two technical workshops were delivered to partners, covering flight planning, mapping procedures, drone safe operations and AI-supported analysis.

Seven (07) drone training sessions have been conducted during the entire project grouping at least 25 to 30 participants for each session. These drone training sessions have been focused on drone operations, mapping, safety and data collection. 20 members of Civil Aviation authority attended the first session to help them on drone operation identification and classification.

For year 2, more improvements have been done in terms of drone regulations updated with Civil Aviation Authority requiring drone registration, pilot certification, flight documentation. A summarized training workshop have been conducted to update partners knowledge. During the last workshop, the aim was to guide them on how to proceed for drone operator certification, registration, how to certify the pilot as Durrell is not an Official training centre but during the project and based on Durrell's drone instructor level, Civil Aviation Authority allows us to conduct drone training. All trained pilots must take the national exam to confirm their level and get the drone permit.

Online deployment and demo have been conducted during the last workshop in July 2025 to share with partners and stakeholders the workflow and result of tree detection (Annex 12).

Output indicator 1.6 Paper submitted to an international journal, on effective monitoring of reforestation using drones by end of project

Data analysis and post-processing are ongoing and will contribute to an international peer-reviewed publication showcasing this novel reforestation monitoring approach. Publication is under writing and affined to meet academic/scientific but also understandable workflow, processing and expected results.

Output 2. Capacity developed for using drones for environmental conservation in Madagascar

The project delivered comprehensive training programs, including drone pilot certification, AI workshops, and regulatory briefings. Over 50 MEDD staff and more than 30 MNP agents participated in these sessions. The AI workshop in September 2024, led by LJMU professors, provided hands-on experience in model development using real-world datasets. The final training session in Diego Suarez completed national coverage, fulfilling the project's capacity-building targets. Significant advancements were made in developing national capacity for drone use in conservation, this step is the first nationwide activity which provide skilled and trained drone pilot in terms of conservation like mapping, aerial patrol, fire detection and rescue. The curricula have been validated by the Civil Aviation authority and meet the requirements in drone operations for safe and responsible use

Output indicator 2.1 Cross NGO/government working group created on drone use by Y1Q2

Madagascar Conservation Drone Community (MCDC) was launched in February 2024, connecting NGOs, government, and academia, civil authority and students all working in the environmental and conservation sectors. There has been a steady increase in the number of members in the Drone Community over the project, through training participants signing up, and in Y2 the group has become a dynamic and helping hub for drone users in Conservation in

Madagascar. This working group is now integrated to the wider Conservation Drone hub which is a collaboration with LJMU and worldwide practitioners.

Output indicator 2.2 At least four meetings of the drone working group in each year of the project

One online meeting was conducted for the drone working group. However, best practice and standard drone operation procedures have been shared during drone training sessions and workshops to meet the national needs in terms of safety, operations and results. Machine learning, AI model creation and data processing have been shared during a workshop with LJMU in Tana to MEDD, MNP, NGOs, students and researchers.

Output indicator 2.3 Two knowledge sharing workshops delivered to working group participants by end of project (middle and end)

The first national knowledge-sharing workshop took place in May 2024, second one in September 2024, with the British Embassy, MoE, Civil Aviation Authority, NGOs and partners in conservation in Madagascar, and last one in July 2025 (the final was more of a project update than a technical sharing exercise, involving the British Embassy, Civil Aviation Authority, NGOs and MEDD for the drone registration procedures, AI assisted tree detection and data analysis sharing. This workshop was focused on questions and answers to share detailed information about the progress and what we achieve during the last two years).

Output indicator 2.4 At least 50 pilots trained and passing UK theory exams (or equivalent) to demonstrate competence by end of project

196 of 240 new drone pilots completed certified training and submitted verified flight logs. The ones who did not submit their flight log yet will do it as soon as they will complete it (Annex 5.2 for the disaggregation across regions and Annex 6 for sample training report and certification).

Advanced maintenance workshops trained staff from MEDD and MNP. After this training, the technicians can fly more models of drone including, VTOL, heavy weight drone and long range drones.

Output indicator 2.5 Advanced training provided in drone maintenance to four people (Two from MNP, Two from MoE or major NGO using drones) by end of project

Two staff members from the Ministry of Environment's drone department received training in drone maintenance and advanced operations, including VTOL (Vertical Take-Off and Landing) aircraft. This training enabled them to support institutional drone use for conservation monitoring and patrols. In Y2, building on the initial training, MoE staff received advanced instruction in thermal imagery and high-precision mapping. This enabled them to obtain flight permits from the Civil Aviation Authority, expanding their operational range and coverage. Durrell also provided technical assistance for heavy-lift drone maintenance, resulting in the successful redeployment of these aircraft for mangrove restoration activities in northern Madagascar.

Output 3. Drones demonstrated as an effective detection and deterrence mechanism for environmentally damaging behaviour and informing and responding to SMART patrol activity

Output indicator 3.1 Reduced illegal activity detected by SMART community patrols after deterrence flights in treatment plots

During the project we conducted 45 operational flights, 30 ground missions, 07 training runs, and 25 aerial patrols. These operations have been conducted during field work and improve the understanding of drone extended patrosl. More area has been covered, and more information have been collected on potential threat inside the protected area especially in Ambadira.

Quantitative evidence from SMART patrol reports and satellite imagery analysis shows a reduction in detected threats over the project period. In 2023, 969 threats were recorded; this number dropped to 492 in 2024 and further to 183 in 2025. This represents a reduction of 477 threats between 2023 and 2024, and a further 309 between 2024 and 2025. These figures reflect combined detections from both ground patrols and satellite verification. Annex 7 shows this threat data.

Output indicator 3.2 Drone monitoring flights are being used to detect smoke and illegal activity by project end

In the Menabe Antimena Protected Area, drones were successfully deployed for threat detection and mitigation. In Year 1, initial tests were conducted using both standard and thermal drone sensors. While standard RGB sensors were effective for detecting smoke during daylight hours, thermal drones enabled detection both during the day and at night. During the 2023 fire season in Menabe, drones were deployed to identify active fire points and guide firefighters to the most accessible routes. Two fire incidents were successfully managed with drone-assisted coordination.

In Year 2, drone-based fire detection started to become a complementary activity integrated into routine aerial patrols. Field teams used drones to identify active fires in real time and supported local communities and patrollers in fire suppression efforts. This operational use of drones demonstrated their potential as a valuable tool for emergency response and highlighted an opportunity to expand their role in supporting firefighting operations during peak fire seasons.

Output indicator 3.3 Drone tracks and incursion data integrated into Durrell's SMART database and informing SMART adaptive management by end of project

Data were uploaded into SMART systems (CSV and GPX) to improve adaptive patrol planning. This process was customised to be user friendly and allow for mid-level user to register and upload data. As this step require the use of laptop and smartphones, data are centralized in Tana and main town to be processed and sent back to the field.

Custom flight plans aligned with threat maps, enabling real-time fire monitoring and emergency response coordination. Adding communication standard and tools will improve this step specially in some area where cellular network is not available. We suggested to the patroller to use long range talkie-walkie for quick and sustainable communication.

During drone aerial patrol and ground patrol, potential drone use extension have been also identified like Lake mapping inside the PA and birds' detection. By flying around the Lake Bedo in Menabe, we have been able to detect bird which stood inside the lake and took some video footage which could be processed with the AI model to detect the species and population counting without disturbing the birds.

Output 4. The first robust, range-wide survey of Alaotran gentle lemur is delivered using drone-based infra-red detection of lemurs as a model for animal detection using this technology in Madagascar

Output indicator 4.1 Drone flights conducted for lemur detection across the Lac Alaotra marsh by the end of Y1

48 transects in Lake Alaotra over the 2 years led to the detection of 16 lemur groups using infrared-equipped drones. This detection flight operations follows predefined methodology designed to collect right data but also avoid disturbing the lemurs in their natural habitat. A safe

height of 50 meters and safe distance of 45m between drone and lemurs have been adopted. These parameters have been tested and give acceptable resolution from thermal sensor but also keep a noise disturbance as low as possible.

After initial testing in Y1, the first flights in Y2 were mostly focused on standard protocols and field validation (noise level, safe distance, right time for detection) and the second flights mostly focused on data collection and data preparation for processing using AI model. These two flights, added to the initial tests allow for robust estimation of Bandro population inside the marsh. (Bandro detection flight log in Annex 8).

Output indicator 4.2 Ground truthing surveys conducted for lemur populations and compared to drone data by end of Y1

Ground truthing was conducted by Durrell staff in collaboration with local community patrols across four key areas of Lake Alaotra, in both Y1 and Y2, and in parallel with drone flights. Lemurs detected via drone-mounted thermal sensors were verified on-site to ensure accurate identification and count. Two students were recruited for a six-month internship to support data analysis and model development. They built a Python-based framework to process drone footage, which now serves as a knowledge base for lemur detection and classification.

Ground truthing enabled comparative analysis of lemur behaviour and population estimates, validating drone-based detections against field observations. The integration of aerial and ground data strengthened the reliability of the AI model and informed refinements to detection protocols.

Output indicator 4.3 Semi-automated infra-red processing algorithm developed enabling processing of range-wide survey data

A semi-automated AI algorithm was successfully developed to process thermal infrared imagery collected during drone-based lemur surveys. The processing workflow was designed to handle video-based data and is structured in four key stages: (1) conversion of video sequences into frames, (2) segmentation of frames into individual images, (3) image labelling and model training, and (4) semi-automated detection of lemur signatures. A workflow diagram and code samples are provided in the Annex 9.

Ground verification was conducted during each flight to validate drone detections. A pirogue team accompanied every mission to confirm that thermal signatures corresponded to actual lemur sightings, ensuring high data accuracy and reliability.

Two student interns supported the development and refinement of the AI model. They contributed to footage analysis and species recognition algorithm enhancement. The model was trained specifically to detect Alaotran gentle lemur, *Hapalemur alaotrensis* (Bandro), using Python, OpenCV, and Visual C++. The resulting platform is modular and adaptable, allowing for future improvements and potential application to other species or habitats.

Output indicator 4.4 Manuscript submitted on the detection of Alaotran gentle lemurs with drone-based thermal infra-red

Manuscript writing for Bandro detection is part of a bigger document in the topic of drone use in conservation in Madagascar. This part represents one chapter and has been submitted internally to LJMU supervisors for review before submission to official journal and academic publication.

3.2 Outcome

Outcome: Drones are being used to effectively monitor and improve biodiversity conservation in Madagascar

Outcome indicator 0.1 Drones are being utilised for reforestation monitoring, including individual survival, across at least four reforestation plots by end of project

Four reforestation plots have been used for reforestation efforts monitoring in Lake Alaotra. At least two drone flights during dry season and rain season have been conducted, and a the first working version of the pipeline for tracking individual survival of trees has been shared in the latest knowledge-sharing workshop.

Outcome indicator 0.2 A conservation drone working group drives the uptakes of drones for conservation in at least 10 protected areas across Madagascar by project end

The project's outcome to establish a sustainable, nationally distributed capacity for drone-assisted conservation monitoring has been substantially achieved. Between April and November 2024, 90 additional drone pilots were trained, bringing the total to 240 across six provinces and 19 regions with 40 completing UK-equivalent theory exams and submitting verified flight logs. This exceeds the original target and demonstrates widespread technical uptake. These individuals now form a decentralized technical network capable of conducting aerial surveys, processing spatial data, and applying AI models for ecological analysis.

The Madagascar Conservation Drone Community (MCDC) was expanded and formally linked to the International Conservation Drones Network, providing a sustainable platform for knowledge exchange and peer support.

Outcome indicator 0.3 Drones are adopted in management plans for the deterrence of illegal activities in core protected zones in at least two protected areas

Drone-derived data were successfully integrated into the SMART patrol system in Menabe, directly informing patrol routes and threat response. This represents a significant operational shift in how protected areas are monitored.

The project also catalysed the publication of new drone regulations in collaboration with ACM and MEDD, ensuring legal and safe drone use for conservation. This policy-level outcome strengthens the enabling environment for long-term drone deployment.

Outcome indicator 0.4 A range wide survey of the Alaotran gentle lemur using drone-based infra-red data is completed and provides a model for infra-red animal monitoring in Madagascar

The project delivered two functional AI tools: a tree detection pipeline and a lemur detection algorithm, both validated through field trials and integrated into open-access platforms. These tools are now being used by trained stakeholders. A population estimate for Bandro has been developed and the technique has potential application to other species.

3.3 Monitoring of assumptions

0.1a The model for processing drone-imagery to track individual tree survival on reforestation plots is developed successfully

Comments: In Year 2, the AI pipeline for tree detection was developed and tested on dry land reforestation plots. The pipeline was presented during the final project workshop, where partners were introduced to its functionality and provided with access to the open-source repository. Recognising that many NGOs do not have access to LiDAR sensors, the pipeline was adapted to process RGB drone imagery following photogrammetry. It supports input files in TIF format, which are commonly produced by drone mapping software.

To ensure usability across different contexts, the pipeline was designed to be modular and user-trainable. Each user is expected to generate their own detection model using the shared workflow, which includes guidance on using Label Studio for image annotation and model training. A basic tree identification model, developed using data from Lake Alaotra, was provided as a reference to support initial implementation and adaptation.

0.1b Reforestation efforts continue post-election

Comments: In 2023–2024, the official national reforestation campaign began in February, with drones deployed in Menabe Antimena to support 50 hectares of mangrove restoration in Marofandilia. This activity was carried out in collaboration with the Ministry of Environment and Sustainable Development (MEDD) and local communities, using Avicenia seeds. In 2024–2025, drones were not used during the official reforestation event. Instead, MEDD focused on enhancing monitoring capacity through the deployment of newly acquired VTOL drones, received in May 2024. These aircraft were used for surveillance and post-planting monitoring. Manual planting activities were conducted with local communities during the official campaign, led by the Ministry of Environment.

0.2 Conservation drone users continue to engage in our workshops and meetings

Comments: Throughout the project, close communication was maintained with conservation drone users via a dedicated WhatsApp group. This platform remained active after each training session, enabling users and pilots to exchange technical advice on drone operation, maintenance, data processing, and troubleshooting. In Year 2, the community was further strengthened through integration with the Conservation Drones website, which now hosts video tutorials, scientific resources, and practical guidance tailored to conservation applications. This expanded access to peer support and technical materials has helped sustain engagement and foster a collaborative learning environment among practitioners across Madagascar.

0.3 Experiment shows that drones are successful in deterring illegal behaviours in protected areas, and do not displace activities to other areas of the park.

Comments: Drone flights based on alarms and notifications from the SMART team have improved the accuracy and allowed the drone team to extend the aerial patrol zone. After training, the field team conduct more drone flights and combine them with ground patrols. With data compilation and comparison, threats have decreased from 2023 to June 2025. Beyond deterrence, drones also played an educational role. During field missions, aerial footage was shared with local communities to raise awareness about forest degradation and conservation priorities. This visual engagement helped foster understanding and support for protected area management.

0.3b Drone maintenance enables sufficiently regular flights to maintain deterrent effect

Comments: Drone training include maintenance and regular inspection on each aircraft. This is the guarantee that the aircraft stay in operational state. The detailed checklist for drone maintenance has been updated in Y2 for the field team to allow them to fly and maintain the drones following regular time. The most important component is the batteries, so more instructions have been added to the checklist for the maintenance period.

0.3c Deterrent effect does not wane, significantly, through time

Comments: Regular drone flights maintains a consistent deterrent effect against illegal activities in protected areas. Patrol routes can be changed, with drones deployed across different zones within the protected area to preserve the element of surprise. These operations were conducted in compliance with civil aviation authorisations, allowing patrols to launch at any time and from various locations.

Threat statistics compiled from SMART patrol data between 2023 and mid-2025 confirmed that the deterrent effect remained strong. Drone flight plans were also adjusted based on real-time intelligence from ground patrols, enabling broader and more targeted surveillance. This adaptive approach ensured that the deterrent impact of drone presence was sustained over time and across different parts of the protected area.

0.4a Development of semi-automated detection of drones in the infra-red imagery continues to progress successfully

Comments: Progress continued in Year 2 on the development of semi-automated detection algorithms for lemur identification using infrared drone imagery. Temperature signature accuracy improved significantly through the integration of customised AI code, enabling more precise detection of lemurs in marsh habitats. A key challenge from Year 1, vegetation colour interference, was addressed by incorporating additional parameters into the colour detection module, allowing better differentiation between thermal signatures and background vegetation. This enhancement was combined with object and form recognition techniques, resulting in a more robust and reliable detection process.

Assumption 0.4b: No negative reaction to drones is observed during surveys (not to date, but regularly monitored)

Comments: By maintaining the safe distance from the lemurs, no negative effects have been observed. This distance is now set and respected for optimal resolution without disturbing the animals.

Assumption 1.3a: GNSS resolution is high enough to ensure individual trees can be identified aerially across multiple longitudinal images

Comments: Photogrammetry methodology with high GNSS accuracy allows for photo processing to give high resolution orthophotos which can be integrated into AI algorithm for tree aerial identification.

Assumption 1.3b: Trees can be distinguished from background vegetation in drone imagery at all life stages

Comments: AI colour and form recognition allows for tree to be distinguished from background vegetation. This process take time but offers improvements in algorithm customisation for detection of differences between bushes and young trees.

Assumption 1.4: AI can be trained to detect differences in RGB imagery between tree species

Comments: Depending on season and weather condition during flights, the RGB imagery offers details in colour and forms which conduct to tree species identification. This step is in progress as it is only available for android operating system for the moment and need to be customised for PC to be developed more.

Assumption 1.5: There is interest amongst working group for the session

Comments: When the training session registration was launched and published on Durrell Madagascar Facebook page, in the first week 45 people registered. From December 2023 to March 2024 450 people registered on the google form. The online workshop was well attended.

Assumption 1.6: Techniques for processing drone data for reforestation monitoring are successful and scalable

Comments: Young trees are clearly visible from drones' imagery. For the moment, there is no free dedicated software for reforestation monitoring by drones. The aim of the developed algorithms is to offer open platform for MoE and NGOs for accurate reforestation monitoring. First results shows that it is more efficient than manual monitoring.

Assumption 2.2: Government officials can regularly attend working group meetings alongside drone professionals

Comments: By giving the first drone training session to Civil Aviation Authority, this allows our drone course to be validated as effective and meet the safety requirements for drone users in conservation domain. This step convinced government officials about the efficiency as well as the necessity of undergoing training and joining the community.

Assumption 2.4: If the Madagascar government creates its own theory exam, this target would change to completion of this exam

Comments: The official exam website for drone pilot in Madagascar will be hosted at Civil Aviation Authority server. The online platform development is in progress for drone exam, and we worked closely with civil aviation staff to provide technical support. The exam is based on ICAO drone topics and the UK-CAA platform is the best reference for interactive and secured platform.

Assumption 2.5: MNP / Government / NGO staff are able to attend regular drone training sessions

Comments: For capacity building and drone piloting training, the initial assumption was to train 50 people from different entities until the end of the project. However, after the initial sessions, we received requests from other NGOs and regional departments of the Ministry of Environment and Sustainable Development.

Assumption 3.1: Illegal activities are not displaced to other areas of the protected area (control sites). This will be monitored.

Comments: Drone aerial patrol allows for deterrence and illegal activities detection. These flights are based on ground patrol received from SMART ground patrol and verified. Illegal activities displacement will be monitored.

Assumption 4.1: No adverse reactions observed in lemurs in response to drone flights (none to date, but constantly reviewed)

Comments: Drone flight path and height are regularly reviewed to keep safe and less disturbance for the lemurs. Across the project, since setting the safe height and distance, no adverse reactions observed.

Assumption 4.3: Thermal infra-red continues to successfully detect lemurs in different habitats across the marsh

Comments: conducting thermal infra-red flights inside the marsh in different season, different time of the day/night and different habitats was successful and continuous improvements are done to offer more accuracy in thermal signature and forms.

Assumption 4.4: Thermal infra-red system continues to successfully detect lemurs enabling development of semi-automated algorithm

Comments: Drone detection of lemurs in Lake Alaotra has also seen advancement in accuracy compared to the initial hypotheses, which aimed to detect individuals during the season when the lake water level is low. After the latest fieldwork, we were able to identify the optimal conditions both in terms of weather conditions and lemur activity hours. The images used to feed the machine learning knowledge base offer higher resolution after the modifications of the protocol used and the configuration parameters of the drone during flights. During training sessions, we showcase samples of thermal images that have attracted participants' attention towards using drones with thermal cameras for their monitoring.

3.4 Impact

Impact: Reduction in deforestation, enhanced reforestation monitoring and improved monitoring of conservation targets throughout Madagascar

Over the course of the project, substantial progress has been made toward improved biodiversity conservation and poverty reduction in Madagascar by strengthening technical capacity, ecological data collection, and institutionalizing innovative monitoring practices.

Impact on biodiversity conservation

The project developed and operationalised innovative tools for enhanced monitoring of reforestation and other biodiversity such as endangered lemur species, making it less time-consuming and labour intensive than direct field measurements. For example, the semi-automated tree detection pipeline allows monitoring of reforestation plot survival rates with spatial consistency across seasons. Furthermore, improved detection and population monitoring of the Alaotran gentle lemur, *Hapalemur alaotrensis*. using infrared imagery and machine learning, will contribute to more informed conservation planning for the species.

Drone surveillance and deterrence missions in Menabe led to improved detection of illegal fires and logging, with aerial patrol data integrated into SMART for the first time. This should increase the efficiency of response teams to fire, which will reduce the destruction of the biodiversity in these critical habitats.

Impact on human development and poverty reduction

The project directly delivered capacity building to underserved regions and institutions, and to NGO staff, community members and government personnel across Madagascar. Skills gained in drone piloting, data processing, and AI applications can therefore lead to new employment opportunities in conservation / research / environmental management for participants and improves local capacity and ownership for this work. Involving women (at least 25% of Project Board members and 60% of partners led or co-led by women) further supported a gender-equitable approach to capacity building.

Reducing the destruction of critical habitats and improving biodiversity conservation will also benefit the heavily resource-dependent communities around our project area, through maintaining the ecosystem services and natural capital that they rely on.

4 Contribution to Darwin Initiative Programme Objectives

4.1 Project support to the Conventions, Treaties or Agreements

The project successfully built the capacity of Protected Area and Madagascar National Parks (MNP) professionals, training over 200 individuals to use drones for environmental conservation. Two national knowledge-sharing workshops were held, and the Madagascar Conservation Drone Community (MCDC) was formally established in February 2024. These efforts contributed directly to Madagascar's National Development Plan Target 5 – enhancing natural capital and building resilience to disaster risks.

The project also made measurable contributions to Madagascar's National Biodiversity Strategy and Action Plan (NBSAP), particularly Strategic Objectives 2 (recognising and integrating biodiversity values and benefits from sustainable use), 5 and 14 (protecting and restoring habitats and ecosystems), 11 (managing protected areas more effectively), and 12 (improving the conservation status of threatened species). Improved monitoring and deterrence mechanisms supports more efficient governance of the forestry sector, aligning with the Malagasy Forestry Policy. The project's development of adaptive reforestation monitoring techniques and carbon sequestration assessment tools also contributed to Madagascar's

National Policy against Climate Change, specifically Axis 5 (promoting research, technological advances, and adaptive management), and supported commitments under the UNFCCC. Two members of the government drone department received advanced training in drone maintenance and operations, including VTOL systems, strengthening the sustainability of these contributions.

The project promoted the value and importance of biodiversity conservation in line with CBD Target 1. Its work on adaptive ecosystem restoration monitoring (particularly in protected areas) contributed to CBD Targets 5, 11, 14, and 15, and Ramsar Targets 5, 7, and 12. The development of lemur monitoring methodologies supported CBD Target 12, while the broader capacity-building efforts across Madagascar's protected area network contributed to CBD Targets 19 and 11, and Ramsar Targets 14 and 16.

Through our direct work on biodiversity and ecosystems, the project also supported the United Nations Sustainable Development Goals (SDGs), particularly Life on Land (SDG 15), No Poverty (SDG 1), Clean Water and Sanitation (SDG 6), and Partnerships for the Goals (SDG 17). Enhanced deterrence and detection of illegal activities in protected areas further strengthened biodiversity governance and reinforced the importance of conservation.

Engagement with the UK Embassy, MEDD, and ACM resulted in profile-raising of drone-based monitoring at national events (e.g. World Environment Day, ACM co-hosted workshop). These collaborations reinforce the UK–Madagascar partnership in conservation innovation and demonstrate alignment with the Darwin Initiative's diplomatic objectives. The project workshops were also attended by British Embassy, Civil Aviation Authority NGO and MEDD, showing the close collaborations between us.

4.2 Project support for multidimensional poverty reduction

The project's contributions to poverty reduction are both direct and indirect, with measurable benefits in capacity development, institutional empowerment, and ecosystem service protection.

Direct poverty reduction: The project trained 240 drone pilots across six provinces and 19 regions, including representatives from NGOs, government agencies, and local communities. Many of these individuals came from underserved or rural areas with limited access to technical education. By equipping them with practical skills in drone operation, spatial data processing, and AI-assisted monitoring, the project encouraged new employment pathways in conservation and land-use / environmental planning. In addition, two individuals from MoE received advanced training in drone maintenance and VTOL aircraft operations (Indicator 2.5), enabling them to support institutional drones and reduce reliance on external contractors. These skills are transferable and could be income-generating, particularly in a context where drone services are increasingly in demand.

Indirect poverty reduction: By improving the monitoring of reforestation and lemur populations, the project supports the long-term restoration of ecosystem services such as water regulation, soil stability, and biodiversity-based tourism. These services underpin rural livelihoods and food security, particularly in areas like Lake Alaotra and Menabe Antimena, where communities depend on natural resources.

The integration of drone data into SMART patrol systems has also improved the governance of protected areas, improved fire-fighting response, and therefore has enhanced the security in the area, which is a key part of multidimensional poverty.

4.3 Gender Equality and Social Inclusion (GESI)

GESI Scale	Description	Put X where you think your project is on the scale
Not yet sensitive	The GESI context may have been considered but the project isn't quite meeting the requirements of a 'sensitive' approach	
Sensitive	The GESI context has been considered, and project activities take this into account in their design and implementation. The project addresses basic needs and vulnerabilities of women and marginalised groups, and the project will not contribute to or create further inequalities.	
Empowering	The project has all the characteristics of a 'sensitive' approach whilst also increasing equal access to assets, resources and capabilities for women and marginalised groups	X
Transformative	The project has all the characteristics of an 'empowering' approach whilst also addressing unequal power relationships and seeking institutional and societal change	

Rights: Legal and customary / Representation: Participation, inclusion & power

From inception, the project was designed with a commitment to inclusion. The GESI context was assessed during the planning phase through consultations with local NGOs, government partners, and community representatives. This informed the development of a participatory "train, share, apply" model that addressed barriers to access and participation for women and marginalized groups.

The project ensured that women were represented in both governance and implementation. Women made up 25% of the Project Board and 60% of partner institutions had women in senior leadership roles. During training sessions, women were actively encouraged to participate, and gender balance was monitored through disaggregated attendance records (Standard Indicator DI-A01). In several regions, women-led NGOs joined the Madagascar Conservation Drone Community (MCDC), contributing to peer learning and leadership in conservation technology.

Practice: Attitudes, customs & beliefs / Environment: Stressors & vulnerability

Recognizing that women and marginalized groups often face time and mobility constraints, training sessions were scheduled with flexibility and held in accessible regional hubs. The project also provided travel stipends and on-site support to reduce participation barriers. These adaptations were particularly important in rural areas where environmental stressors (e.g. climate vulnerability, land degradation) disproportionately affect women's livelihoods.

Roles and Responsibilities: Division of time, space & labour / Resources: Access & control of assets and services

The project challenged traditional gender roles by training women in drone piloting, spatial data analysis, and AI model development fields typically dominated by men. Women were given equal access to equipment, mentorship, and certification opportunities. This increased their technical confidence and visibility in the conservation sector. In some cases, women trainees have since been recruited by local NGOs or government departments to support drone-based monitoring missions.

Lessons learned
One challenge encountered was the underrepresentation of women in the initial training cohorts, particularly in remote provinces. In response, the project adjusted its outreach strategy by working with women's associations and local leaders to identify and encourage female candidates. This led to a measurable increase in women's participation in the second year of implementation.

4.4 Transfer of knowledge

Knowledge transfer was a central pillar of the project's strategy, ensuring that the tools, methods, and insights generated through the Darwin Initiative were effectively shared with both practitioners and policy makers to inform conservation practice on the ground and at institutional levels.

To practitioners, knowledge was transferred through structured technical trainings for 240 drone operators across six provinces and 19 regions. Training combined theoretical modules (e.g. drone regulations, photogrammetry, AI-based classification) with field application, enabling local conservationists, park rangers, and NGO staff to operationalize new technologies in real-world scenarios. Hands-on workshops on AI and machine learning were conducted by international experts from LJMU. These sessions not only taught basic concepts but also co-developed working models for lemur detection and tree classification, facilitating immediate application in protected areas such as Menabe and Lake Alaotra.

The creation and support of the Madagascar Conservation Drone Community (MCDC), a nationwide platform fostering peer-to-peer learning and troubleshooting. The MCDC remains active via its Google Group, serving as a forum for field insights, software tips, regulatory updates, and flight planning coordination among trained members.

The project has had a close collaboration with policy makers, through a high-level national workshop on drone regulation and conservation, co-hosted with the Civil Aviation Authority (ACM), MEDD, and the UK Embassy. This event resulted in the endorsement of new drone guidelines and their application in national parks, marking a significant policy advance. We also have ongoing collaboration with the Ministry of Environment, where project outputs (e.g. tree detection pipeline, AI mapping tools, lemur survey results) were presented to key decision-makers. Project briefs and protocols are also shared with park management bodies and protected area authorities, who have begun incorporating drone-based deterrence models into SMART patrol plans.

International knowledge transfer was achieved through the Madagascar Conservation Drone Community's new affiliation with the International Conservation Drones Network, which enables the sharing of tools and lessons learned with global peers via webinars and online forums. A peer-reviewed paper is in development at the time of writing on reforestation monitoring using AI-enhanced drone data, and presentations during regional and international biodiversity forums (e.g. Oppenheimer Research Generation Conference) raised awareness of Madagascar's leadership in conservation innovation.

4.5 Capacity building

Across six provinces and 19 regions, 240 new drone pilots (30% female) were trained, including over 80 representatives from the Ministry of Environment and Sustainable Development (MEDD), Madagascar National Parks (MNP), and local NGOs. Drone competencies were verified via UK-equivalent theory exams and flight log submissions. Additionally, two MEDD personnel received advanced maintenance training on VTOL systems. Moreover, the project catalysed the drafting and implementation of national drone regulations, co-led with ACM and MEDD. This legal framework now governs safe drone use by NGOs, researchers, and government actors, demonstrating institutional policy alignment and sustainability.

Staff from the Ministry of Environment and Sustainable Development (MEDD) and Madagascar National Parks (MNP) who participated in drone and AI training sessions have since been invited to contribute to national-level discussions on conservation technology. Notably:

Two MEDD staff trained in advanced drone maintenance and VTOL operations were appointed to lead the ministry's internal drone unit and now support regional departments in deploying drones for reforestation and protected area surveillance.

MNP agents who completed drone and SMART integration training were selected to represent their institution in the national working group on drone regulation, co-led by ACM and Durrell.

5 Monitoring and evaluation

The M&E framework was built around clearly defined indicators for each Output and Outcome, with corresponding means of verification including drone flight logs, training attendance sheets, workshop reports, SMART patrol data, and AI model documentation. M&E responsibilities were shared across partners. Durrell led data consolidation and reporting, while LJMU provided technical support of AI outputs. MEDD and MNP contributed field-level verification during workshop, including SMART patrol data and post-training evaluations. Information was shared through a combination of WhatsApp groups. This collaborative approach ensured that all partners had access to real-time progress updates and could contribute to decision-making.

No major structural changes were made to the logframe during the project. However, some adjustments to indicator timelines were made to accommodate delays in LiDAR equipment delivery and the need to reschedule some planned flights. These changes did not alter the overall logic or ambition of the project and were managed within the existing reporting framework.

The M&E system was instrumental in ensuring accountability, learning, and responsiveness throughout the project. It enabled partners to track both quantitative and qualitative progress, manage risks proactively, and ensure that the project remained aligned with its intended outcomes and impact.

6 Lessons learnt

Over the course of the project, several important lessons emerged which we have outlined below. We hope that these insights offer valuable guidance for future Darwin Initiative projects, particularly those operating in remote, biodiversity-rich contexts with emerging technological applications.

In terms of what worked well, our "train, share, apply" model proved highly effective in building local ownership and technical confidence. By combining theoretical instruction with field-based application and peer exchange, the project ensured that training translated into real-world conservation impact. We also established the Madagascar Conservation Drone Community (MCDC) creating a sustainable platform for knowledge sharing and troubleshooting. This has continued to grow organically and now effectively connects practitioners across all 23 regions in Madagascar. The integration of drone data into SMART patrol systems also significantly improved the responsiveness and precision of protected area management, particularly in Menabe Antimena PA.

Reflecting on what didn't go to plan includes the late arrival of the LiDAR drone batteries which resulted in delayed comparative flights and reduced the time available for RGB–LiDAR analysis. This limited the ability to conduct a full six-month interval dataset before project closure. The bushfire at the Ambohidavakely reference site also disrupted long-term monitoring and required the rapid selection of new plots. While this was managed effectively, it highlighted the vulnerability of single-site baselines in fire-prone regions. Upon final analysis, initial gender representation in training cohorts was lower than anticipated, particularly in remote provinces. This was addressed through targeted outreach in Year 2, but earlier engagement with women's networks could have improved balance from the outset.

Taking into account the above, in future project planning we will ensure we will do the following:

- Build in redundancy for reference sites from the beginning, especially in areas vulnerable to climate-related risks such as fire or flooding.
- Procure and test all critical equipment (e.g. LiDAR batteries, VTOL components) well in advance of scheduled fieldwork to avoid cascading delays.
- Establish mentorship structures earlier in the training process to support newly trained pilots with post-training application and troubleshooting.

Our recommendations for future similar projects include:

- Investing in local institutional partnerships early. The success of this project was largely due to the strong engagement of MEDD, MNP, and ACM, which ensured policy alignment and long-term uptake.
- Combine open-source tools with hands-on training. The use of Python, Google Colab, and Conservation AI allowed for cost-effective, scalable model development and empowered local users to continue refining tools post-project.
- Prioritize inclusive recruitment and disaggregated monitoring from the outset to ensure equitable participation and track progress on GESI goals.

7 Actions taken in response to Annual Report reviews

Please provide a more detailed assessment of the ability of the reforestation AI to reliably measure relevant forest indicators and the lemur AI to identify lemurs - see section 4.2 (Assumptions).

- With the support of experts at LJMU, the code and AI model have been re-written and tested improving our ability to detect and define the reforestation assessment and lemur's detection. When compared with the initial algorithm used, our tests show that this updated model is providing improved object classification and categorisation. Model creation has been improved by defining not only the tree but also the soil and grass around each young tree considered as detection model.

The AR claims that drone surveillance has successfully reduced illegal activities in Menabe PA because the number of such acts reduced from 17 to 16, but a reduction of 1 is not credible evidence. Please refrain from over-claiming like this.

- This output has been reviewed since our last annual report as it was only determined based on threat detected over one single flight and not the overall reduction statistics for 2023 and 2024. It is now updated within the SMART database (threats in Annex 7, protocol in Annex 10) and provides a more detailed and accurate review of differences before and after drone use.

While the role of drones in protecting forests provides long-term benefits to local communities, the association of drone flights with law enforcement has the potential to create conflicts.

Please provide more detail on interactions with local communities and whether this issue is a concern.

- With drone's high resolution camera, clear identification of people who are conducting illegal activities inside the PA is possible. This has been clearly communicated to the local communities who we meet with before every flight mission. They have welcomed our ability to provide more effective enforcement as they are negatively impacted by the individuals conducting the illegal activity and are frustrated by the current high levels of impunity.

Please provide brief commentary on the points raised in the award letter.

- Please see Annex 5 for the responses to the award letter which were included with the first half year report.

8 Risk Management

Two significant risks emerged in the final year of the project that were not fully anticipated in the original risk register; the fire damage to our reference plot and the delay in the delivery of the LiDAR batteries.

In September 2024, a major bushfire destroyed the Ambohidavakely reforestation monitoring plot, including key calibration markers and baseline data. This site had been surveyed since the start of the project and was scheduled for comparative LiDAR-enabled analysis. The loss disrupted the long-term monitoring sequence and risked compromising Output 1.1 (tree detection algorithm validation). In response the team selected three new reference plots in diverse ecological zones, dispersing risk and allowing for comparative analysis in case of further environmental disruption. Ground control markers and aerial baseline datasets were rapidly established, and coordination with local stakeholders was prioritized to secure and monitor the new plots.

The batteries and components for the LiDAR drone were received late (September 2024), reducing the time available for planned comparative RGB–LiDAR flight missions before the end of the project. This compressed timeframe posed risks to Output 1.3 (tool validation) and limited the opportunity for two-season analysis within the intended interval. In response the team deferred software license activation until equipment was on site, thereby avoiding cost inefficiencies. LiDAR flights were rescheduled for November 2024 and early 2025, and extended support from trainee cohorts was secured to assist with post-flight data processing.

To reduce exposure to future delays and technical dependencies, the project began training a core group of advanced drone operators in preventive maintenance and VTOL system calibration. This capacity now resides within MEDD and MNP field teams and supports long-term sustainability.

Overall, the risk mitigation strategies employed enabled the project to maintain momentum, safeguard key outputs, and prepare partners for autonomous continuation of activities beyond project closure.

9 Scalability and Durability

The project prioritized early engagement with stakeholder's key to future scale-up, including the Ministry of Environment and Sustainable Development (MEDD), Madagascar National Parks (MNP), the Civil Aviation Authority (ACM), and civil society organizations. These groups became active collaborators through workshops, training sessions, and the development of regulatory tools. Stakeholders were not only informed of the project's aims and methods but also directly involved in its implementation, thereby harnessing both the practical benefits and manageable costs of adopting drone and AI tools for conservation.

Evidence of this awareness includes participation of over 80 staff from MEDD and MNP across workshops and trainings, national-level media and institutional visibility of the “Aligning Biodiversity Conservation and Drone Regulation” workshop in May 2024 and adoption of project methodologies into SMART patrols and protected area management protocols with MNP.

Adopters have found the tools both accessible and adaptable. The use of open-source software (Python, QGIS, Google Colab) and consumer-grade drones lowered financial and technical barriers. The machine learning models developed are applicable to a range of biodiversity challenges including reforestation monitoring, species detection, and fire surveillance, making them useful beyond the initial pilot areas. The creation of the Madagascar Conservation Drone Community (MCDC) further supports skill transfer and peer-based scaling. In addition, the co-development of the national drone regulatory framework with ACM and MEDD created policy alignment and formalized support. Moreover, MEDD’s subsequent investment in new VTOL drone fleets and continued collaboration with trained project alumni signals institutional ownership.

The increase in locally led drone missions, data analysis, and policy contributions by national actors reflects a shift in both capacity and mindset. Where drone work was once outsourced, it is now being independently executed by trained Malagasy professionals. The participatory and inclusive training model helped foster not only technical literacy but also a new culture of distributed conservation technology ownership.

The MCDC platform will continue coordinating drone activities beyond the project period. Several graduates are now embedded in regional MEDD and MNP offices and will act as focal points for ongoing application. LJMU and Durrell are also exploring future research collaborations to sustain the momentum.

To summarise, the achievements of this project most likely to endure in the long-term include:

- The legal framework co-produced with ACM and MEDD, as it embeds drone governance within national policy.
- The trained workforce of 240 practitioners distributed across 19 regions.
- The open-source AI tools developed, which can continue evolving through local contributions.
- The MCDC, which has become a recognized hub for practitioner exchange and innovation.

10 Darwin Initiative identity

The project has consistently promoted the Darwin Initiative (DI) and acknowledged the UK Government’s support through both formal communications and public engagement activities.

The Darwin Initiative logo was prominently displayed on all training materials (e.g. presentations, manuals, certificates), official project reports and guidance documents shared with stakeholders and banners and media backdrops used during national events, including the May 2024 drone regulation workshop in Antananarivo.

In every case, branding guidelines were followed to ensure that the DI was clearly recognised as the source of funding and a key driver of the project’s innovation.

The UK Government’s support was publicly recognised during high-level events, including by the Minister of Environment and the UK Ambassador at the 2024 regulation workshop and July 2025 capitalization workshop (Annex 12). Remarks made during this event acknowledged the pivotal role of UK funding in enabling technological innovation in Madagascar's conservation sector. Acknowledgments were also included in formal speeches, media coverage, and partner communications. Project updates, training highlights, and workshop announcements were shared via institutional social media channels, including cross-posts by MNP, MEDD, ACM and partner organizations and LJMU's academic and public outreach platforms.

11 Safeguarding

[redacted]

[redacted]

12 Finance and administration

[redacted]

12.1 Project expenditure

Project spend (indicative) since last Annual Report	2024/25 Grant (£)	2024/25 Total actual Darwin Initiative Costs (£)	Variance %	Comments (please explain significant variances)
Staff costs (see below)				

Consultancy costs				
Overhead Costs				
Travel and subsistence				
Operating Costs				
Capital items (see below)				
Others (see below)				
TOTAL				

Staff employed **(Name and position)**	**Cost** **(£)**
TOTAL	

Capital items – description	**Capital items – cost (£)**
TOTAL	

Other items – description	**Other items – cost (£)**

TOTAL	

12.2 Additional funds or in-kind contributions secured

Matched funding leveraged by the partners to deliver the project	**Total (£)**
TOTAL	

Total additional finance mobilised for new activities occurring outside of the project, building evidence, best practices and the project	**Total (£)**
TOTAL	

12.3 Value for Money

13 Other comments on progress not covered elsewhere

No comments on progress not covered elsewhere.

14 OPTIONAL: Outstanding achievements of your project (300-400 words maximum). This section may be used for publicity purposes

I agree for the Biodiversity Challenge Funds to edit and use the following for various promotional purposes.

This project has delivered transformative change in conservation practice across Madagascar, helping to establish a nationally owned and legally sanctioned drone and AI monitoring system for biodiversity. Over two years, the initiative trained 240 conservation practitioners, including 30% women, from 19 regions, significantly broadening access to geospatial technology and embedding equity across local institutions.

A breakthrough was the co-development and national ratification of Madagascar's drone regulatory framework. Through close coordination with the Ministry of Environment and Sustainable Development (MEDD), the Madagascar Civil Aviation Authority (ACM), and the National Parks Authority (MNP), the project ensured that conservation drone operations now operate under a clear, enabling legal structure. This support to national policy fulfils Darwin Initiative objectives to strengthen biodiversity governance and deliver durable enabling environments.

Technically, the project achieved two key innovations; an open-source drone-AI pipeline to detect forest regeneration and rare species (e.g. *Hapalemur alaotrensis*), built in Python and capable of generating shapefiles from drone-collected imagery and a web-based platform (Flask-based GUI) that allows non-programmers to upload drone imagery and receive annotated outputs and spatial data files, now used by trainees in field missions in Alaotra and Menabe.

One of the most outstanding achievements was the creation of the Madagascar Conservation Drone Community (MCDC), a first-of-its-kind national movement for drone-enabled conservation. MCDC now connects practitioners, regulators and researchers through knowledge exchange, technical support, and field coordination. It has 100+ active members and is independently sustaining post-project intervention.

Finally, the project embedded local ownership by transferring equipment to regional offices, deploying Malagasy-led training teams, and forming formal alliances between MEDD, MNP, and civil society groups. These elements ensure that the project's legacy will extend well beyond its formal close.

Annex 11:

File Type (Image / Video / Graphic)	**File Name or File Location**	**Caption, country and credit**	**Online accounts to be tagged (leave blank if none)**	**Consent of subjects received (delete as necessary)**
Image x2	MCDC member	MCDC member in field operation		Yes
Image	AI pipeline workflow	Tree detection algorithm pipeline		Yes
Image	AI pipeline workflow	Lemurs detection algorithm		Yes

Image	Workshop	MEDD, ACM, UK Embassy, Durrell members		Yes

Annex 1 Report of progress and achievements against final project logframe for the life of the project

Project summary	Progress and achievements
Impact Reduction in deforestation, enhanced reforestation monitoring and improved monitoring of conservation targets throughout Madagascar	The project strengthened Madagascar's biodiversity conservation by developing scalable drone and AI tools for reforestation monitoring and endangered species detection, including the Alaotran gentle lemur. Drone surveillance and SMART integration improved threat detection and fire response in Menabe, helping protect critical habitats. These efforts also supported ecosystem services and natural capital relied upon by resource-dependent communities, contributing to long-term poverty reduction.
Outcome Drones are being used to effectively monitor and improve biodiversity conservation in Madagascar	The project successfully established a national network of 240 trained drone pilots; supported the development of a semi-automated tree survival pipeline; and started the development of AI tree species identification. Drone data were integrated into SMART patrol systems in Menabe, improving threat detection and informing adaptive management. Two AI tools, for tree and lemur detection, were validated and shared via open-access platforms. Institutional uptake was secured through collaboration with institutional partners, new national drone regulations, and the formation of the Madagascar Conservation Drone Community (MCDC), helping the long-term sustainability of drone use in Madagascar.
Outcome indicator 0.1 Drones are being utilised for reforestation monitoring, including individual survival, across at least four reforestation plots by end of project	Four reforestation plots have been used for reforestation efforts monitoring in Lake Alaotra. At least two drone flights during dry season and rain season have been conducted.
Outcome indicator 0.2 A conservation drone working group drives the uptakes of drones for conservation in at least 10 protected areas across Madagascar by project end	At least 2 protected area managers from 19 regions attended drone training and deploy drones for their weekly activities for protected area surveillance and mapping.
Outcome indicator 0.3 Drones are adopted in management plans for the deterrence of illegal activities in core protected zones in at least two protected areas	Drones are used for surveillance and deterrence tool in Menabe Antimena and Lake Alaotra for aerial patrol. Clear and easy to use protocol have been shared to allow on site team to conduct safe and regular drone flights for surveillance. Drone integration in PA management have been officially announced by MEDD. Several conservation NGO asked for training as they bought new drones for their activities.
Outcome indicator 0.4 A range wide survey of the Alaotran gentle lemur using drone-based infra-red data is completed and provides a model for infra-red animal monitoring in Madagascar	Thermal imagery and analysis have been completed, open-source platform developed using Python and customized to detect Bandro only. This model has

	been created with YOLO and Open-CV colour and object detection algorithm. (Sample source code provided in Annex 9)
Output 1 Techniques established for semi-automated reforestation monitoring using drones	
Output indicator 1.1 Three reforestation plots surveyed by drones in both dry and rainy season by the end of Y1	Two flights conducted in Y1 with RGB drone in Alaotra (~200ha) in dry and after rainy season, using the same flight planning to allow 6-month data comparison. Same flights completed in Y2 with LIDAR drone for increased accuracy and resolution. Data processing with AI will give survival rate of each plot. First year assessment was done with the RGB drone, the Y2 confirmation will be done with the LIDAR drone.
Output indicator 1.2 Three reforestation plots surveyed for ground truthing n both dry and rainy season by end of Y1	In Y1, ground truthing was carried out based on manual measurement of young trees, recording their GPS position and marking them. Data was integrated in AI for height accuracy verification. After the bushfire in Year 1, three new reforestation plots were chosen, and new references have been taken in Y2 to be integrated to the AI pipeline.
Output indicator 1.3 Technique developed for the processing of drone imagery to track individual survival of trees in reforestation plots allowing carbon sequestration to be accurately tracked, alongside correlates of tree survival	First version of working pipeline has been issued during the last workshop. This version will work with all RGB drone imagery with TIFF extension. A web-based interface has been created to make it user friendly and does not require programming or coding background.
Output indicator 1.4 AI based system developed to accurately detect tree species and coverage in reforestation plots to enable post-hoc monitoring of reforestation plots	This has been developed and tested in Jan 2024 – we have allowed for colour and object detection that will result in species detection. This step is under development and testing based on collected datasets that need to be integrated and added as a model to create species profile. We take in consideration all details that allow us to define which tree species is detected and how accurate the algorithm can detect and classify it.
Output indicator 1.5 One training session delivered to new working group on standardising drone-based reforestation monitoring in Madagascar by end of project	Two sessions of training conducted in Y1 with partners to share the new standardised drone-based reforestation monitoring. This includes flight planning and data processing methodology and tools. Another training has been provided in Y2 for drone-based reforestation monitoring including advanced control points integration and use of reference points. This training focused on dataset customization for AI assisted analysis. We included CAA staff to regulate drone operation across Madagascar.

Output indicator 1.6 Paper submitted to an international journal, on effective monitoring of reforestation using drones by end of project	First paper based on data collection with LJMU and students submitted to LJMU supervisors for review. This paper is part of one chapter in larger publication focused on drone use for conservation in Madagascar.
Output 2. Capacity developed for using drones for environmental conservation in Madagascar	
Output indicator 2.1 Cross NGO/government working group created on drone use by Y1Q2	Madagascar Conservation Drone Community created in Feb 2024, with a steady increase in the number of members in the Drone Community. In Y2 the group is now integrated to the Conservation Drone hub which is a collaboration with LJMU and worldwide practitioners.
Output indicator 2.2 At least four meetings of the drone working group in each year of the project	Online meeting conducted in Y2 for drone working group for activities update and results. Group members become more interested in drone mapping for land cover and forest monitoring.
Output indicator 2.3 Two knowledge sharing workshops delivered to working group participants by end of project (middle and end)	First sharing workshop took place in May 2024 involving, British Embassy, MoE, Civil Aviation Authority, NGOs and partners in conservation in Madagascar. Second knowledge sharing workshop was in September 2024. Last workshop in July 2025.
Output indicator 2.4 At least 50 pilots trained and passing UK theory exams (or equivalent) to demonstrate competence by end of project	More than 200 new pilots passed the UK exam at the end of project. These staff come from MEDD regional department, NGO, Civil Aviation Authority, Students. For Y2, we provided training for Toamasina, Mahajanga, Diego and Tulear. These training hubs allow to share the drone skills in real environment.
Output indicator 2.5 Advanced training provided in drone maintenance to four people (Two from MNP, Two from MoE or major NGO using drones) by end of project	2 staff members from MoE received advanced drone maintenance and operations, including VTOL, and heavy-lift drone maintenance. This enabled them to obtain flight permits from the CAA.
Output 3. Drones demonstrated as an effective detection and deterrence mechanism for environmentally damaging behaviour and informing and responding to SMART patrol activity	
Output indicator 3.1 Reduced illegal activity detected by SMART community patrols after deterrence flights in treatment plots	Based on patrol report and satellite comparison, we found 969 threats in 2023, 492 in 2024 and in 183 in 2025 so far, showing a reduction.
Output indicator 3.2 Drone monitoring flights are being used to detect smoke and illegal activity by project end'	Drones were deployed for threat detection and mitigation. Two fire incidents in Menabe in Y1 were successfully managed with drone-assisted coordination. In Y2, drone-based fire detection started being integrated into standard patrols.

Output indicator 3.3 Drone tracks and incursion data integrated into Durrell's SMART database and informing SMART adaptive management by end of project	Drone flight route and logs integrated in SMART database in Y1 by using .GPX file. Track and threat recordings have been added with accurate information based on ground and aerial patrol. New recent drone model was deployed in Menabe for more efficiency and to increase flight distance and time.
Output 4. The first robust, range-wide survey of Alaotran gentle lemur is delivered using drone-based infra-red detection of lemurs as a model for animal detection using this technology in Madagascar	
Output indicator 4.1 Drone flights conducted for lemur detection across the Lac Alaotra marsh by the end of Y1	48 transects over 2 years, leading to the detection of 16 lemur groups using infrared-equipped drones.
Output indicator 4.2 Ground truthing surveys conducted for lemur populations and compared to drone data by end of Y1	Ground truthing completed in parallel with drone flights across Y1 and Y2, enabling the verification of the AI model and aerial estimates.
Output indicator 4.3 Semi-automated infra-red processing algorithm developed enabling processing of range-wide survey data	AI algorithm successfully developed to process thermal infrared imagery collected during drone-based lemur surveys using Python, OpenCV, and Visual C++.
Output indicator 4.4 Manuscript submitted on the detection of Alaotran gentle lemurs with drone-based thermal infra-red	Manuscript for Bandro detection has been written and is awaiting review. It is part of a bigger document on the topic of drone use in conservation in Madagascar.

Annex 2 Project's full current logframe as presented in the application form (unless changes have been agreed)

Project Summary	SMART Indicators	Means of Verification	Important Assumptions
Impact: Reduction in deforestation, enhanced reforestation monitoring and improved monitoring of conservation targets throughout Madagascar			
Outcome: Drones are being used to effectively monitor and improve biodiversity conservation in Madagascar	0.1 Drones are being utilised for reforestation monitoring, including individual survival, across at least four reforestation plots by end of project 0.2 A conservation drone working group drives the uptakes of drones for conservation in at least 10 protected areas across Madagascar by project end 0.3 Drones are adopted in management plans for the deterrence of illegal activities in core protected zones in at least two protected areas 0.4 A range wide survey of the Alaotran gentle lemur using drone-based infra-red data is completed and provides a model for infra-red animal monitoring in Madagascar	0.1 Drone flight maps and monitoring reports 0.2 Training records and flight logs and usernames will determine those actively using drones for PA management alongside reports from regular meetings of the working group 0.3 Longitudinal SMART data and research report 0.4 Report on the outcome of the range-wide survey, with recommendations for transference to other systems	0.1a The model for processing drone-imagery to track individual tree survival on reforestation plots is developed successfully 0.1b Reforestation efforts continue post-election 0.2 Conservation drone users continue to engage in our workshops and meetings 0.3 Experiment shows that drones are successful in deterring illegal behaviours in protected areas, and do not displace activities to other areas of the park. 0.3b Drone maintenance enables sufficiently regular flights to maintain deterrent effect 0.3c Deterrent effect does not wane, significantly, through time 0.4a Development of semi-automated detection of drones in the infra-red imagery continues to progress successfully 0.4b No negative reaction to drones is observed during surveys (not to date, but regularly monitored)
Outputs: **1**. Techniques established for semi-automated reforestation monitoring using drones	1.1 Three reforestation plots surveyed by drones in both dry and rainy season by the end of Y1 1.2 Three reforestation plots surveyed for ground truthing n both dry and rainy season by end of Y1	1.1 Drone flight path maps 1.2 Survey reports 1.3 Quarterly progress reports 1.4 Quarterly progress reports 1.5 Workshop minutes and attendance sheet	1.3a GNSS resolution is high enough to ensure individual trees can be identified aerially across multiple longitudinal images

	1.3 Technique developed for the processing of drone imagery to track individual survival of trees in reforestation plots allowing carbon sequestration to be accurately tracked, alongside correlates of tree survival 1.4 AI based system developed to accurately detect tree species and coverage in reforestation plots to enable post-hoc monitoring of reforestation plots 1.5 One training session delivered to new working group on standardising drone-based reforestation monitoring in Madagascar by end of project 1.6 Paper submitted to an international journal, on effective monitoring of reforestation using drones by end of project	1.6 Submitted to peer-reviewed journal and received receipt of submission	1.3b trees can be distinguished from background vegetation in drone imagery at all life stages 1.4 AI can be trained to detect differences in RGB imagery between tree species 1.5 There is interest amongst working group for the session 1.6 Techniques for processing drone data for reforestation monitoring are successful and scalable
2. Capacity developed for using drones for environmental conservation in Madagascar	2.1 Cross NGO/government working group created on drone use by Y1Q2 2.2 At least four meetings of the drone working group in each year of the project 2.3 Two knowledge sharing workshops delivered to working group participants by end of project (middle and end) 2.4 At least 50 pilots trained and passing UK theory exams (or equivalent) to demonstrate competence by end of project 2.5 Advanced training provided in drone maintenance to four people	2.1 Working group meeting attendance report 2.2 Working group meeting attendance report 2.3 Workshop minutes and attendance sheet 2.4 Copies of theory exams successfully completed (names redacted for privacy) 2.5 Training attendance log and feedback	2.2 Government officials are able to regularly attend working group meetings alongside drone professionals 2.4 If the Madagascar government creates its own theory exam, this target would change to completion of this exam 2.5 MNP / Government / NGO staff are able to attend regular drone training sessions

	(Two from MNP, Two from MoE or major NGO using drones) by end of project		
3. Drones demonstrated as an effective detection and deterrence mechanism for environmentally damaging behaviour and informing and responding to SMART patrol activity	3.1 Reduced illegal activity detected by SMART community patrols after deterrence flights in treatment plots 3.2 Drone monitoring flights are being used for to detect smoke and illegal activity by project end 3.3 Drone tracks and incursion data integrated into Durrell's SMART database and informing SMART adaptive management by end of project	3.1 SMART patrol data 3.2 Project report and drone detection rate 3.3. SMART reports including drone patrol tracks	3.1 Illegal activities are not displaced to other areas of the protected area (control sites). This will be monitored.
4. The first robust, range-wide survey of Alatroan gentle lemur is delivered using drone-based infra-red detection of lemurs as a model for animal detection using this technology in Madagascar	4.1 Drone flights conducted for lemur detection across the Lac Alaotra marsh by the end of Y1 4.2 Ground truthing surveys conducted for lemur populations and compared to drone data by end of Y1 4.3 Semi-automated infra-red processing algorithm developed enabling processing of range-wide survey data 4.4 Manuscript submitted on the detection of Alaotran gentle lemurs with drone-based thermal infra-red	4.1 Drone flight path maps 4.2 Survey reports 4.3 Students research reports 4.4 Submitted to peer-reviewed journal and received receipt of submission	4.1 No adverse reactions observed in lemurs in response to drone flights (none to date, but constantly reviewed) 4.3 Thermal infra-red continues to successfully detect lemurs in different habitats across the marsh 4.4 Thermal infra-red system continues to successfully detect lemurs enabling development of semi-automated algorithm

Activities

1.1 Drone flights to collect raw data on each reforestation plot
1.2 Ground surveys to ground truth drone data on each reforestation plot
1.3 Algorithm/pipeline developed to process drone data for the effective monitoring of sapling survival rate and reforestation success and rates of carbon sequestration
1.4 AI algorithm training on identification of tree species and coverage across reforestation plots
1.5 Workshop delivered to disseminate newly developed reforestation monitoring techniques
1.6 Paper writing

2.1 Madagascar practitioners gathered to form a working group 2.2 Working group meetings chaired by Durrell project staff 2.3 Knowledge sharing workshops delivered to working group (at least one per year) 2.4 Seven-day full-time training course and refresher sessions delivered for 50 people for drone piloting - five conducted in total (10 people each session) by project end 2.5 Advanced training delivered to four people on drone maintenance through regular sessions at the Durrell drone lab 3.1 Experimental framework developed for the testing of drones as deterrence measure in Menabe-Antimena National Park 3.2 Drone flights conducted across two fire seasons during project in experimental framework, for at least four weeks at a time 3.3 Longitudinal monitoring using SMART by local village patrols to understand the impact of drone flights on distribution and prevalence of illegal activities in Menabe-Antimena 3.4 Drone detection data is integrated into SMART to inform community patrol activity 4.1 Systematic flights conducted to assess the population of Alaotran gentle lemurs across their marsh range 4.2 Ground truthing surveys in pirogues conducted to validate drone footage and image processing 4.3 Semi-automated pipeline for the detection of gentle lemurs from thermal infra-red imagery trained on data collected during the first field season 4.4 Training given to students to enable them to assist in lemur surveys 4.5 Paper writing

Annex 3 Standard Indicators

Table 1 Project Standard Indicators

Please see the Standard Indicator Guidance for more information on how to report in this section, including appropriate disaggregation. N.B. The annual total is not cumulative. For each year, only include the results achieved in that year. The total achieved should be the sum of the annual totals.

DI Indicator number	Name of indicator	If this links directly to a project indicator(s), please note the indicator number here	Units	Disaggregation	Year 1 Total	Year 2 Total	Total achieved	Total planned
DI-A01	Number of people in eligible countries who have completed structured and relevant training		Number of people	Men	43	102	145	(50 total)
DI-A01	Number of people in eligible countries who have completed structured and relevant training		Number of people	Women	29	43	72	(50 total)
DI-A03	Number of local/national organisations with improved capability and capacity		Number of organisations	Type	15	17	32	2
DI-A03	Number of local/national organisations with improved capability and capacity		Number of organisations	Training weeks	3	4	7	6
DI-C18	Number of unique papers submitted to peer reviewed journals		Number		0	1	1	2
DI-C02	Number of new conservation or species stock assessments published		Number		0	1	1	1

Table 2 Publications

Title	**Type** (e.g. journals, manual, CDs)	**Detail** (authors, year)	**Gender of Lead Author**	**Nationality of Lead Author**	**Publishers** (name, city)	**Available from** (e.g. weblink or publisher if not available online)

Checklist for submission

	Check
Different reporting templates have different questions, and it is important you use the correct one. Have you checked you have used the **correct template** (checking fund, type of report (i.e. Annual or Final), and year) and **deleted the blue guidance text** before submission?	X
Is the report less than 10MB? If so, please email to BCF-Reports@niras.com putting the project number in the Subject line.	
Is your report more than 10MB? If so, please consider the best way to submit. One zipped file, or a download option, is recommended. We can work with most online options and will be in touch if we have a problem accessing material. If unsure, please discuss with BCF-Reports@niras.com about the best way to deliver the report, putting the project number in the Subject line.	X
If you are submitting photos for publicity purposes, **do these meet the outlined requirements (see section 14)?**	X
Have you included means of verification? You should not submit every project document, but the main outputs and a selection of the others would strengthen the report.	X
Have you provided an updated risk register? If you have an existing risk register you should provide an updated version alongside your report. If your project was funded prior to this being a requirement, you are encouraged to develop a risk register.	X
Have you involved your partners in preparation of the report and named the main contributors?	X
Have you completed the Project Expenditure table fully?	Explained in section
Do not include claim forms or other communications with this report.	